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FINISHED PLAN

SHIP NO.	2 2 2 8
SHIP NAME	APL POLAND
DWG. NO.	MA8-LA2001F
LIST NO.	MB-03

MITSUBISHI HEAVY INDUSTRIES, LTD.
NAGASAKI SHIPYARD & MACHINERY WORKS

ISSUED FEB. 25. 2008

MITSUBISHI
HEAVY INDUSTRIES, LTD.

MITSUBISHI-SULZER
RT-flex96C

FINAL PLAN

S.No.2228

MITSUBISHI-SULZER

Operating Instructions

MITSUBISHI HEAVY INDUSTRIES, LTD. KOBE SHIPYARD & MACHINERY WORKS
FEB. 20. 2008
Designing Section
MARINE DIESEL ENGINE BUSINESS UNIT

MITSUBISHI HEAVY INDUSTRIES, LTD.
KOBE SHIPYARD & MACHINERY WORKS

MA8-LA2001 E

Group 0

0

Operating Description **Group 0**

▽ Operating Troubles

For Paticular Attention

1. This manual is put at the disposal of recipient solely for use in connection with orresponding MITSUBISHI-SULZER type Diesel engines. It has always to be treated confidentially by its owners.

   This copy of the manual is handed over to:

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2. The intellectual property regarding the content of this manual, particularly the copyright remains with Mitsubishi Heavy Industries,Ltd. Kobe Shipyard & Machinery Works, Kobe, Japan.

3. The extent of any supplies and services is determined exclusively by the relevant supply contract between the purchaser and the manufacturer of the engine. No claims of any manual regarding any additional supplies or service may be inferred from this manual.

4. The particulars, data, presentations, etc. shown in this manual correspond to the situation existing at the time of going to issue and they are based on drawings made by Mitsubishi-Sulzer. It must be recognized that such particulars, data, presentations, etc. may be subject to later modification, due to further developments, experience, etc.

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

6. This manual has been prepared on the assumption that operation and maintenance of the engines concerned will always be carried out by personnel having the special knowledge and skills needed to handle in a workman-like manner Diesel engines of the corresponding size,the pertaining auxiliary equipment, as well as fuel and other operating media. Therefore, generally applicable rules, which may also concern such items as protection against danger, are specified in this manual in exceptional cases only, i.e. when it must be assumed that the operating personnel qualified as above should not be familiar with the rules concerned.

7. This manual has been prepared to best knowledge and ability of its authors However, neither MITSUBISHI nor their employees assume any liability for claims for any damages whatsoever or of any other nature with regard to this manual or in connection with the use thereof.

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KOBE, JAPAN

General
Preface

1. This booklet is "Operating Manual" of the Instruction Book for handling of MITSUBISHI-SULZER RT-flex96C type Diesel Engine describing important instruction for operation and engine construction to the engineers who are qualified to operate and maintain engines.

2. The engineers who operate and maintain this engine are requested to read this booklet before handling the engine, to grasp the engine characteristics sufficiently, and to manage engine handling without mistakes for safety operation and maintenance.

   The parts indicated with symbols WARNING CAUTION in this booklet describe important matters; therefore, pay special attention to the descriptions.

   WARNING : This symbol indicates that the operator must strictly follow the guidelines preventing danger to the engine operator during engine operation and/or maintenance.

   CAUTION : This symbol indicates that the operator must take certain measures to avoid undesirable conditions and damages to equipment during engine operation and/or maintenance.

   Remark : Related information on the engine operation and/or maintenance and useful information for improving the sufficiency of the engine operator are provided.

3. For maintenance and inspection, please refer to a separate volume "Maintenance Manual".

4. In addition to the numerical instruction applied only to MITSUBISHI-SULZER RT-flex96C type Diesel Engine, this booklet also indicates the most important explanation of the general character about the operation diesel engine.
   We recommended that the engineers should study this booklet well and it should be always referred to. Since we think that the engineers are already familiar with what is necessary for the safety operation of diesel engine, for simplification, this booklet does not indicate in detail.

5. As for the engine accessories such as turbocharger, air cooler, governor, cylinder lubricator and auxiliary blower, please refer to the separate Instruction Book.

6. This booklet must be always stored at the fixed place and must be usable at any time by the people in charge of engine operation and maintenance.

7. It is absolutely forbidden that engine is used with being different from proper purposes and conditions in specifications or handled with being against the described contents in this booklet, because it comes to the causes of the troubles and breakdowns.

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KOBE SHIPYARD & MACHINERY WORKS

Operating Description

Group 0

Engine Monitoring

Group 9

1. Symbols

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

Symbols	Explanation
A	Control air supply unit
B	Fuel supply
C	Fuel injection
D	Servo oil supply
E	Valve unit for start
F	Exhaust valve drive
G	Supply unit
H	Instrument
I	Pressure switch and pressure transmitter
K	Local control panel
L	Control oil pump unit

2. Abbreviations

2.1 General

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

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

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

Abbreviations	Explanation
RCS	**R**emote **C**ontrol **S**ystem
SCR	**S**elective **C**atalytic **R**eduction
SHD	**SH**ut **D**own
SHF	**S**ediment by **H**ot **F**iltration
SLD	**SL**ow **D**own
TDC	**T**op **D**ead **C**enter
WHR	**W**aste **H**eat **R**ecovery system

2.2 Concerning engine control system WECS-9520

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

Group number of the Important Components

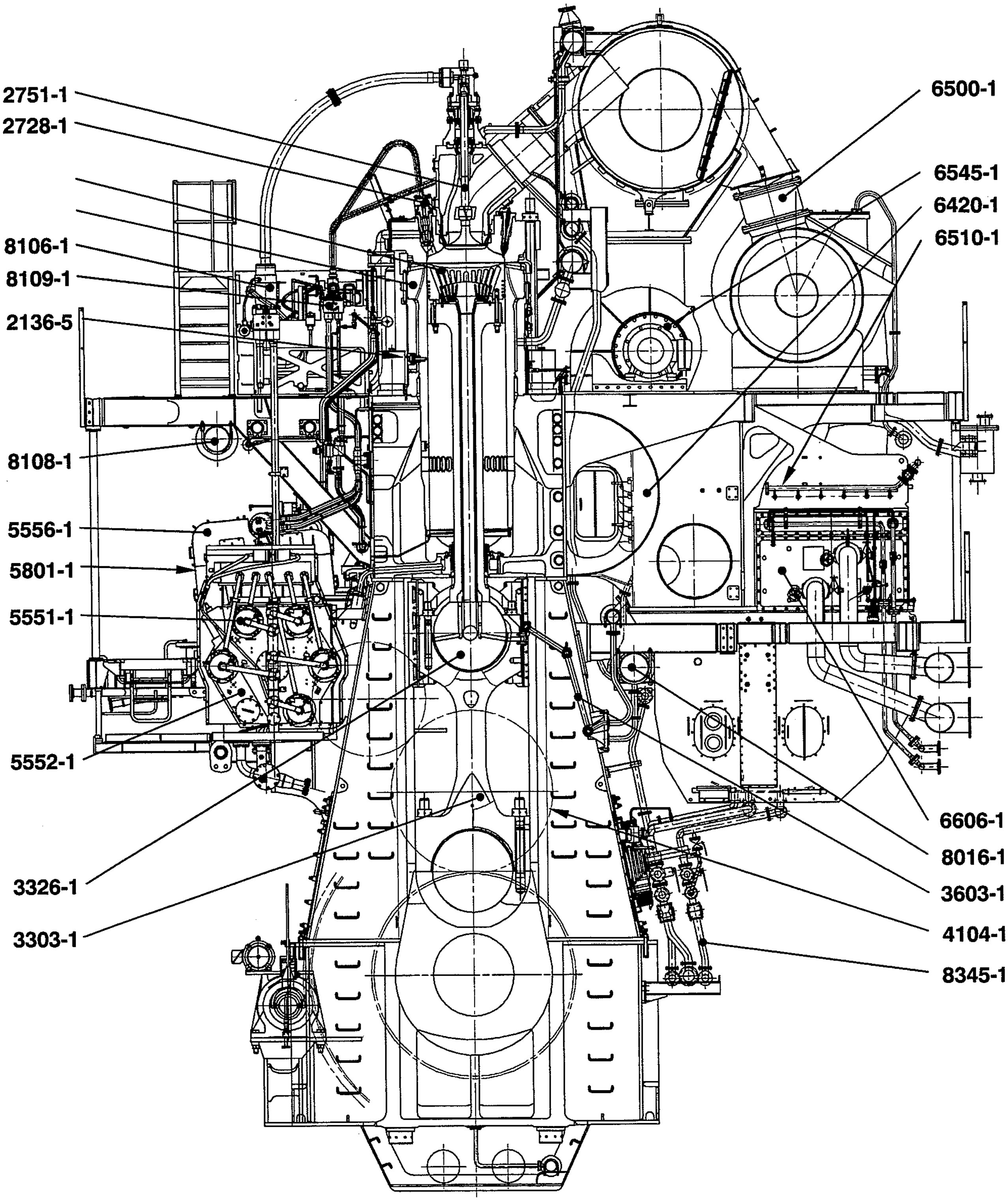
When looking for information on specific components, systems and their function, service data, Measures to be taken, general data, etc., please refer to the Table of Contents (0020-1).

In addition, certain components shown on the illustrations 0040-01 2/3 and 3/3 are marked With the Group numbers used in this book to help in finding the pertinent particulars more quickly.

At the same time, these illustrations provide an overall picture of the basic construction of the engine.
Detail may differ, depending on the model type.

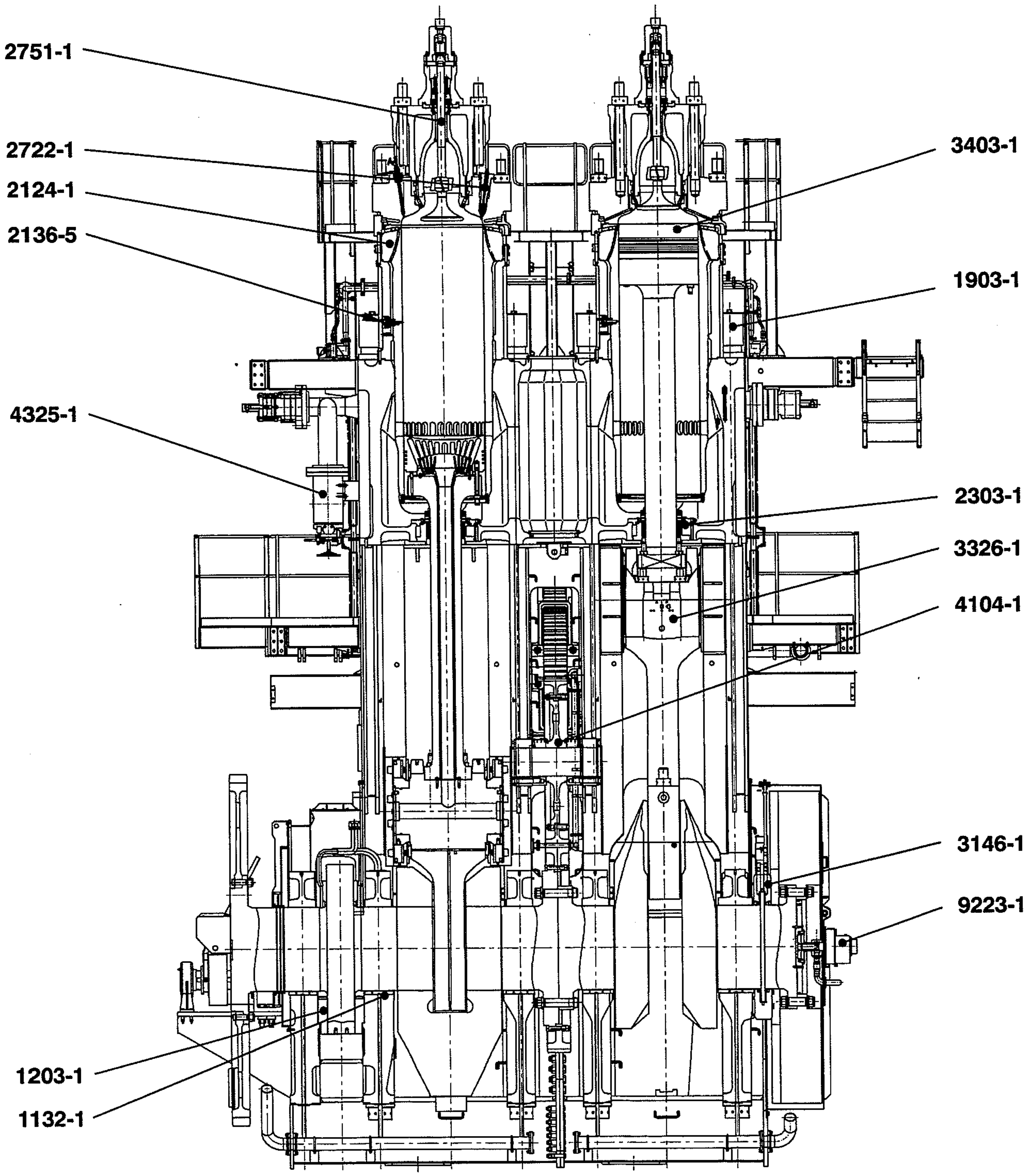
Group number of the Important Components

Cross Section:



Group number of the Important Components

Longitudial Section:



1. General

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

2. System

- The exhaust valves are opened hydraulically by the servo oil system and closed pneumatically. The oil supply in ensured from the bearing oil system through a fine filter. Servo oil pumps in the supply unit provides the servo oil rail with the required pressure via two rising pipes.
- One of the electrically-driven control oil pumps generates the required control oil pressure maintaining it over the entire load range.
- The pistons are cooled by bearing lubricating oil.
- Fuel pumps in the supply unit deliver fuel under high pressure into the fuel rail via HP pipes, intermediate fuel accumulator and rising pipes and subsequently through the injection control units to each injection valves.
- The cylinders and cylinder covers are fresh water cooled.
- For cooling scavenge air single-stage coolers are used as standard with fresh water or sea water by direct cooling.
  Two-stage air coolers are used as an option providing high and low pressure circuits with fresh water for the central cooling system.
- The engine is started by compressed air entering into the cylinders via starting valves, controlled by the WECS-9520.
- The exhaust gases flow from the cylinders through the exhaust valves into an exhaust gas manifold.

- The exhaust gas turbochargers work on the constant pressure charging principle.
- The scavenge air delivered by the turbochargers flows through air coolers and water separators into the air receiver.
  It enters the cylinders via air flaps through the scavenge ports when the piston are nearly at their BDC.
- At low loads independently driven auxiliary blowers supply additional air to the scavenge air space.

General
Working Principle of the Two-stroke Diesel Engine

First Stroke: *(Compression)*

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

Point ES:

- Scavenge ports are being closed by the position.

Point AS:

- Exhaust valve shut, compression begins.

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

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

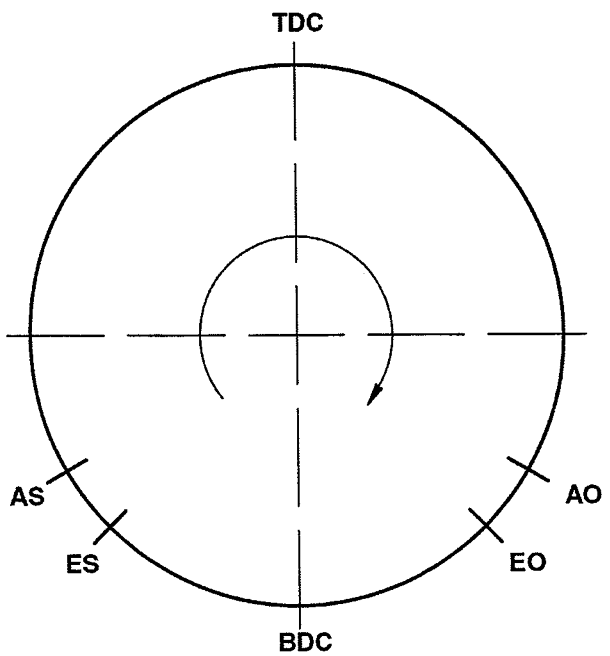
Point AO:

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

Point EO:

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

(See schematic diagram of Turbocharging 6500-1)



1. General

There is a defined relationship between the propeller speed and the absorbed power in ships equipped with fixed pitch propellers.
With a given propeller this relationship mainly depends on its rotational speed.
The following formula provides us with an approximation which is adequate for the general consideration of conventional vessels:

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

Its graph is called the propeller characteristic.

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

In the diagram, the propeller characteristic line through the point of CMCR (**C**ontact **M**aximum **C**ontinuous **R**ating), i.e. normal power at nominal engine speed (100% power at100% engine speed) is called the nominal propeller characteristic. Engines which are to be employed for the propulsion of vessel with fixed pitch propeller are loaded on the test bed according to this propeller characteristic. However, the power requirement of a new ship with a smooth and clean hull should be less and correspond to the range D.

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

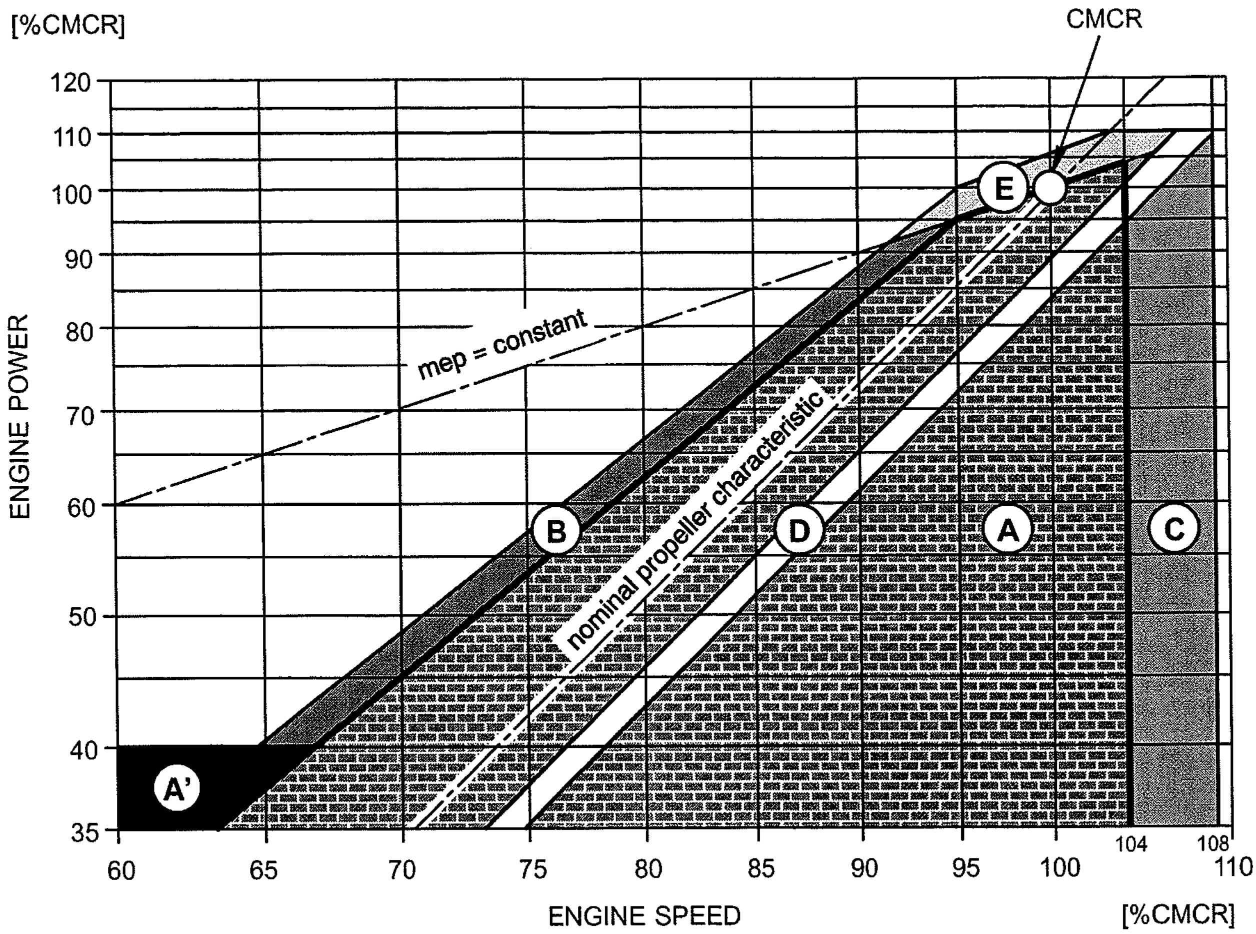
Although cleaning and re-painting will help to reduce the increased resistance of the ship's hull, the original condition can no longer be attained.

Whereas the thermal loading of an engine depends chiefly on the mean effective pressure, the position of the operating point is also important;
the farther left it is situated from the propeller curve in the diagram (Page2/2), the poorer the air supply to the engine and the more unfavourable the engine's operating conditions will become.

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

Explanation:

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



2. Load range

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

3. Simplified method of estimation of engine power

This calculation method can estimate engine power on the basis of fuel oil quantity injected upon the shop trial.
The Power Diagram which is shown the relation between the value of Fuel command (Fc) x engine speed (N) and engine power (PWe) on the basis of shop trial data is contained in the shop test result.
This would be one of the most simplified and convenient method to investigate and estimate the PWe, which has offered us a comparably precise and accurate figure.

3.1 Summary of calculation method

Estimate the value of horse power from power diagram after taking the measurement of the value of Fc x N during the voyage, and then it should be adjusted by characteristic of fuel oil in order to make further correction and accuracy increased.

3.2 Procedure of the calculation method

1^st^ estimation power PS1 :

After measuring the Fuel command (Fc) and engine speed (N) during the voyage, estimate the 1st estimation power (PW1) by the value of Fc x N from power diagram in the shop test result.

Adjustment by means of characteristic of fuel oil :

From the specific gravity and lower calorific value of fuel oil supplier and those of shop trial's, adjustment should be effected by the following formula.

$$PWe = PW1 \times \frac{\gamma_a}{\gamma} \times \frac{Hua}{Hu}$$

Where: γ_a : Specific gravity of fuel oil used actually at engine inlet temperature
γ : Specific gravity of fuel oil upon shop trial at engine inlet temperature
Hua : Lower calorific value of fuel oil used actually
Hu : Lower calorific value of fuel oil upon shop trial

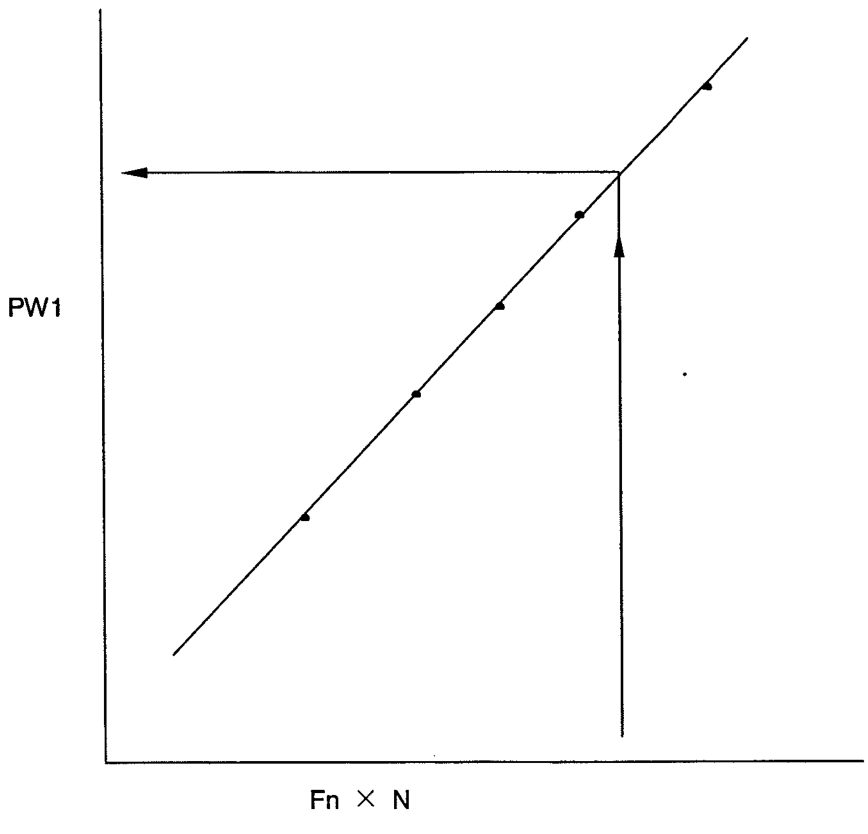
- The specific gravity of fuel oil at engine inlet temperature can be estimated by using the graph shown in Fig. 'A'.
- Regaring lower calorific value of fuel oil, you may use the value shown in the analysis table of fuel oil prepared by oil supplier and in case of no data for it, you can estimate it by using the graph shown in Fig. 'B'.

In the graph, you may obtain the value at the condition of the specific gravity at 15℃.
Furthermore, you are required to check and investigate the value beforehand as possible as you can when you purchase fuel oil, in order to reduce the error of the engine power calclation.

Suppliment :

- The calclation is for estimating the value of horse power on the assumption that the combustion condition is same as that of shop trial's.
- As to the unbalance of horse power at each cylinder, we wish you to make clear the reason and cause for it, putting the condition of compression pressure (Pc) ; Maximum firing pressure (Pmax) of indicator curve, exhaust gas temperature and so on into consideration together.

POWER DIAGRAM

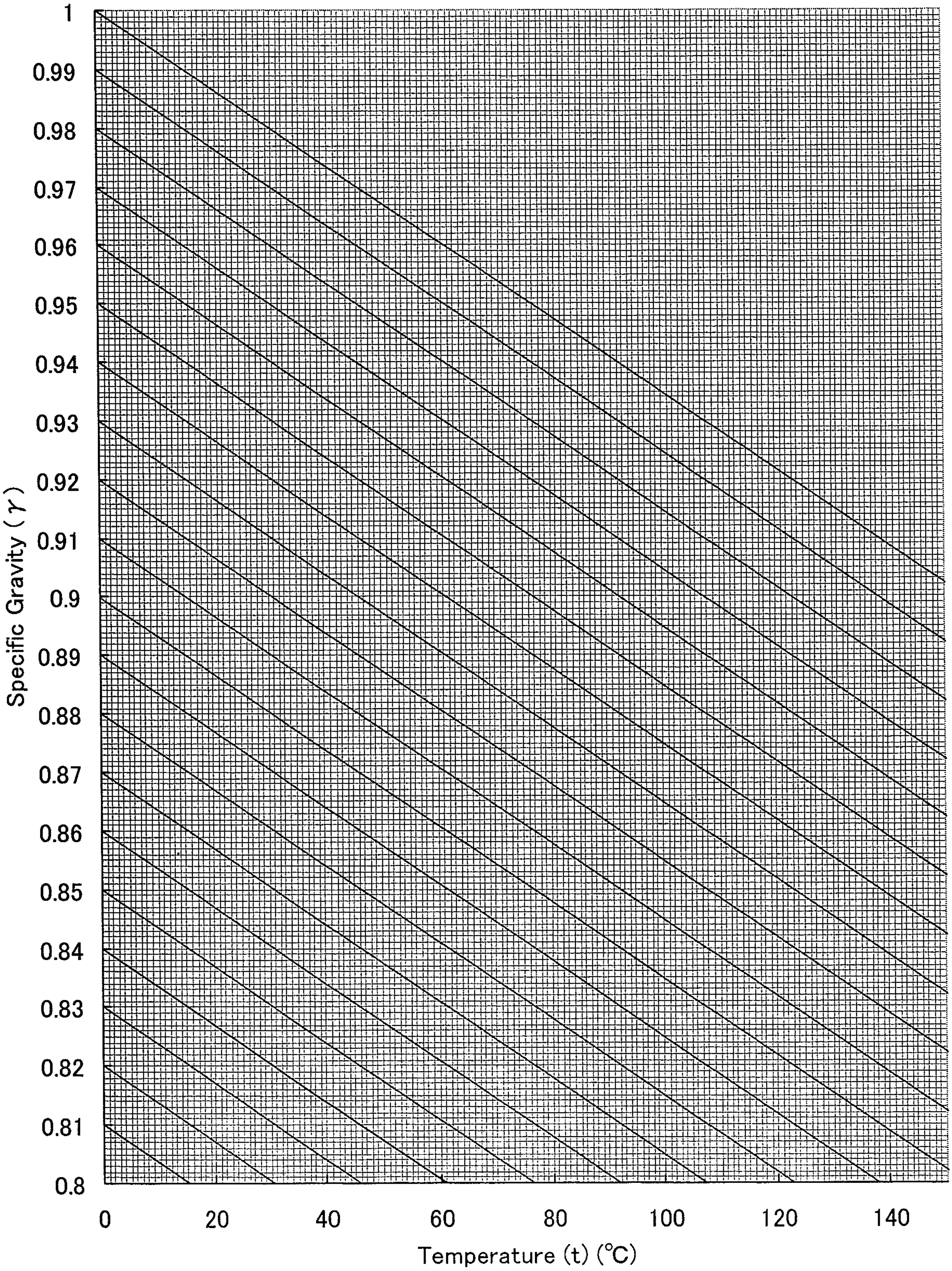


General
Interrelationship between Engine and Propeller

(A) Temperature – Specific Gravity (γ) of Fuel oil

$$\gamma = \gamma' - 0.00065 \times (t - 15)$$

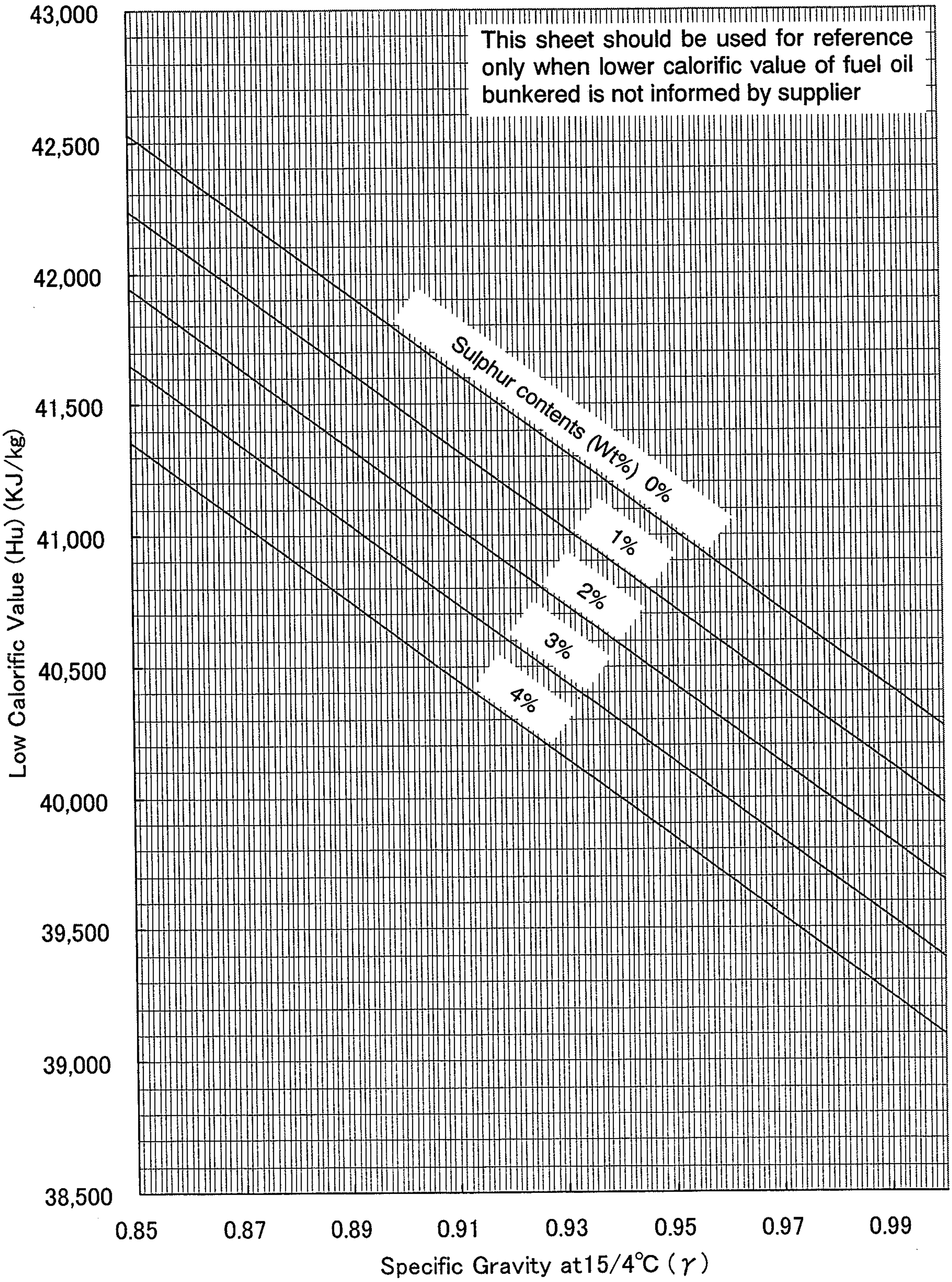
γ' : Specific gravity at 15/4℃



B Specific Gravity (γ) – Lower Calorific Value (Hu) of Fuel oil

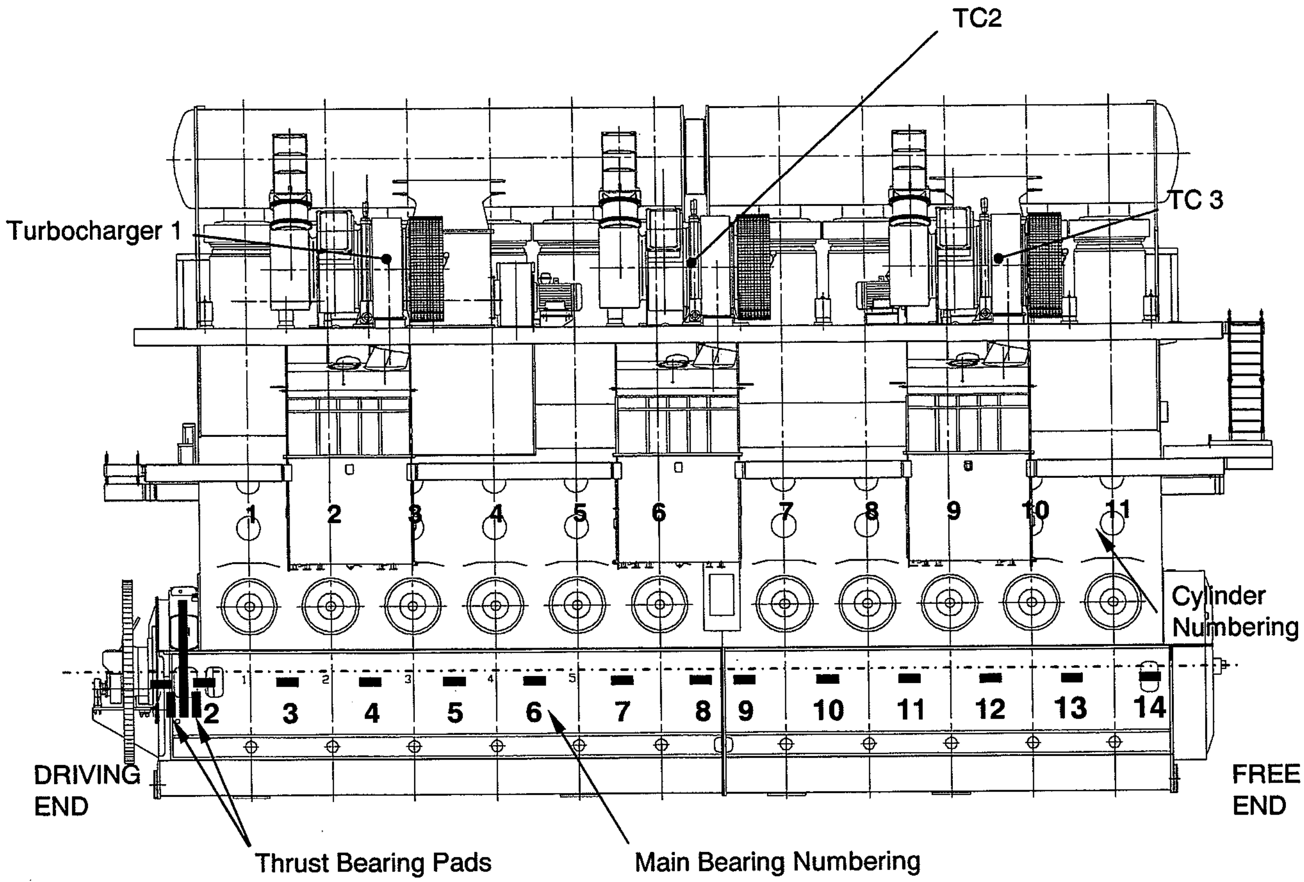
$$Hu = 4.18605\{(3.672 - \gamma) \times 3600 - (S\% \times 70)\}$$

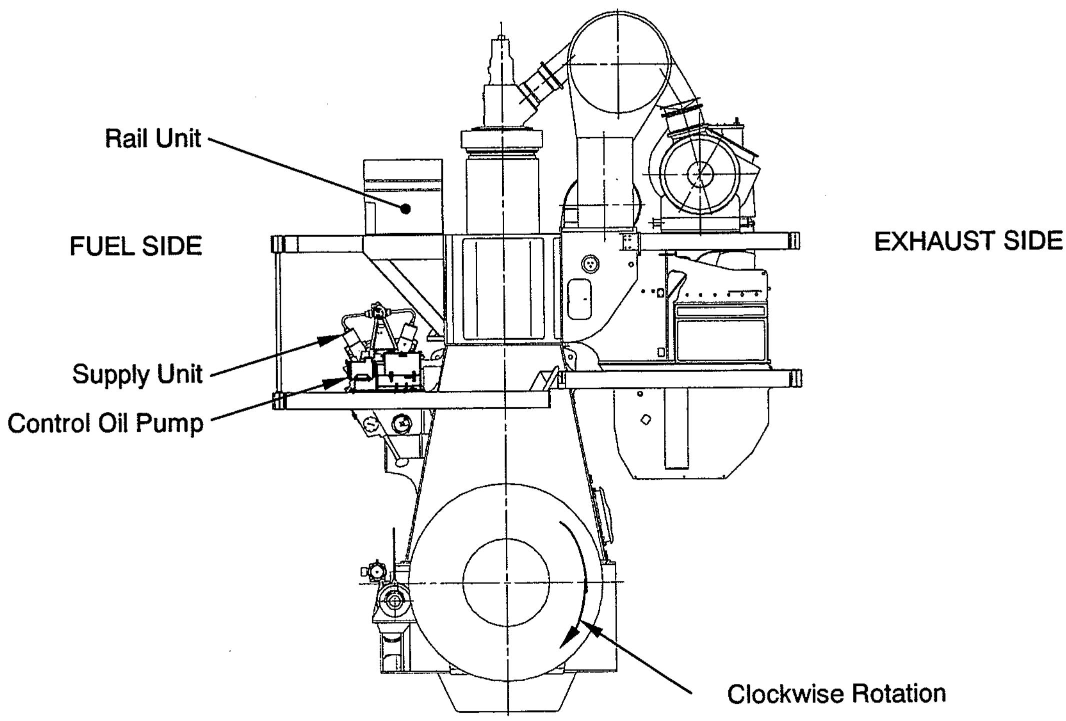
S : Sulphur %



General

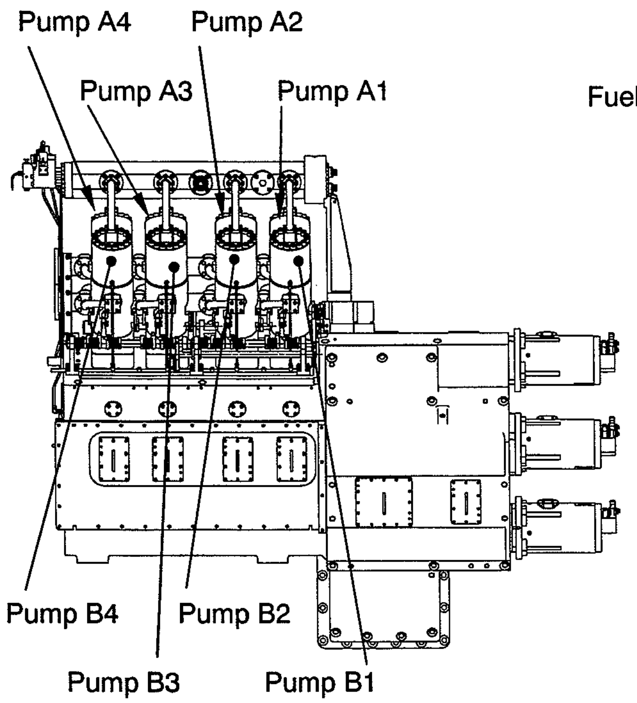
Engine Numbering and Designations

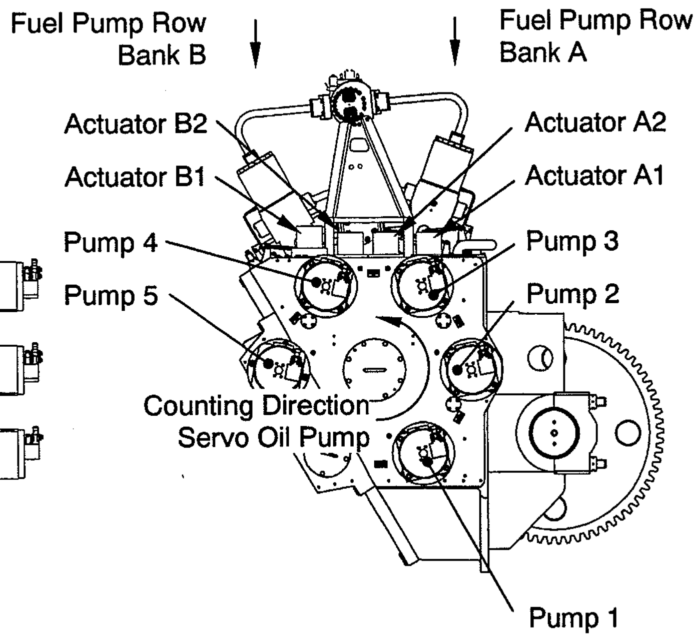




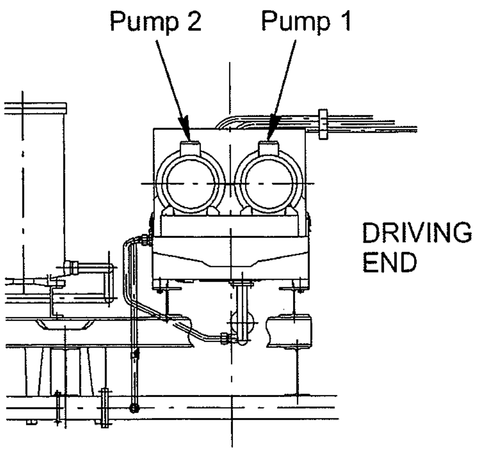
General

Engine Numbering and Designations



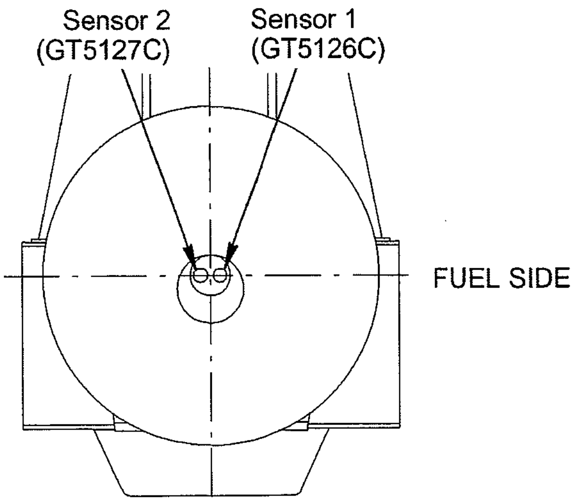


Control Oil Pumps



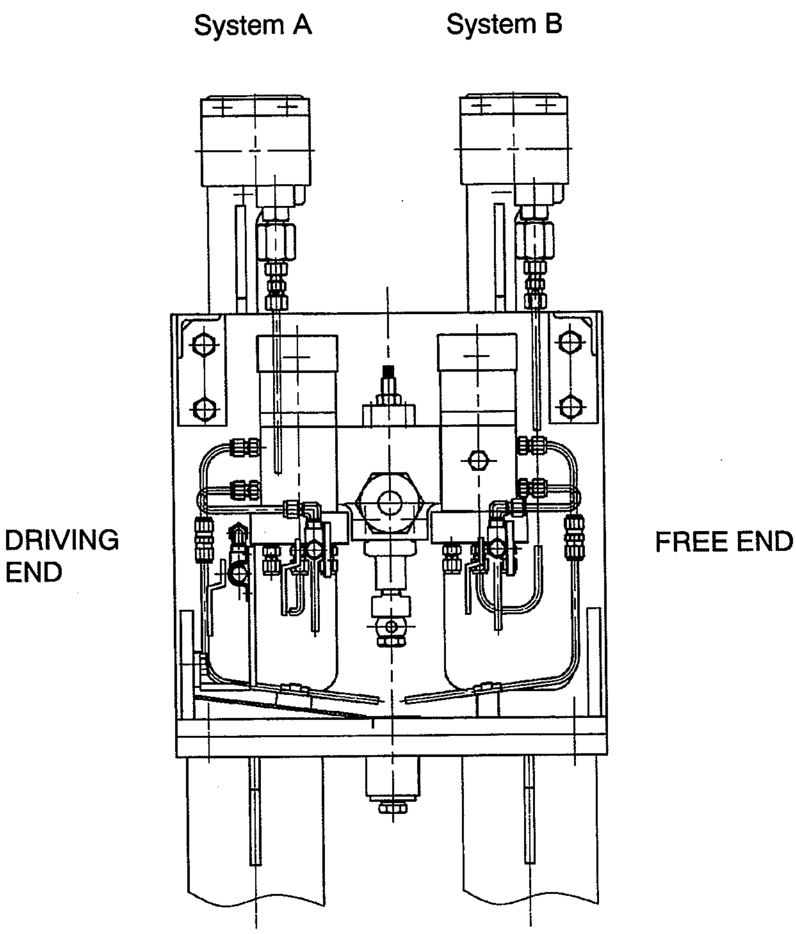
FUEL SIDE

Crank Angle Sensors



FREE END

ECL Distributor unit



General
Management of IMO(2000)-NOx Compliant Engine

When the main engine of the ship is IMO(2000)-NOx compliant engine, the following matters should be kept for the operation and the maintenance.

1. Engine operation

1) The maximum cylinder pressure (Pmax) must not exceed the pressure mentioned in the Technical File.
(For the adjusting method, refer to the sheets 0420-1.)

2) The fuel injection begine can be adjusted in the range of $\pm 0.5°$ from $0°$.

3) The adjustment of FQS setting can be adjusted in the range of $\pm 1°$ from $0°$.
However, the value of item 1) should be kept by the adjustment.

2. Engine maintenance

1) When the parts mentioned in the Technical File are exchanged, confirm the parts which ID-number are stamped and exchanged them.

2) For spare part, the part must be used after confirming it that ID-number stamped.

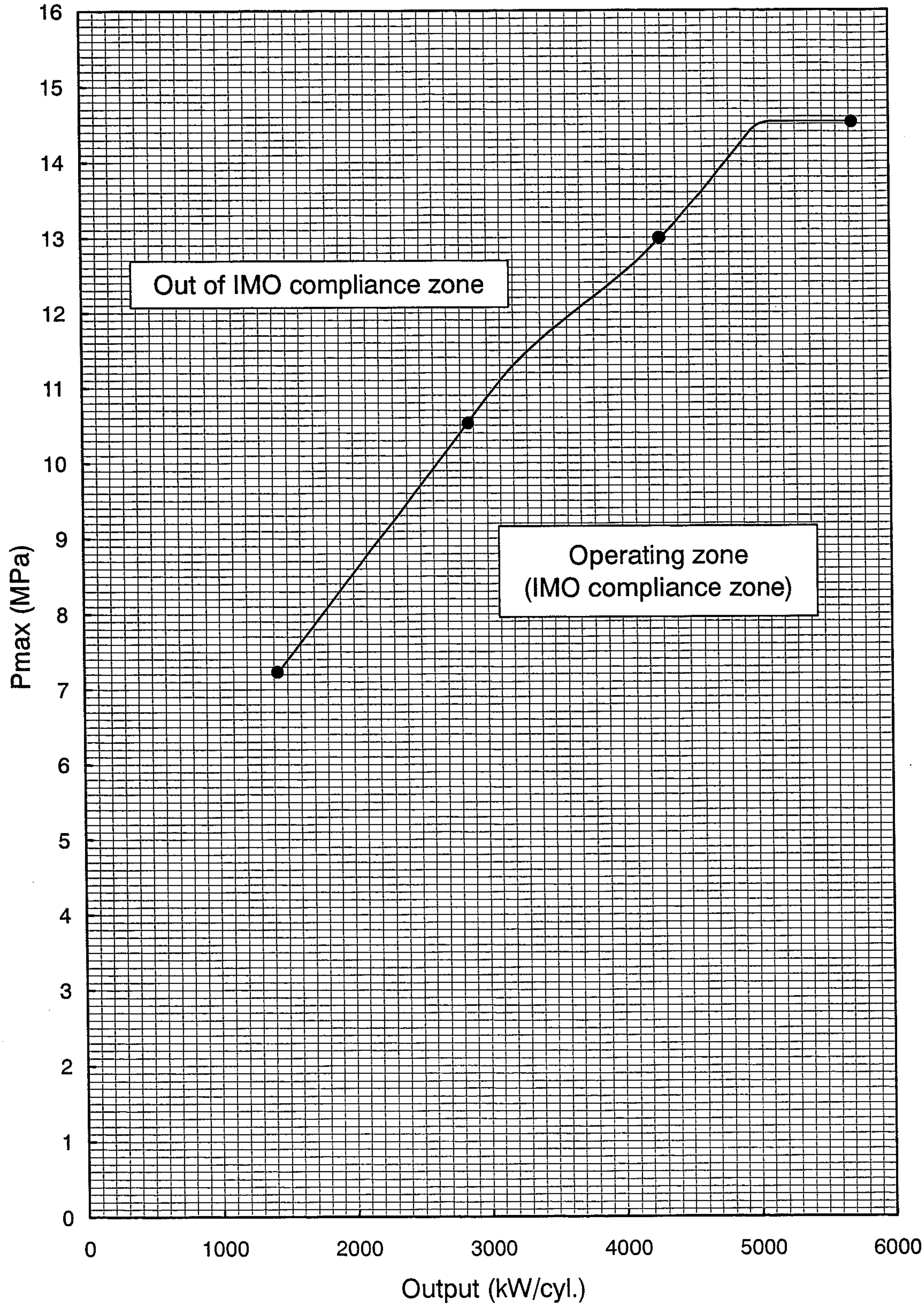
3) When the parameter check method is selected at the periodic inspection, the exchanged record (exchanged data, ID-number or adjusted value and sign) of the parts must be entered in the maintenance record book and kept.

CAUTION

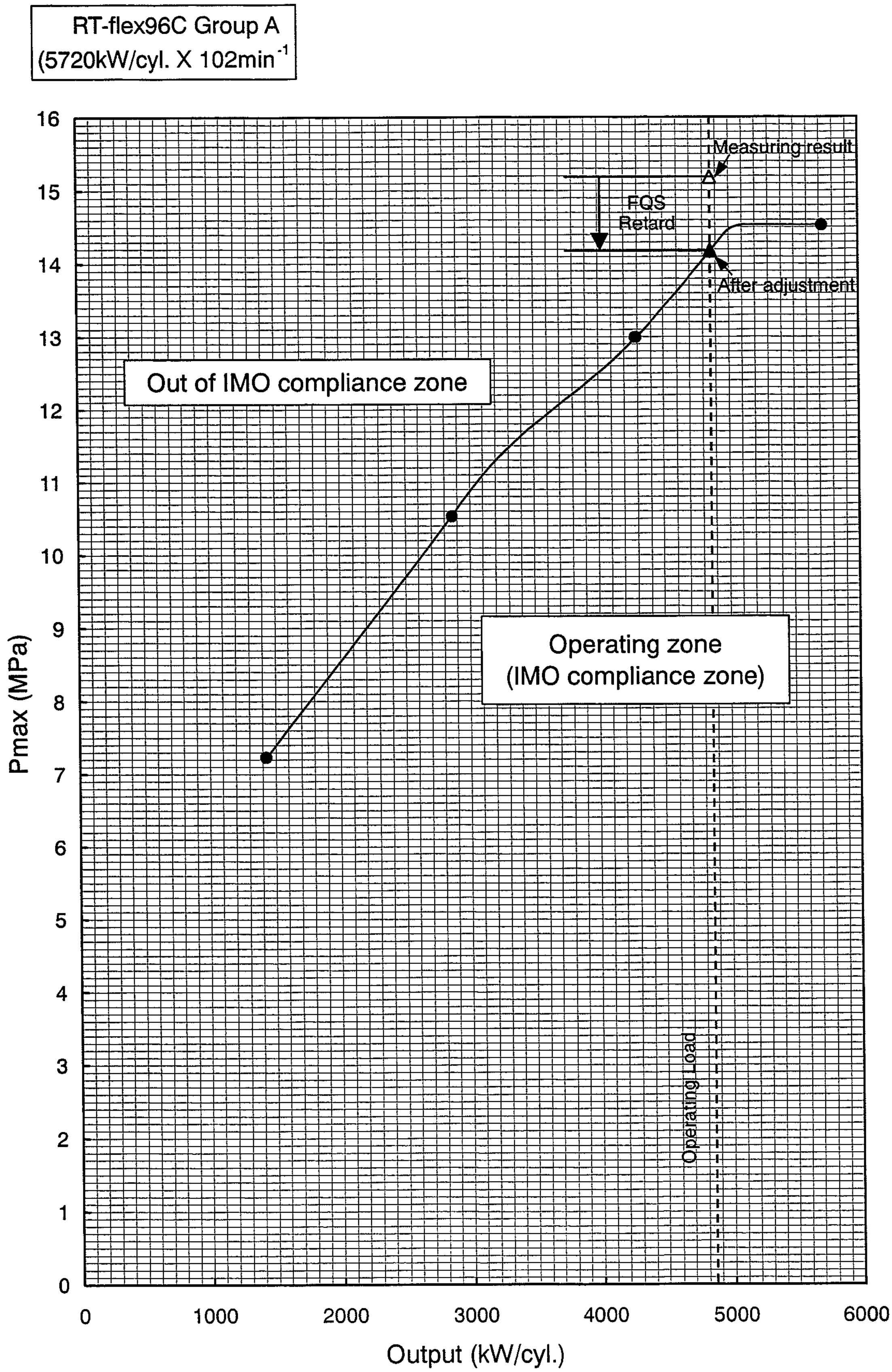
In the parts having ID-numbers, the parts except for being recognized with the Technical File cannot be used.

Pmax curve for RT-flex96C

RT-flex96C Group A
(5720kW/cyl. X 102min^{-1}



Pmax curve for RT-flex96C



1. Starting position

It is assumed that:

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

CAUTION

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

2. Check and preparation

⇒ Check the fluid levels of all the tanks in the in the engine systems (including the leakage drain tanks).

⇒ Check that all the shut-offs for the engine cooling water and lubricating oil systems are in the correct position.

⇒ Open the air supply from the shipboard system and from the starting air bottles (9.01) to the control air supply [A].

⇒ Preheat the lubricating oil to about 35 °C (via separating circuit or heating in oil drain tank).

⇒ Preheat the cylinder cooling water to min. 60 °C.

⇒ Switch on the remote and engine control system WECS-9520.
- Switch on all breakers in the power supply box E85.
- Check that both green indication LEDs light up on all FCM-20 modules.

- The FCM-20 modules are able to function if no red LEDs light up after the countdown process.

⇒ Prepare the servo and control oil system (see 0130-1).

⇒ Start up the pumps for cylinder cooling water, bearing and crosshead bearing lubricating oil as well as for turbochargers with external oil supply systems and set the pressures to their normal values (see Operating Data Sheet 0250-1).

⇒ Switch on control box for automatic filter (see documentation of the automatic filter manufacturer).

Preparation before Taking into Service
Preparations before Starting after a Short Shut-down (One or More Days)

⇒ Switch on main switch of the control oil pumps.

⇒ Prepare the fuel oil systems (see 0120-1).

⇒ Ensure that all systems are correctly vented.

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

⇒ Open each cylinder cover's indicator valve. With the aid of the turning gear, turn the engine through several revolutions to check that all the running gears are in order. At the same time, operate cylinder lubricators to priming. Neither water, oil fuel may spray out of the indicator cocks. If so, depending on the liquid, check cylinder liner, cylinder cover, piston or injection valves.

⇒ Shut indicator valves.

⇒ Check to ensure that all the crankcase doors are locked **with all the clamp.**

⇒ Check that the fuel pump regulating linkage moves freely in the spring links.

⇒ Check the pressure in the starting air bottles and open their drains until any condensate has been drained.

⇒ Open the drain and test valve (2.06) of the shut-off valve for starting air (2.03) until no more water comes out.

⇒ Close venting valve (2.21) and (2.27) and open the main shut-off valves on the starting air bottles (9.01).

⇒ Bring the shut-off valve for starting air (2.03) to position "AUTOMAT.".

⇒ Open the shut-off cocks at connections "A1" and "A2" (see Control Air Supply 4605-1).

- The pressure gauges on the instrument panel must now show starting air, control air and air spring pressre.
- A pressure must also be indicated on the pressure gauges for the control air supply.

The different circuit are:

– Air spring air
– Control air

- Air supply from the board system via pressure reducing valve 23HA, and back-up supply from the starting air system via the pressure reducing valve 19HA.

Required pressures see Operating Data Sheet 0250-1.

⇒ Set the switches on the control panels for the auxiliary blowers to “AUTOMATIC”.

⇒ Disengage the turning gear and secure the lever.

⇒ Open the test valve (2.06) of the shut-off valve for starting air (2.03) for a short time and listen if the valve opens (can be heard distinctly). Close the test valve again.

⇒ Press SLOW TURNING button in WECS-9520 manual control panel on the local control panel (4618-1). The engine well perform one slow revolution (see also Slow Turning 0220-1).

⇒ Depending from where the engine will be started (either the bridge, control room or local control panel), the corresponding button in WECS-9520 manual control panel (local control panel) and the corresponding takeover buttons of the remote control must be activated.

⇒ Check again to ensure that no personnel are near the flywheel.

⇒ Inform readiness to the bridge.

1. For diesel oil operation

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

⇒ Set the three-way valve (21) in the suction line of the low pressure feed pump (23) so that diesel oil flows from the daily tank (3) to the pump and to the mixing unit (24).

⇒ Check to ensure that the shut-off valves before and after engine are open.

⇒ Start up pumps (23) and (25).

⇒ Drain daily tanks and mixing unit.

⇒ Set pressure in fuel oil system using pressure regulating valve (31). When running with diesel oil (and low fuel temperature) a slight over-pressure is sufficient. If later a change-over to heavy fuel oil required, setting of normal pressure is recommended from the beginning.

⇒ Set fuel oil pressure at fuel pump inlet using pressure retaining valve (31a) (3.53) (pressure difference before/after pressure retaining valve see Operating Data Sheet 0250-1).

2. For heavy fuel oil operation

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

Remark : The fuel oil system is not ready for service until the heavy fuel oil before the fuel pumps has reached the required temperature (see Viscosity-Temperature Diagram 0270-2).
The high pressure circuit on the engine must be preheated for at least four to six hours after a prolonged shut-down period (more than 24 hours).
Before that, the engine may not be started on heavy fuel oil!

⇒ Turn on the heating for the heavy fuel oil daily tank (2), mixing unit (24), endheater (26) and filter (27).

⇒ Turn on the heating for the fuel oil system on the engine (fuel rail (10) (3.05), rising pipes (9) (3.29) and fuel leakage system; see 8019-1).

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

⇒ Set the three-way valve (21) in the suction line of the low pressure feed pump (23) so that heavy fuel oil flows from the daily tank (2) to the pump (23) and to the mixing unit (24).

⇒ Drain settling, daily tanks and mixing unit.

⇒ Check to ensure that the shut-off valves before and after engine are open.

⇒ Start up pumps (23) and (25).

- Heat up the heavy fuel oil. This is neccesary to bring it to the required viscosity (see Changing Over from Diesel Oil to Heavy Fuel Oil 0270-1)

⇒ Set pressure in fuel oil system using pressure regulating valve (31).

⇒ Set fuel oil pressure at fuel pump inlet using pressure retaining valve (31a) (pressure difference before/after pressure retaining valve see Operating Data Sheet 0250-1).

3. High pressure circuit on the engine

(see Fuel Oil System 8019-1)

⇒ Check to ensure that stop valves (15) (3.62-1 & 2) after intermediate fuel accumulator 8 (3.04), stop valves (16) (3.33-1 & 2) before fuel rail (10) (3.05) and stop valves (17) (3.33-3 & 4) of connecting pipe between fuel rails DE and FE are open **till the stop** and tightened with a torque of 100 Nm.

⇒ Check to ensure that no screw plugs are fitted (tool 94585 for shut off injection control unit), and plug (18) (3.35) is tightened with a torque of 270 Nm, in the injection control unit (11) (3.02).

⇒ Check whether drain screws 44 in the valve block before fuel rail (10) (3.05) are closed and tightened with a torque of 200 Nm.

4. Priming the fuel system on the engine

(see 0720-1 ‘Layout of the fuel oil system’ (items in parentheses), and Fuel Oil System 8019-1)

Priming (venting) the fuel system on the engine manually is not necessary if the whole system has been filled up or if rising pipes (9) (3.29) or fuel rail (10) (3.05) have been drained. It is advisable also after maintenance works on the fuel rail.

Procedure:

⇒ Carry out checks according to section 3.

⇒ Start low pressure feed pump (23) and booster pump (25).

- When starting booster pump (25) fuel oil circulates throuth fuel pumps (3) (3.14).

⇒ Actuate emergency stop button in the control room or on local control panel.

- Fuel pressure control valve (26) (3.06) opens and intermediate fuel accumulator (8) (3.04), fuel rising pipes (9) (3.29) and fuel rail (10) (3.05) are filled via fuel return pipe (4).

⇒ Loosen plugs (18) (3.35) by two to three turns on injection control units (11) (3.02) of the first and last cylinders. Close and tighten them with a torque of 270 Nm as soon as fuel flows bubble-free.

Remark : Priming (venting) manually the fuel oil system on the engine is not necessary if only HP pipes (7a) (3.47) or injection control units (11) (3.02) have been drained.

⇒ Remove plug (38) (3.39) and the nut with conical plug on stop valve (3.40) and connect the pipe (tool 94583) between fuel rail (10) (3.05) and control oil rail (3.75).

⇒ Switch on bearing oil pump and control oil pump (main switch).

- The required system pressure is generated by the control oil pump.

⇒ Start the vent function of the fuel oil system in the remote control (user parameter, functions 'inj. Venting' and 'Venting all').

⇒ Repeat the vent function till no big fuel pressure drop is noted (see pressure indication on control panel [K]).

⇒ Close stop valve (3.40). Relieve pressure in fuel HP system and control oil rail (3.75).

⇒ Remove the pipe (tool 94583). Apply Never-Seez NSTB-8 to the thread and seating surface of plug (38) (3.39) and tighten it with a torque of 270 Nm. Refit and tighten the nut with the conical plug on stop valve (3.40).

CAUTION

If the pipe (tool 94583) must remain attached for special reasons, stop valve (3.40) must open.
Never consider operation with connecting pipe built-on as a permanet codition!

1. General

(see 8016-1 'Servo and control oil system')

CHECK *Check-list:*

⇒ Stop valve (20) (4.37) opened before automatic filter (2) (4.20).

Control oil pump unit:

⇒ Stop valve (46) (3.79-1 & 2) opened on distributor block.

⇒ Drain screw (leakage oil drain) on distributor block closed and tightened with a torque of 200 Nm (see Control Oil Pump Unit 5571-1).

Servo oil supply:

⇒ Stop valve (21) (4.25-1 & 2) opened till the **stops** and tightened with a torque of 200 Nm on collector block (3) (4.52).

⇒ Drain screw (43) (4.72) tightened in collector block (3) (4.52) (see 8016-1 'Filling, draining of servo and control oil system').

Rail unit:

⇒ Stop valve (52) (3.80-1 & 2) opened before control oil rail (15) (3.75).

⇒ Stop valves (54) (3.80-1 & 2) opened before control oil rail (15) (3.75).

⇒ Drain screws (41) and (41a) (3.68) in valve block 'VB' of control oil rail (15) (3.75) at driving and free ends closed and tightened with a torque of 200 Nm (see 8016-1 'Filling, draining of servo and control oil system').

⇒ Stop valve (40) (3.40) on control oil rail (15) (3.75) at free end closed and nut with conical plug fitted.

⇒ Stop valves (22) (4.26-1 & 2) before servo oil rail (9) (4.11) and stop valves (23)(4.26-3 & 4) of connecting pipe between servo oil rails DE and FE opened till the **stops** and tightened with a torque of 200 Nm.

⇒ Drain screws (24) and (24a) tightened in the valve blocks before servo oil rail (9) (4.11).

⇒ No shut-off plugs (tool 94586 for cut-out of the exhaust valve drive) fitted in exhaust valve drives 10 (4.10).

⇒ Screws (64) of plug (37) (4.32) in connecting element 'VE' between servo oil rail (9) (inlet) and exhaust valve drive (10) (4.10) tightened with a torque of 130 Nm.

⇒ Screws of plug (38) (4.33) in connector block (outlet) tightened with a torque of 130 Nm.

⇒ Plugs (44) (4.34) for draining actuator pipe (12) (4.66) closed on all exhaust valve drive (10) (4.10).

⇒ Stop valves (30) (4.30-1 to 4) of servo oil rail (9) (4.11) at driving end and connection to control oil rail (15) (3.75) at free end opened.

1. General

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

For operation under abnormal conditions, see 0500-1.

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

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

Thanks to the fuel circulating system in parallel with the fuel injection system, fuel also circulates when the engine is at a standstill as long as the booster pump is running. Pre-conditions are that the installation too is laid out to suit, the heavy fuel oil has been correctly treated and it is kept at the correct temperature during the whole period in service, including manoeuvring and “Stand-by”. This requires energy.

Operation
General Matters that Demand Special Attention on Operation

1. General

There are dangerous parts on the engine since it rotates at high speed during engine operation, has high temperature parts, and has pressure fluids such as compressed air, oil, and water flowing inside.
In order to operate the engine in good condition, it is important that the engine should be maintained for trouble-free and safe operation. The following items should be managed by considering all possible cases, and try correct handling in accordance with this booklet so as to be without trouble.

2. Attention to rotation

WARNING

> It is very dangerous that your body or a thing touches rotating parts, because it is caught in the engine or fly off.

- Before starting the engine, make sure whether engine surrounding people are safe.
- During engine operation, do not remove the protecting cover.
  Besides, do not touch the rotating and moving parts such as the flywheel and couplings.
- Do not touch engine parts in remote control and at automatic starting.
  It is very dangerous that some engine parts are carelessly touched because it is feared that rotating and moving parts suddenly.
- At inspection and maintenance, start to do the work after the following operation must be carried out and then make sure the engine does not rotate.

  (1) Engine control position is at "REMOTE (Auto.) CONTROL" position.
  (2) Valves in starting air system are at "close" position.
  (3) Lever of turning gear is "engaging" position.
- After inspection and maintenance, restore the removed protecting cover of rotating and moving parts as it was before.

3. Attention to temperature

WARNING

> There is the possibility to get burnt on the engine in running and right after stopping, specially, on the exhaust pipes, turbocharger, indicator valves, and parts around cylinder covers, whose temperatures are high.

- Do not remove lagging on the pipes, etc. during engine operation.
- Do not touch the engine in running and right after stopping with bare hands and skin. Be sure to put on the protector such as cloth gloves at measurement and inspections.
- Carry out overhauls and maintenance of the parts after cooling down the engine fully.

4. Attention to pressure

WARNING

High temperature and pressure oil and water flow in pipe systems in running and right after stopping. In particular, leaking from oil pipe system is connected with serious fire trouble.

- Be careful of leaking from pipe systems during engine operation, and immediately stop the engine if leaking is found and repair it. In particular, take care so that cocks, valves, etc. are liable to leak liquids or gases from packing or sealing part due to long use.

- When overhauling pipe systems, do priming surely after assembling pipes, ascertain no leaking, and then start the engine.

5. Attention to fire

WARNING

If there are explosive gases, vapours, or fuel liquids in the engine room, it is connected with serious fire trouble.

- Carry out welding and other work after confirming that there is no cause of fire such as explosive gases, vapours, fuel liquids, paint, combustible solvent in the engine room.

- When opening the crankcase door, open it after the engine has cooled down sufficiently.

WARNING

· Do not open the crankcase door and each inspection door for 20 minutes after stopping engine to prevent crankcase explosion. · When the temperature of crankcase door is abnormally high even after 20 minutes passing, do not open the crankcase door and each inspection door.

WARNING

· For 20 minutes after stopping engine and being abnormally high temperature on the crankcase door, anyone must be distance from the crankcase safety valve and its blowing direction to avoid accidents arising from blowing off of the safety valve.

- Since insulating material which has soaked up either oil or fuel (leakage) is combustible, renew the material.

- Wipe off oil, etc. in the engine room, on the floor plate, etc. regardless of the quantity and eliminate the cause of fire.

- Set all kinds of valves, cocks, etc. in oil pipe systems at the regular position and ascertain there is no oil leakage.
  Refer to “Measure against Fouling and Fires in Scavenging Air Chamber” of this booklet “0450-1”.

6. Lightening

It is recommended that sufficient permanent lighting is equipped in engine room and hand lamps are prepared at necessary and near around the engine.

7. Cleanliess

WARNING

Since the floor in the engine room and the engine are slippery with oil adhering to them, take care so as not to cause a falling-down accident.

- Always keep the engine room including engine itself as clean as possible.
- Special care must be taken to keep the WECS electronic control boxes clean and dry on the rail unit.
- Wipe oil leakage, etc. regardless of the quantity and stop the leakage as quick as possible.
- Prevent dust or sand, etc. from entering the engine room.
- When doing the work which is welding or produces machining tips near the engine, cover engine opening parts and the air suction casing of turbocharger.

8. Protecting aids

WARNING

Be sure to put on earhole plugs when entering the engine room during engine operation.

- Put on earhole plugs against engine noises in the engine room during engine operation. Besides, put on the protecting aids such as helmet and safety belt according to the condition.

9. Tools

WARNING

Before using tools, make sure there is no damage on them.

- Sorts of tools should be inspected, maintained, and stored by putting them in order with the condition of being able to use easily in near area where the tools will be used frequently.
- In particular, protect measuring tools, etc. so as not to receive physical damage and store them by taking rust prevention.

10. Spare parts

- Store large spare parts as near as possible to where the parts will be used, near the overhead crane in the engine room, and at where the parts securely supported, and the parts must be protected so as not to rust and not to receive physical damage.
- Check the quantity of spare parts properly and fill up it if it is short.

11. Temperature sensing by touch

WARNING: Put on cloth gloves at the inspection.

- When the engine is starting again after running gear parts have been overhauled, make a check by feeling with the hand after about 10 minutes and then again after about an hour's running time to see if any of parts have become excessively hot.
- Confirm this check again after a short run at normal service output.

12. Measuring and indicating instruments

Check and calibrate measuring and indicating instruments periodically.

13. Freezing

If there is the possibility that machines and tools are damaged by originating from freezing while the engine is stopped, precautions must be taken to drain the water in the engine, the pumps, coolers, and cooling system or to heat the engine room.

Remark : Further instruction concerning safety precautions for maintenance work see Maintenance Manual 0012-1.

Operation
General Matters that Demand Special Attention on Maintenance

1. General

Engine maintenance items and maintenance schedule after entering service are mentioned in the maintenance manual 0380 as guidelines. Engine maintenance schedule should be suitably determined by judging engine service condition (running output, using fuel oil and lubricating oil, etc.) together with engine circumstances which is understood on the base of experienced knowledge getting from the forementioned engine condition and many other conditions in order to maintain good conditions in order to maintain good condition of the for long time.

When doing engine maintenance and inspection work, read the “Maintenance Manual” and “Operating Manual” beforehand, grasp the structure of the parts in question and the contents of work, study working procedure sufficiently, and then set to work. If the work is done with insufficiet preparatory study, not only it spends wasteful labor but also it is connected with an accident due to miss-assembly and engine damage.

The parts which damage is detected and using limit has been reached and will be reached until next inspection as the result of inspection must be replaced with the designated regular parts. If it is difficult to take measures against troubles on board or on the spot, communicate with the engine maker service department and take suitable measures.

2. Precautionary measures before beginning of maintenance work

Before starting any maintenance work on the engine (particularly on the running gear), take the following precautionary measures:

⇒ Close the shut-off valves on the starting air bottles.

⇒ Close all the shut-off valves in the control air supply unit, and open the drains on both air bottles until it is depressurized.

⇒ Close by hand the (automatic) shut-off valve for starting air and open the vent and drain valve to the main starting air piping on the engine as well as the vent valves on the shut-off valve starting air, and leave them in this position until maintenance work is completed.

⇒ Open all indicator cokes on the cylinder covers and leave them in this position until maintenance work is completed.

⇒ Engage turning gear (gear pinion must be in engaged position) and lock the lever.

- Where the engine has been stopped due to overheated running gear or bearings, wait a least 20 minutes before opening the crankcase doors.
- **The crankcase doors must always be locked with all the clamps whenever the engine is running,** even if this is only for a short time in order to make temperature checks (e.g. after changing bearing during an overhaul, etc.).
- In the case of a fire in the engine having been extinguished by means of CO_2, the spaces affected must be well ventilated before work can be carried out within them.

WARNING

When performing electric welding near or on the engine, electromagnetic fields or peak voltage may occur, which may damage the electronic components of the WECS-9520 engine control and monitoring system.

Prior to performing electric welding in the vicinity of WECS-9520 the following precautions must be taken:

- Stop the engine if it is operation.
- Power off the electronic system and wait one minute.
- If the welding point is within a radius of two metres from an electronic module FCM-20 and/or a sensor, disconnect the modules and/or sensors.
- Close the covers of all electric boxes and protect cables, sensors, etc. against sparking and heat.
- Shield the check and control units with a conductive material and connect them to earth.
- Run the welding cable from the welding apparatus directly to the welding point without any unnecessary loops; also, avoid leading the welding cable parallel to cables of the electronic control unit.

3. Attention to safety

WARNING

· Do not open the crankcase door and each inspection door for 20minutes after stopping engine to prevent crankcase explosion. · When the temperature of the crankcase door is abnormally high even after 20 minutes passing, do not open the crankcase door and each inspection door.

WARNING

For 20 minutes after stopping engine and being abnormally high temperature on the crankcase door, anyone must be distance from the crankcase safety valve and its blowing direction to avoid accidents arising from blowing off of the safety valve.

- Do not open the crankcase door until the engine has cooled down sufficiently.
- If fresh air flows into the crankcase when the engine is overheated, there is the possibility that oil mist catch fire and explode.

WARNING

If CO_2 extinguishing system has been used, there is the possibility of suffocation and very dangerous.

- If a fire takes place in the engine room or the engine and CO_2 extinguishing system is used, ventilate the related area and remove the fire extinguisher completely.

WARNING

When maintenance or inspection work is carried out, put on the protecting aids such as gloves, helmet, safety shoes, protecting glasses, safety belt and protective mask.

- There is high temperature on the engine in running and right after stopping, especially, on the parts such as exhaust pipes, turbocharger, indicator valves, and parts around cylinder covers.
  Put on cloth gloves so as no to get burnt in the hand and then set to work.

Operation
General Matters that Demand Special Attention on Maintenance

WARNING

When maintenance or inspection works, watch your steps carefully so that a falling-down accident and a fall accident which is working at a height cannot happen.

WARNING

At all times when somebody is inside the engine casing another person must stand by in order that he can give the necessary aid if something unexpected happens to the person inside the engine. The person who is inside the engine casing must be equipped with all safety gears which are required to prevent suffocation within the limited space and atmospheric conditions. Moreover an antifall guard must be carried at dangerous places!

- The floor in the engine room and the engine are slippery with oil adhering to them. When work is carried out, wipe oil on floor and the sole of shoes and watch your steps carefully so that a falling-down and a fall accident cannot happen.
- When taking out the parts, especially, exhaust valve, cylinder cover, and piston, install an adequate cover at the opening.
- When the work is carried out inside the engine, install steady foot steps as occasion demands.

WARNING

When overhauling each pipe system, keep all valves connected to engine outside "closed" and release the pressure by loosening air vent plugs, etc. gradually.

- If strainers and pipe joint parts are overhauled right after engine stopping, there is a possibility that temperature oil and water spout due to remaining pressure.

WARNING

If the engine is turned during maintenance and inspection work, it is very dangerous due to the accident being caught in the engine.

- Before working, return the engine control position to "REMOTE CONTROL" position, keep the valves of starting air system and automatic starting air stop valve "closed" surely, and the lever of the turning gear is "engaging" position. Set to work after confirming that the engine is not turned.
- When the crankshaft is turned, be sure to carry it out while giving signals, after confirming whether rotating parts are out of contact with other parts and workmen and surrounding people get into danger by turning the crankshaft.
- During turning the engine, do not touch moving parts.

WARNING

When the devices of the engine are overhauled, it is very dangerous since there is a possibility of spring dashing out.

- When overhauling various valves and devices which are used with springs, the take care since there is a possibility of spring dashing out.

Operation
General Matters that Demand Special Attention on Maintenance

WARNING

> Lift up overhauled heavy parts by using the chain block.

- Be sure to lift up overhauled heavy parts by using the lifting tool such as chain block without lifting by human power.
- Do not approach under lifting parts.

WARNING

> Before using tools, make sure that there is no damage on them.

- Check the hydraulic jack before using since there is the possibility that high pressure oil spout out at the time of using tool if there is a crack in the hydraulic jack and damage such as cut on the hose.
- If In particular, if there is a crack in the lifting tool, do not use the tool since there is the possibility that the lifting parts fall down.

WARNING

> Before maintenance around electric and electronic components, especially FCM-20, with welding, keep power source "OFF". If do it, electric and electronic components have possibilities to be occured.
> Communication abnormal due to noise

WARNING

> Before handling electric parts for maintenance and inspection, be sure to keep power source "OFF".

- Before handling electric parts for maintenance and inspection, do it after keeping main power source and the power source of handling electric parts "OFF" due to danger of getting an electric shock.

WARNING

> Do not bring a light or a fire close to fuel oil, oil, anti-corrosive agent, cleaning agent, etc.

- There is the possibility of catching fire if a light or a fire is brought close to fuel oil, oil, ant-corrosive agent, cleaning agent, etc. When handling liquids, keep the following things strictly.

WARNING

· Fuel oil, Lubricating oil	: Combustible	←	The lighting of fire is prohibited.
· Cooling water anti-corrosive Agent, Cleaning agent	: Combustible Poisonous	←	The lighting of fire is prohibited. Not to drink
· Mercury (Thermometer)	: Poisonous	←	Not to drink

- Put on gloves and protective glasses when handling liquid and fully wash liquids with cold fresh water when it has adhered to you skin mistake.
  Furthermore, consult a doctor immediately when it has adhered to your eyes or drinking it by mistake.
- When using other liquids, chemical products, etc. , follow the instruction book of each product maker.

4. Attention during maintenance and inspection

CAUTION

Install adequate covers at the pipes and joints removed at connecting parts or at the opening of removed parts so as not to admit foreign matters such as dust.

CAUTION

Change the parts which damage is detected and using limit has been reached and will be reached until next inspection with the designated regular parts.

5. Attention at the time of ending maintenance and inspection

CAUTION

Ascertain that bolts and nuts are tightened and locked without forgetting.

- When tightening bolts and nuts, take care so as not to damage the thread part and tighten them after making close contact (to do metal touch) of tightening surface surely. Besides, for tightening main bolts, refer to Maintenance Manual 0352-1.
- Carry out locking securely at the parts of where it needs.

CAUTION

Restore the protecting cover removed at maintenance and inspection as it was before.

CAUTION

Make sure that used tools are not left inside and around the engine.

- If the engine is turned by leaving tools inside the engine, there is the possibility of giving damage on the engine.
- Do not leave tools on the floor plate, passages, parts, etc.

CAUTION

After assembling parts, make sure that there is in good order at each part of the engine by turning and priming.

- During engine turning, keep all indicator valves on cylinder covers "open".
- At engine starting, keep all indicator valves on cylinder covers "closed".

CAUTION

Make sure that all kinds of valves, cocks, etc. in pipe systems are set at the regular position.

CAUTION

Close the crankcase doors and tighten them securely.

- During engines operation, lock the crankcase doors surely.
- Keep from using the impact wrench as there is the possibility that the gasket is damaged.

Operation under Normal Condition
Slow Turning

1. General

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

2. Turn by the turning gear

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

3. SLOW TURNING with starting air

The running gear can be turned at approx. 5 ~ 10 rpm by releasing a controlled amount of starting air.
In the engine control system WECS-9520 the command SLOW TURNING is provided for this operation. Depending on the active control stand it is initiated:

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

3.1 Conditions

Beforehand the following conditions must be fulfilled:

- Turning gear disengaged.
- WECS-9520 engine control system switched on.
- Oil pumps operating (bearing, crosshead and control oil).
- Corresponding control stand activated.
- Indicator valves closed.
- Handwheel (2.10) on shut-off valve for starting air (2.03) in position AUTOMAT.
- Shut-off valves on the starting air bottles open.
- For slow turning the cylinder lubrication must be switched-on.

3.2 Function

The procedure is similar to starting of the engine. The following designation numbers refer to the Control Diagram 4003-2.

- The shut-off valve for starting air (2.03) is opened by the control valve (2.05) and starting air reaches the starting air valves (2.07) in the cylinder covers.
- By FCM-20 modules the 5/2-way solenoid valves before the starting valves are controlled in such a way that the starting valves are opened and shut for short intervals only.
- The slow turning speed of the engine can be optimized in the remote control by varying the timing (open/close) of the starting valves.

1. Attention to safety

The condition for each engine start-up, also for trials and rotation with starting air, is its full **operating condition**. (see Preparation before Taking into Service 0110-1, Prepare the Fuel Oil System for Operation 0120-1 and Prepare the Servo and Control Oil System 0130-1).

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

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

2. Starting at the control stand in the control room

Additional preparation:

⇒ At WECS-9520 manual control panel (see 4618-1), press button REMOTE AUTOM. CONTROL (Remote Control) for mode transfer to remote control.

⇒ At the control room console, press button REMOTE AUTOM. CONTROL (Remote Control) to take over the control.

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

3. Starting at local control panel

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

Additional preparation:

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

Stating:

⇒ Switch on all auxiliary blowers.

⇒ Press button FUEL CONTROL MODE.

⇒ Turn rotary knob for fuel injection quantity to approx. 15% start fuel charge (see display).

⇒ Press requested button START AHEAD or START ASTERN until the engine runs.

⇒ Slowly adjust rotary switch for fuel injection quantity until the engine runs at the required speed. The corresponding value can be read on display and speed indicator.

CAUTION

Pay attention to the instructions for speed/power increase (see Manoeuvering 0260-1) and to the monitoring data (see Operating Data Sheet 0250-1)

Remark : The above mentioned starting procedure may also be carried out on ECR manual control panel.
However, buttons and rotary switch function only in the corresponding mode of operation, i.e. with active control stand (see 4618-1 'WECS-9520 manual control panel').

Operation
Normal Running

1. General

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

2. Check and precaution

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

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

- Check the scavenge air pressure drop through the air cooler. Excessive resistance will lead to a lack of air to the engine.

- The fuel oil has to be carefully cleaned before being used. Refer to the recommendations in 0720-1 "Fuel treatment" and the separator manufacturer's instructions. Open the drain cocks of all fuel tanks and fuel oil filters regularly for a shot period to drain off any water or sludge which may still have collected there. Maintain the correct fuel oil pressure after low pressure feed pump and the inlet to the mixing unit (see Operating Data Sheet 0250-1 and 0720-1 "Layout of fuel oil system"). Adjust the pressure at fuel pump inlet with the pressure retaining valve in the fuel oil return pipe so that the fuel oil circulates within the low pressure circuit of the engine at the normal delivery capacity of the booster pump.

- The heavy fuel oil has to be sufficiently heated to be ensure that its viscosity before inlet to the fuel pumps lies within the prescribed limits (see viscosity-Temperature Diagram 0270-2).

- Sometimes determine the cylinder lubricating oil consumption. For normal consumption and calculation method, see 7218-2.

- The cooling water pumps should be run at their normal operating point, i.e. the actual delivery head corresponds with the designed value. Thereby the designed delivery rate is obtained and the temperature difference between inlet and outlet will approximately correspond with the desired value (see Operating Data Sheet 0250-1). Should it be considerably higher, the pump concerned must be put in order at the next opportunity.

- The vent at the uppermost points of the cooling water spaces must be constantly kept open to permit air to escape.

- Check the level in all water and oil tanks, as well as all the drainage tanks of the leakage piping. Investigate any abnormal changes.

- Observe the cooling water. The cause of any contamination or oiliness has to be investigated and the fault rectified.

- Look at the charge air receiver drainage manifold's sight glass to see if any water is draining away and if so, how much. It must be determined whether or not it is sea-water (cooling leaking) or fresh water (condensation).

- Check the pressure drop across the oil filter. Clean them if necessary.

- The temperature of the running gear should be checked by feeling the crankcase doors. Bearings which have been overhauled or replaced must be given special attention for some time after being put into service. Observe the precautions for preventing crankcase explosions (see 0460-1).

- Always keep the covers of the rail unit closed with the engine in service.

- Listening to the noise of the engine may reveal any irregularities.

- Hand drawn indicator diagrams provide information on the combustion process and pressure within the cylinder (see Indicator Diagram 0420-1). When the quality of the fuel used changes (diesel oil, heavy fuel oil from various bunkerings), the maximum pressure in the cylinder at service power must be determined at the earliest opportunity and compared with the pressure measured during the corresponding shop trial (speed, power).

In case considerable firing pressure differences are detected, i.e. too high or too low, they must be adjusted by the electronic FQS in remote control (see 4002-3 'User parameters').

However, in IMO-NOx compliant engine, the maximum combustion pressure is to be adjusted in the range of not exceeding the value of the maximum combustion pressure mentioned in the Technical File.

- Centrifuge the lubricating oil. Samples should be taken at regular intervals, and compared with the values given in Lubricating Oils 0750-1.
- Check periodically the lubricating and fuel oil systems for leakages (see 8016-1 'Servo oil leakage system' and 8019-1 'Fuel leakage system'). Leakages can be localized in the rail unit by opening the corresponding hinged covers and casings. Ascertained leakages must be remedied at the next opportunity.
- Check the dirty oil drain pipes from the piston underside for free passage. An obstruction can be detected by touching the individual drain pipes with the hand (temperature difference). If one has only surrounding temperature, the line must have been blocked by carbon deposits and needs to be cleaned as soon as possible.

Operating Data Sheet
Pressure and Temperature Range, Alarm and Safeguards at Continuous Service Power MCR

Measuring point			Pressure 1) MPa		Temperature 2) ℃		
			Min.	Max.	Min.	Max.	Diff.
Fresh water	Cylinder cooling water	Inlet	0.3	0.5	55	-	Apprx. 15
		Outlet of each cylinder	-	-	75	80	
	Charge air cooler water	Inlet	0.1	0.4	25	38	-
		Outlet	-	-	-	-	-
Lubricating oil	Crosshead bearing oil	Inlet	1.0	1.2	40	50	-
	Servo oil	Servo oil pumps inlet	0.38	0.65	-	-	-
	Main bearing oil	Inlet	0.48	0.60	40	50	-
	Piston cooling oil (Parallel with bearing oil)	Inlet	0.48	0.60	40	50	Max. 30
		Outlet of each piston	-	-	-	80	
	Thrust bearing	Bearing outlet	-	-	-	65	-
	Turbocharger bearing oil 4) (Type : MET)	Inlet	0.09	0.18	40	50	-
		Outlet	-	-	-	85	-
Cyl. lub. oil	Middle pressure system	Outlet of pump	7.9	8.1	-	-	-
		Inlet of press. retaining valve	7.9	8.1	45	60	-
	Low pressure system	Inlet of pump	0.0	-	-	-	-
		Outlet of heater	-	-	45	60	-
Fuel oil	Supply unit	Inlet	0.7	1.0	Refer to 0270/1		-
	After press. retaining valve	Return	0.3	0.5	-	-	-
Charge air	Air filter on turbocharger (Type : MET)	Admissible air press. drop (Water head) 8)	-	1960Pa (200mm)	-	-	-
	Charge air in receiver	Air cooler outlet	-	-	25	60	-
	Charge air cooler	Admissible air press. drop (Water head) 8)	-	4900Pa (500mm)	-	-	-
	Charge air piston under side	A fire in receiver	-	-	-	-	-
Air	Starting air	Engine inlet	1.2	2.45	-	-	-
	Control air	Engine inlet	0.6	0.75	-	-	-
	Air spring of exhaust valve	Main distributor	0.6	0.75	-	-	-
Exhaust gas	Exhaust gas	Cylinder outlet	-	-	-	515	±50 9)
		Turbine inlet	-	-	-	515	-
		Pressure at turbine outlet (Water head) 8)	-	4900Pa (500mm)	-	-	-

Operating Data Sheet

Pressure and Temperature Range, Alarm and Safeguards at Continuous Service Power MCR

RT-flex96C			Set point						
			Alarm			Slow-doun [5]		Auto-stop [6] or [7]	
Measuring point			MPa [1]	°C [2]		MPa [1]	°C [2]	MPa [1]	°C [2]
			Min.	Min.	Max.	Min.	Max.	Min.	Max.
Fresh water	Cylinder cooling water	Inlet	0.3	55	-	0.28	-	-	-
		Outlet of each cylinder	-	-	85	-	88	-	-
	Charge air cooling water	Inlet	-	-	-	-	-	-	-
		Outlet	-	-	76	-	-	-	-
Lubricating oil	Crosshead bearing oil	Inlet	1.0 [3]	40	-	0.9	-	-	-
	Servo oil	Inlet	0.38	-	-	-	-	-	-
	Main bearing oil	Inlet	0.48	40	50	0.47	55	0.46	-
	Piston cooling oil (Parallel with bearing oil))	Inlet	-			-		-	-
		Outlet of each piston	-	-	80	-	85	-	-
		Diff. in outlet of each					±5		
	Thrust bearing	Bearing outlet	-	-	65	-	70	-	85
	Turbocharger bearing oil [4] (Type : MET)	Inlet	0.09	-	50	0.08	55	0.07	-
		Outlet	-	-	85	-	-	-	-
Cylinder lubricating oil		Inlet of press. retaining valve	7.4(L) 8.5(H)	45	60	7.0	-	-	-
Fuel oil	Supply unit	Inlet	0.7	Refer to 0270/1		-	-	-	-
	After press. retaining valve	Return	-	-	-	-	-	-	-
Charge air	Air filter on turbocharger (Type : MET)	Admissible air pressure drop (Water head) [8]	-	-	-	-	-	-	-
	Charge air in receiver	Cooler outlet	-	25	60	-	-	-	-
	Charge air cooler	Admissible air pressure drop (Water head) [8]	-	-	-	-	-	-	-
	Charge air piston under side	A fire in receiver	-	-	80	-	120	-	-
Air	Starting air	Engine inlet	1.2	-	-	-	-	-	-
	Control air (Normal supply)	Engine inlet	0.6	-	-	-	-	-	-
	Control air (Safety supply)	Engine inlet	0.55	-	-	-	-	-	-
	Air spring of exhaust valve	Main distributor	0.55	-	-	0.5	-	0.45	-
Exhaust gas	Exhaust gas	Cylinder outlet	-	-	515	-	530	-	-
		Diff. of cyl. outlet	-	-	±50	-	-	-	-
		Turbine inlet	-	-	515	-	530	-	-
		Turbine outlet	-	-	480	-	-	-	-

Remark : Extent of measuring points for Alarm, Slow -Down, and Automatic Stop is subject to agreement between engine maker, Wärtsilä-Switzeland., Classification Societies and customer.

1) Pressure measured about 5.0 m above crankshaft center line (local manoeuvring stand at middle platform).

2) Approx. temperature rise at continuous service power (recommended stand limiting-values for alarm system with computer).

3) At reduced load the crosshead bearing oil pressure may be lower (the alarm and the delayed slow-down is cut out if engine speed is lower than 70 min^{-1}, and fuel command is lower than 40%.

4) See instructions for turbocharger.

5) Automatic or manual slow-down or 6).

6) Set-point for automatic shut-down in electric cut-out device : overridable for emergency run.

7) Set-point for automatic stop in electric cut-out devices.

8) Approx. max. values in service (fouled condition). To be kept as low as possible.

9) Deviation of each cylinder from average ±50 °C.

10) Automatic or manual slow-down, accord to setting the delayed time to setting point for alarm.

1. General

Correct manoeuvring and the resulting increase in engine load up to service power, as well as decrease in load from the service power, is very important with the usual high engine powers of today.

CAUTION

Experience has shown that changing the load too quickly in the upper power ranges can result in increased wear and fouling, especially of the piston rings and cylinder liners.

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

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

2. Manouvring

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

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

Remark : Possible critical barred speed ranges have to be taken into account. Depending on torsional vibration situation, a barred speed rang might exist.

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

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

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

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

The operational data given in 0250-1 basically also apply during manoeuvring.

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

2.1 Reversing under normal operation at the control room manoeuvring console

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

2.2 Reversing at local control panel

(see also Local Control Panel 4618-1 and 4003-1 'Engine local control')

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

⇒ At the control room console, press button LOCAL MANUAL CONTROL (Local Control) for made transfer to <u>local manual control</u>.

⇒ At WECS-9520 manual control panel (see 4618-1), press button LOCAL MANUAL CONTROL to take over the control.

⇒ Press button FUEL CONTROL MODE.

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

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

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

Reversing:

⇒ Turn rotary knob to 15% fuel injection quantity (about display).

⇒ Press requested button START AHEAD or START ASTERN until the engine runs in the correct direction.

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

The above mentioned reversing procedure can also be carried out on ECR manual control panel.
However, buttons and rotary switch function only in the corresponding mode of operation, i.e. with active control stand (see 4618-1 'WECS-9520 Manual control panel').

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

For the reasons given at the beginning, the engine load should only be increased and decreased over a certain time span, usually 1 ~ 2 hours, between full manoeuvring and service power. However, this time span may not be less than 30 minutes when increasing the load and 15 minutes when decreasing it.

This increase and decrease in load is carried out by manual operation of corresponding devices on control room console and the local control panel:

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

4. Emergency manoeuvre

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

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

1. General

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

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

To ensure safe changing over, consider the following items:

2. Recommended viscosity at inlet to fuel pumps

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

The preheating of the fuel is controlled by a viscosimeter or a thermostat.

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

2.1 Changing over from diesel oil to heavy fuel oil (see schematic diagram 0720-1)

Plant side:

After changing over the three-way valve (21) the result is a mixture of diesel oil and heavy fuel oil in the mixing unit (24). The viscosimeter controls the end-heater (26) in such a way that the required viscosity (preheating temperature) of the mixture is maintained.

CAUTION: This preheating should be done only **slowly** (temperature rise max. 1 ~ 2 °C /min.). Sudden temperature changes can lead to seizing of the fuel pump plungers.

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

Check fuel pressure after low pressure feed pump (23)and at fuel pump inlet (see Operating Data Sheet 0250-1).

Engine side:

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

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

2.2 Changing over from heavy fuel oil to diesel oil

Plant side:

CAUTION

In case to change over from normal heavy fuel oil service to diesel oil, This preheating should be done only **slowly** (temperature drop max. 1 ~ 2 °C/min.).

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

Engine side:

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

WARNING

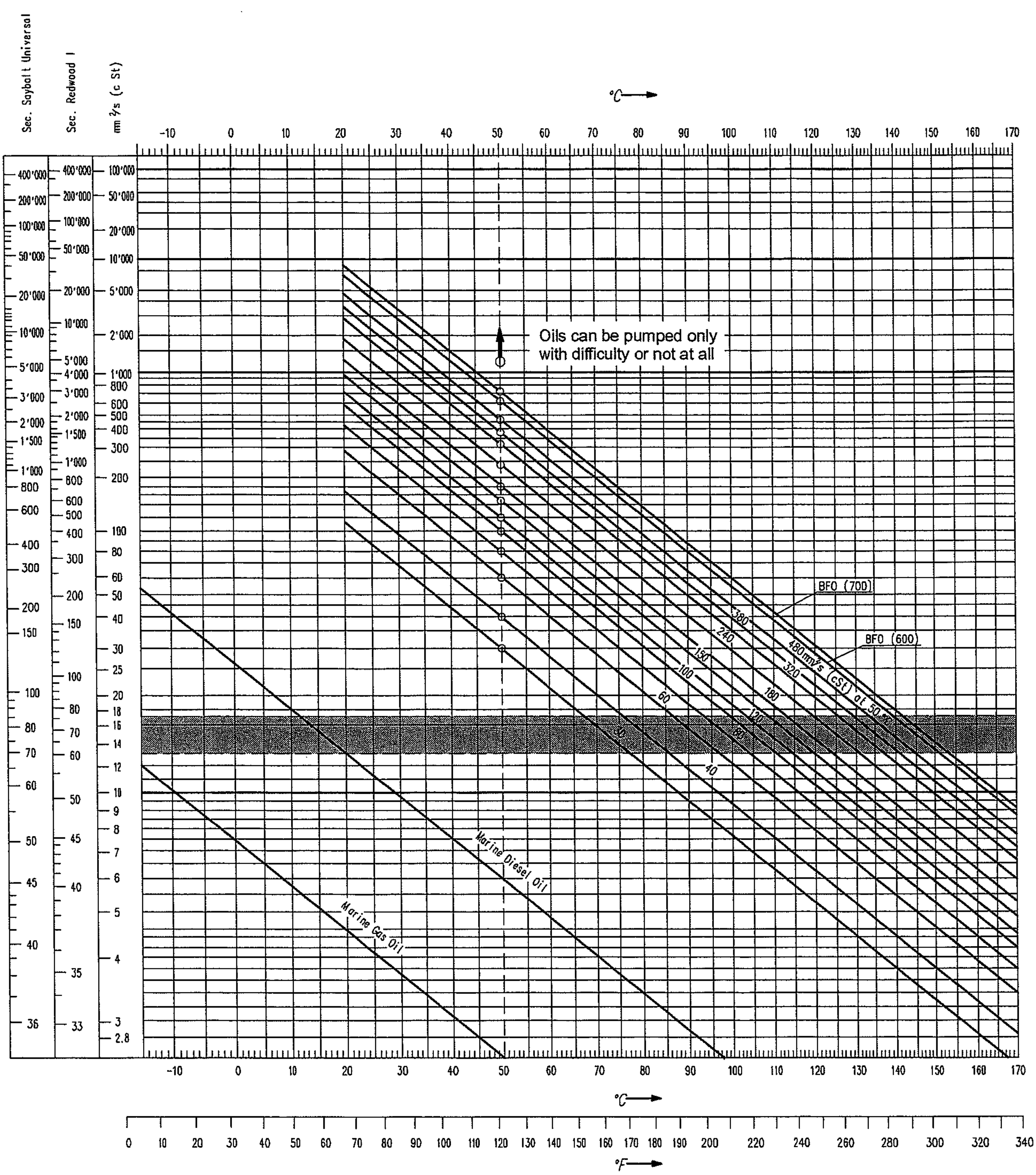
Running on diesel oil and with turned on trace heating is extremely dangerous for the engine!

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

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

Viscosity - Temperature Diagram

Typical Values of Petroleum Fuel Oils



Recommended viscosity before fuel pumps

Example:

To obtain the recommended viscosity before fuel pumps a fuel oil of 150 mm²/s (cSt) at 50 °C must be heated to 108 to 120 °C.

1. General

Pay attention to the following details:

- Checks and precautions in 0240-1.
- Trace heating of the fuel oil system in operation.
- Temperature of cooling medium within the normal range (see Operating Data Sheet 0250-1).
- Careful treatment of the fuel oil is of importance (see Fuel Treatment, Fuel Oil System 0720-1).

CAUTION

Keep the fuel pre-heating temperature at the upper limit (see 0270-1).

- The cylinder lubricating oil quantity is automatically adapted to the lower load. If the engine is continuously operated at low load it will soon become evident whether the cylinder lubrication is at its optimum setting for these special conditions.

2. WECS-9520 Injection control

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

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

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

1. General

Where permitted by the contract and the regulations of the responsible authorities, societies etc., a well-maintained engine with a clean charging system can run at the contracted overload power for a limited period of time.

CAUTION

This is normally limited to 110% of the full powers output for the maximum of 1 hour. (See also Interrelationship between Engine and Propeller 0070-1)

When running on overload, the engine must be monitored particularly are fully. Upon any indication of irregularities, the power has to be reduced.

During this period attention has to be paid to the following:

- **The load indication (fuel injection quantity) and the exhaust gas temperature before the turbine (s) serve to indicate the measure of engine load** (see Operating Data Sheet 0250-1 and acceptance records).
- The coolant temperatures have to be kept within their normal ranges (see 0250-1).
- In normal service the full load position of the load indication (fuel injection quantity) may not be exceeded (see Acceptance Records).
- The maximum permissible position of the load indication (fuel injection quantity) is to be found in the acceptance records. It may not be exceeded.
- When running into strong head winds, in heavy seas or with heavy growth on the ship's hull, ship resistance increases.

  Without any alteration to the speed setting the governor will maintain the engine speed ; the position shown on the load indication (fuel injection quantity) will increase.
  This means that, despite the same speed, the load is higher than before and the engine may possibly be overloaded (see also 0070-1, Where this is the case, the engine speed must be correspondingly reduced).

CAUTION

In spite of the above, if you operate at overload, please contact us (MITSUBISHI HEAVY INDUSTRIES, LTD.
KOBE SHIPYARD & MACHINERY WORKS DIESEL ENGINE DEPARTMENT).

1. Unloading

Whenever circumstances permit, we recommend that the load be reduced slowly, see Manoeuvring 0260-1.

2. Stopping

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

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

From control room by backup control box:

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

From local control panel: *(see Control Diagram 4003-2 and Local Control Panel 4618-1)*

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

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

2.1 In case of emergency

- The engine can be stopped immediately by pressure releasing in the fuel rail via fuel pressure control valve (3.06) by pressing EMERGENCY STOP button in the control room (control console) or on the local control panel. At the same time the fuel pump actuators move the regulating linkages to position '0'.

2.2 Further possible way of stopping the engine

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

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

CAUTION

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

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

1.1 Engine manoeuvrable

CAUTION

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

- WECS-9520 engine control system must remain switched on.
- All the pumps for cooling water, lubricating oil and fuel have to be kept running.
- Control oil pumps (3.72-1) or (3.72-2) on the engine has to be kept running.
- Control air must be available and the starting air bottles should be replenished.
- Maintain cylinder cooling water at the preheating temperature, and the lubricating oil is not to be cooled down.
- The fuel must be held at the required temperature according to Viscosity-Temperature Diagram 0270-2.

1.2 Engine not manoeuvrable

- After the engine has been stopped, the cooling water and lubricating oil pumps should be left running for at least a further 20 minutes in order to allow the temperatures to equalize. These media should not be cooled down below their normal inlet temperatures. The sea-water pump can, therefore, usually be stopped immediately.
- Should the engine have been shut down during operation with heavy fuel oil, then the circulation must be maintained via the fuel pumps and the fuel oil system must remain in operation.
- The heating of the fuel oil pipework at the engine must be turned on. If the heating needed to be stopped for maintenance works it must be turned on again about four hours before engine start. Should this measure not be required, then the engine operation must be changed to diesel oil before shutting down the engine (see 0270-1 'Changing over from heavy fuel oil to diesel oil' and Measures to be taken before Putting Out of Service for Extended Period 0620-1).
- The low pressure feed pump (23) and booster pump (25) can be stopped, if the engine has been shut down while operating with diesel oil (see 0720-1 'Layout of the fuel oil system').
- The starting air supply has to be closed after stopping the engine, i.e. **close the shut-off valves on the starting air bottles,** turn the handwheel (2.10) to position "CLOSED" (closed by hand) at the shut-off valve for starting air (2.03) and drain it by using venting valves (2.21) and (2.27) (see Control Diagram 4003-2).
- The indicator valves in the cylinder covers are to be opened.
- The turning gear can be engaged.
- WECS-9520 engine control system can be switched on.

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

Post-lubrication of cylinders:

- For the post-lubrication the crankshaft must be turned by the turning gear by several turns. At the same time, execute the priming of ECL system.

⇒ Close the shut-off valves on the control air supply (supply of air from the starting air bottles and the board system).

- Where possible, keep the cooling water warm in order to prevent the engine from cooling down too much. The cooling water pump is, therefore, kept running unless required to be stopped for maintenance work.

⇒ At relatively frequent intervals, turn the engine through by several revolutions with indicator valves open, using the turning gear (possibly done daily in damp climates). Execute the priming of ECL system at the same time. After completing this procedure, ensure that the piston comes to rest in a different position each time.

⇒ Repair all the defects detected in service (leaks, etc.).
Follow all the safety regulations when carrying out repair work or any overhauls which are due. If necessary, release pressure from fuel oil system.

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

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

Special Measures in Operation
Running-in of New Cylinder Liners and Piston Rings

Overview

1. General

After the fitting of new cylinder liners or even only after replacing piston rings, these must be run-in.
The purpose of running-in is to achieve a good sealing of the rings as soon as possible. Under no circumstances must any seizings occur on the running surfaces of cylinder liner and piston rings.

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

⇒ Carry out all starting preparations according to 0110-1.

Furthermore, check the following points:

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

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

1.2 Remarks on running-in

CAUTION

- The load-up program should not be faster than shown in section 6.
- During running-in of new cylinder liners it is also recommended to take care the increasing rate of the engine speed.
- It is necessary to occasionally inspect the condition of the running surfaces of the piston rings and the cylinder liner to assess the status of running-in.
- The stability and the level of the cylinder cooling water temperature must be checked frequently (no fluctuations in temperature are permitted), (see Cylinder Liner 2124-1).
- For running-in of single cylinders their load can be reduced temporarily by function 'Inj. correction factor' (see 4002-3 'Maintenance settings').

2. Fuel

For running-in, the same fuel (HFO) should be utilized as for normal operation, whereby a fuel with more than 1% sulphur content is advantageous. The fuel should be correctly treated and properly preheated.

Remark : If it is for some reason not possible to start the engine on HFO, it is highly recommended to change over to HFO as soon as the required pre-heat tempera-ture is reached, which should be before the engine reaches a load of 60% CMCR.

3. Cylinder Lubricating Oil

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

4. Cylinder Lubricating Oil Feed Rate

The guidance of cylinder oil feed rate at initial running stage is shown in 0410-1-5/5 and also cylinder oil feed rate after replacing new cylinder liners or even only new piston rings is shown in section 6.

5. Cylinder Cooling Water Temperature during Running - In

By lowering the cooling water temperature the running-in can be favorable influenced. Therefore it is recommended to hold the cooling water outlet temperature to about 70 °C during the first 48 hours.

6. Running-in Program

Cylinder oil feed rate after replacing new cylinder liners or even only new piston rings is shown as follows.

New cylinder liner:

Fixed Pitch Propeller		Cylinder lubricating oil quantity *
1 hour	about 70%N	1.3 g/PSh at MCR (1.75 g/kWh)
1 hour	about 75%N	
1 hour	about 80%N	
2 hours	about 85%N	
3 hours	about 90%N	
6 hours	about 95%N	
10 hours		

followed by gradual decrease to normal quantity

N : Rated engine speed
P : Rated engine power
* : Cylinder lub. oil consumption at 100% load

Only new pistonring:

Fixed Pitch Propeller		Cylinder lubricating oil quantity *
1 hour	about 70%N	(present setting) +0.22g/PSh (+0.30g/kWh) (50hours)
1 hour	about 75%N	
1 hour	about 80%N	
2 hours	about 85%N	
3 hours	about 90%N	
6 hours	about 95%N	
31 hours		
50 hours		+0.18g/PSh (+0.25g/kWh)
50 hours		+0.15g/PSh (+0.20g/kWh)
50 hours		+0.11g/PSh (+0.15g/kWh)
50 hours		+0.07g/PSh (+0.10g/kWh)
50 hours		+0.04g/PSh (+0.05g/kWh)

N : Rated engine speed
P : Rated engine power
* : Cylinder lub. oil consumption at 100% load

7. Running-in with Fuels having less than 0.5% Sulfur Content

For this proceed as follows

- Double running-in periods from the table "Running-in Program" for 80%N(50%P) and above.
- A check on the condition of piston ring and cylinder liner running surfaces is strongly recommended after about 6 operationg hours (visual inspection through the scavenge ports).
- When the piston rings do not yet show an even sealing surface ring, i.e. the grammo-finish only slightly run off, or in case scuffing marks are already visible, then the load should not yet be increased. Further checks are then unavoidable. In this case a temperature reduction of the cylinder cooling water outlet to be about 60°C is definitely recommended.

8. Running-in under TimeLimitation

Provided not more than a quarter of the cylinders must be newly run in and a power output increase in accordance with the table "Running-in program" is not possible, fuel injection quantity of respective injection control units has to be reduced by function 'Inj. correction factor' (see 4002-3 'Maintenance settings'). Should the maximum possible power output be immediately necessary, the value of 'Inj. correction factor' should set to a default value at least 24 hours. After putting the setting back to original value, the power output for higher load ranges should only gradually be increased.

CAUTION

Restriction in the use of function 'Inj. correction factor'

- On installations with PTO or flexible couplings the maximum permissible non-uniformities or alternate angles respectively should not exceed the values specified by the makers.
- On installations with shaft generators, without couplings, which rotate at nominal engine speed (min^{-1}), problems with synchronization may occur.

9. Preparation for Running in new Piston Rings in Used Cylinder Liners

In addition to the careful grinding-off of the wear ridge it is recommended for the following case to “stone” the running surface of the cylinder liner manually, using a coarse carborundum block, to roughen to upper region (above the lubricating points).

- On areas which show seizure marks or scratches respectively.
- In case of “scuffing” the so-called “white hard layer” should be abraded, i.e. no slipping off of the grinding block should be felt.
- In case of hard-“glazed”, sometimes slightly wavy surfaces.

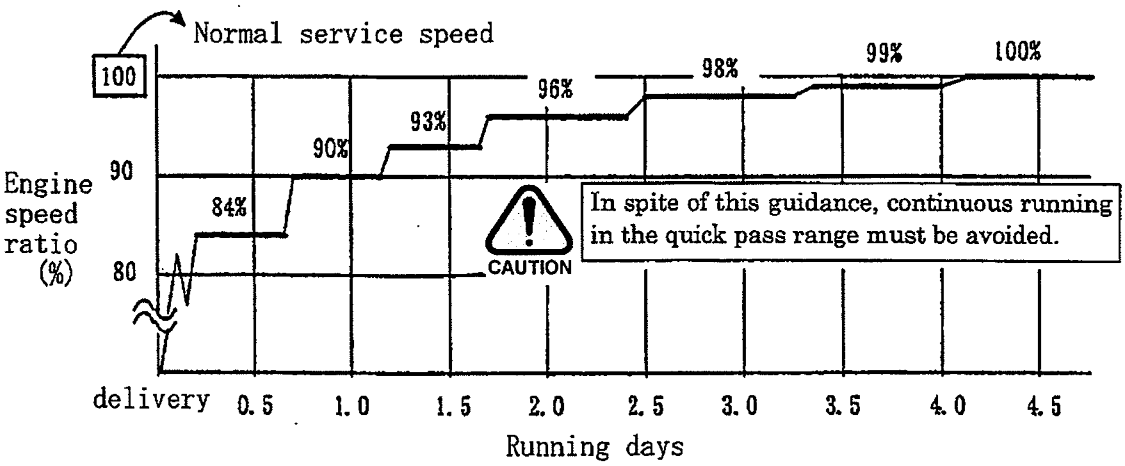
10. Guidance of Increasing the Engine Speed

10.1 At first departure on maiden voyage

- According to the following chart, increase the engine speed slowly and by steps in such a way that it reaches the normal service speed at least after four days since the ship has been delivered.
- In case of accelerating the engine speed from one to the next, it should be cofirmed there are no abnormal temperature, pressure and noise at every parts of the engine.

CAUTION

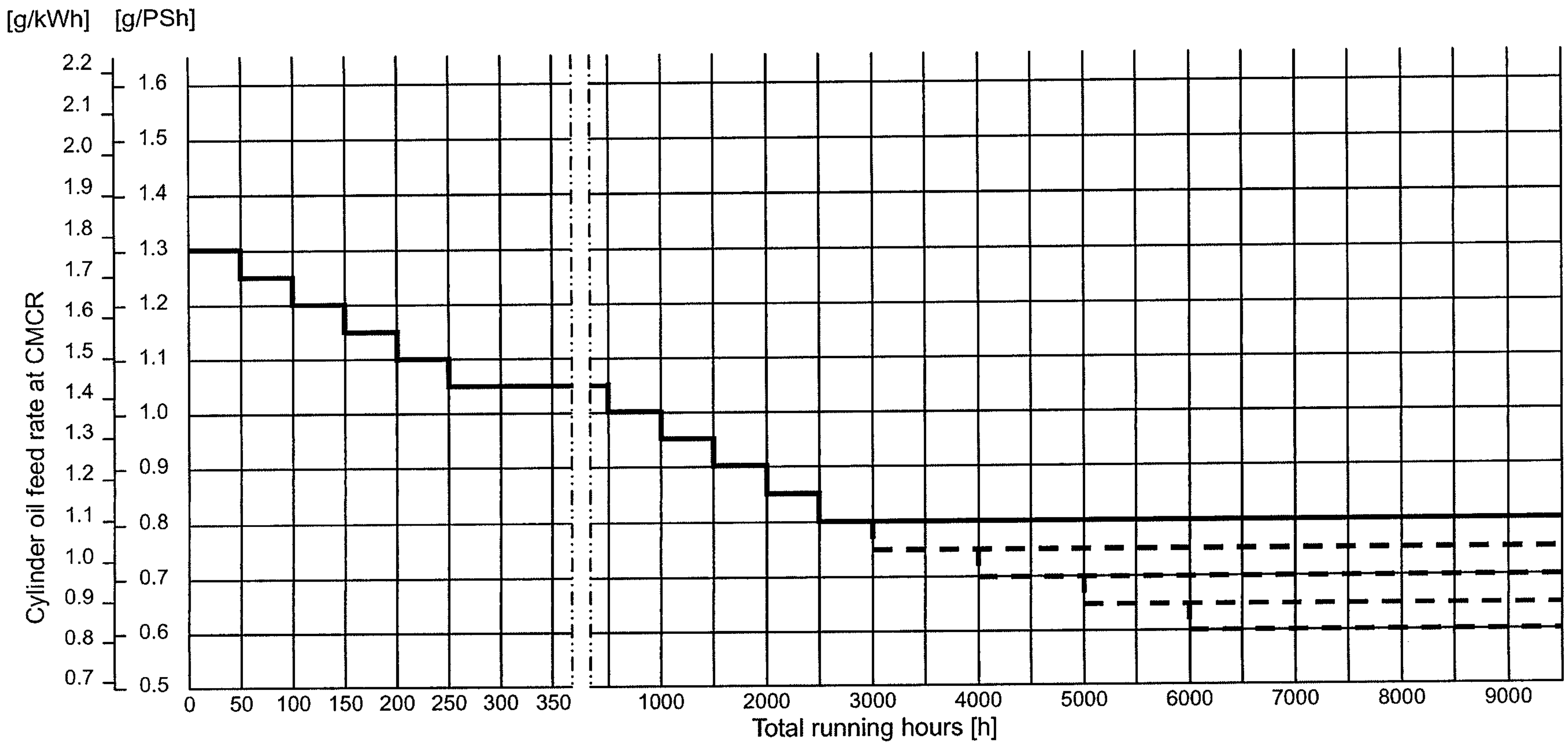
In any cases, the rapid increase of engine speed should be avoided.



11. Guidance of the Cylinder Oil Feed Rate with ECL system

Remark :

- The feed rate on figure below should be regarded as reference for the cylinder lubrication at max. rating output.
- Thereby, the practical cylinder oil feed rate should be adjusted depending on character of cylinder oil/fuel oil, engine load condition, and actual running condition of cylinder liner and piston ring.
- Sudden decrease of the feed rate is to be avoided. Make it max. 0.07 g/kWh (0.05 g/PSh) for each reduction steps.
- Before reducing cylinder oil feed rate afterwards, examine the cylinder liner/piston ring conditions by all means, and their good conditions should be confirmed. (The ring gap on piston to be measured, possible when examine the ring condition through the scavenging ports.)



1. General

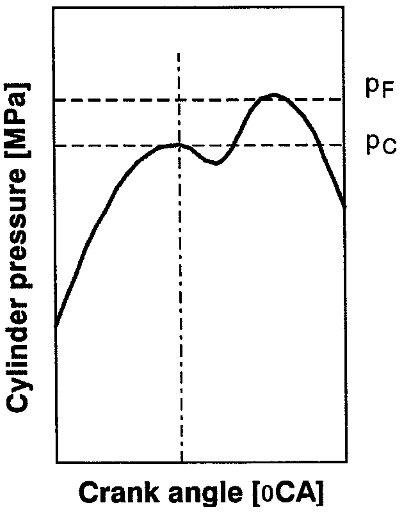
Indicator diagrams shall only be drawn with a suitable, well working indicator at constant power and speed, and in case of marine engines in calm sea and deep water. For the interpretation of the indicator diagrams note the respective cylinder number, engine speed, the value of the fuel command and VIT.

2. Definitions of cylinder pressures

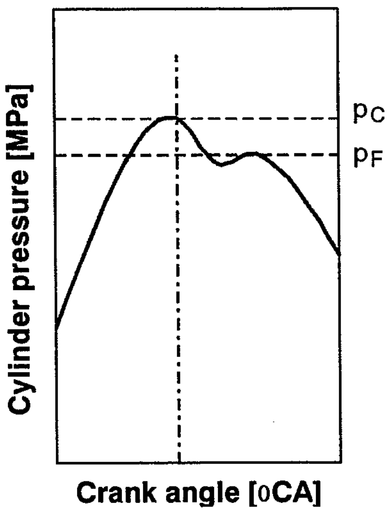
Higher compression ratio and fuel injection delay have been introduced to reduce the NOx value for engines in compliance with the IMO rules.

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

Case A



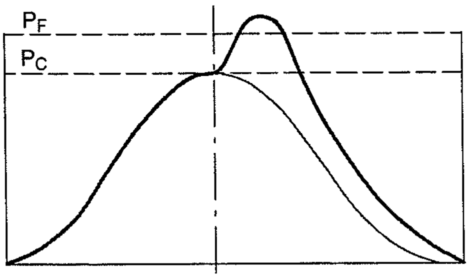
Case B



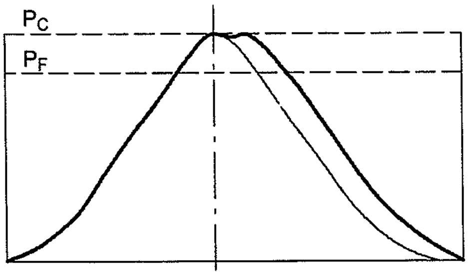
Pc= Compression pressure at TDC **P_F= Maximum firing pressure**

3. Interpretation of indicator diagrams and corresponding engine adjustments

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



Case A



Case B

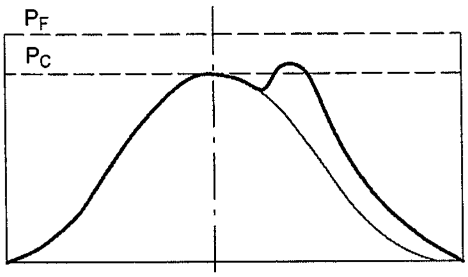
Maximum firing pressure too high at correct compression pressure.

Possible causes:

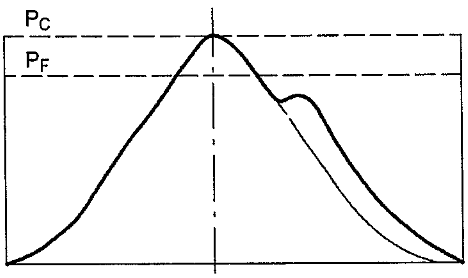
- Ignition (start of injection) too early for the fuel type in use.

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

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



Case A



Case B

3.2 Maximum firing pressure too low at correct compression pressure.

Possible causes:

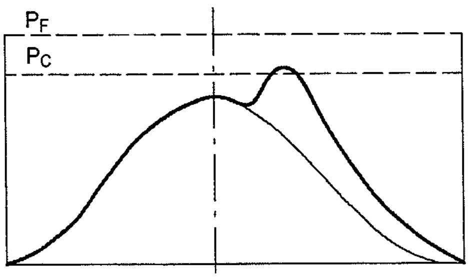
- Poor combustion: Nozzle tip with trumpets or worn out.

⇒ Check the injection nozzles.

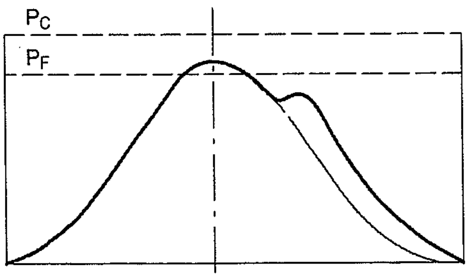
- Ignition (start of injection) too late for the fuel type in use.

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

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



Case A



Case B

Compression and maximum firing pressure too low.

Possible cause:

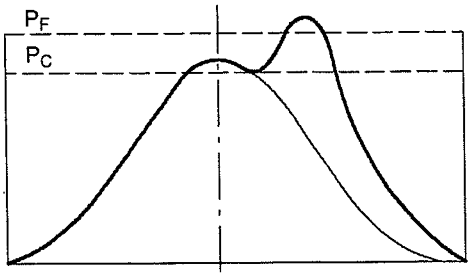
- Actual load lower than assumed.
- Exhaust valve leaking.

⇒ Check exhaust valve.

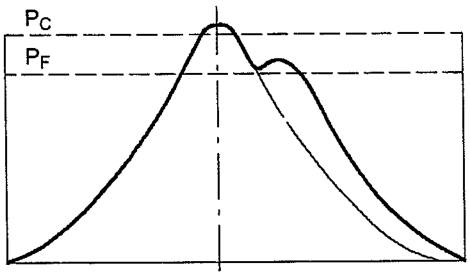
- Scavenge air pressure too low.

⇒ Clean turbocharger or scavenge air cooler.

- Suction temperature too high.
- VEC timing wrong i.e. exhaust valve closing time too late (parameter in WECS-9520).



Case A



Case B

Compression pressure and maximum firing pressure too high.

Possible cause:

- Engine overloaded.
- VEC timing wrong.

Special Measures in Operation
Measures against Fouling and Fires in the Scavenge Air Spaces

1. General

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

2. Cause and measures

2.1 Cause of poor combustion

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

2.2 Causes of blow-by of combustion products

- Worn, sticking or broken piston rings.
- Worn cylinder liner.
- Cylinder lubricating oil shortage, according to ECL-SIP valves and distributors are not working.
- Damage to the running surface of the cylinder liners.

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

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

2.3 Causes of fires

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

CAUTION

Periodically check the bottom of the cylinder jacket (including piston underside) and if necessary clean it.

2.4 Indications of a fire

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

2.5 Fire fighting measures

We recommend the following:

- Reduction of engine power.
- Cutting out the fuel injection of the cylinder concerned. (user parameter Inj. CUT OFF in remote control).
- Should for any reason a fire be feared then shut down the engine and fill the scavenge space with CO_2 gas.

CAUTION

Pay attention to instruction after CO_2 extinguishing system is used in 0210-2 'General Matters that Demand Special Attention on Maintenance'.

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

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

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

CHECK ***The following checks should be carried out :***

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

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

2.6 Preventive measures

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

- Use of correctly spraying injection nozzles and keeping the air and gas passages clean (regular inspection and cleaning).
- To check the quantity of cylinder lubricating oil and readjust the lubricating oil setting, in order to avoid too much or too short lubricating oil feed rate, if necessary (see 7218-2).
- The permanent drain of dirty oil from the piston underside must always be assured.
- To prevent accumulation of dirt, check the dirty oil drain pipes from the piston underside for free passage. An obstruction can be detected by touching the individual drain pipes with the hand (temperature difference). If one has only surrounding temperature, the line must have been blocked by carbon deposits and needs to be cleaned as soon as possible.

Special Measures in Operation
Instructions Concerning the Prevention of Crankcase Explosions

1. General

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

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

Engines are equipped with an oil mist detector, which continuously monitors the intensity of oil mist in the crankcase and triggers an alarm if the mist exceeds a limit of admissible intensity.

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

2. Measures to be taken in case of an alarm

WARNING

If there is any indication of danger of explosion, the engine is to be stopped immediately and the space in question filled with steam or CO_2.

WARNING

If the engine has been stopped on account of danger of parts running hot, neither doors nor inspection openings of crankcase must be opened for the time being (at least 20 minutes).

WARNING

The hot components should be permitted to cool down during **at least 20 minutes,** to prevent ignition due to the access of fresh air.
In order to avoid accidents caused by safety valves blowing off, the engine-room staff are warned to keep away from the side of the engine, which is fitted with the explosion doors, during that time.

In the absence of fire extinguidhing plant fitted to the engine, a fire extinguisher must be kept close at hand when the crankcasedoors are opened later.

Please refer to section 0210-1 before entering the engine after CO_2 has been used.

Operation under Abnormal Conditions
General Information

1. General

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

2. Reduced power output

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

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

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

3. Taking cylinder out of operation

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

Should the 'surging' occur at short intervals or even continuously, the speed has to be suitably reduced. (With controllable pitch propeller installations, the speed has to be suitably reduced or the propeller pitch has to be suitably reduced.)

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

Operation under Abnormal Conditions
Operation with Injection Cut Out (One or More Cylinder)

1. Measures

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

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

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

WARNING: For safety reasons the plugs must be disconnected from the rail valves of the corresponding cylinder.

Should the engine be kept running with the injection cut out for an extended period, the lubricating oil feed rate for the respective cylinder must be reduced to the minimum (see 7218–1 'Pump element'). For a later restoring, the previous settings must be noted.

1.1 Shut off injection control unit

A cracked injection control unit (with heavy leakage to outside) must be shut off as an immediate measure.

WARNING: Shutting off the injection control unit can only be carried out at engine standstill! The control oil rail and fuel rail must be pressureless.

WARNING: Always use gloves when working on hot components and wear safety goggles!

Procedure:

⇒ Stop the engine.

⇒ Switch off fuel booster pump (3.15) and bearing oil pump.

⇒ Open drain screw (2) or (3) by about two turns for pressure relief in control oil rail (4) (see Fig. 'A' and 'B').

⇒ Loosen drain screw (17) by about two turns for pressure relief in fuel rail (9) (see Fig. 'C').

⇒ Remove screw (5) with washer (6). Loosen and remove plug (10)from injection control unit (8). Apply Never-Seez NSBT-8 to the thread of screw plug (14) (tool 94585) and tighten it with a torque of 270 Nm (see Fig. 'D' to 'F').

⇒ Remove flexible pipe (12) between control oil rail (4) and valve block (11) of injection control unit. Fit and tighten nut with conical plug (15) (tool 94587) to the connection of the control oil rail (see Fig. 'D' to 'F').

Operation under Abnormal Conditions

Operation with Injection Cut Out (One or More Cylinder)

⇒ Remove flexible pipe (13) between servo & control oil return piping (7) and valve block (11) of injection control unit (unscrew also connection nipple from the latter). Fit and tighten nut with conical plug (15) (tool 94587) to the connection of the servo & control oil return piping (see Fig. 'D' to 'F').

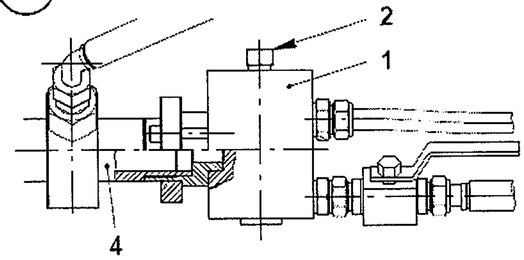
⇒ Close drain screw (2) or (3) and tighten it with a torque of 200 Nm.

⇒ Close drain screw (17) and tighten it with a torque of 200 Nm.

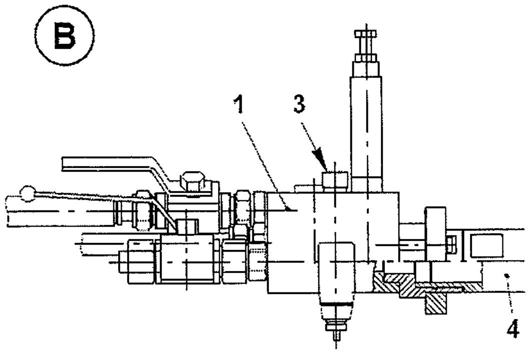
CAUTION

> With injection control unit shut off and injection cut off (Inj. CUT OFF), the engine can only be operated at reduced load. Generally the remarks in 0500–1 must be observed.
> Furthermore the exhaust temperature after cylinders may on no cylinder exceed the **maximum of 515 °C**.

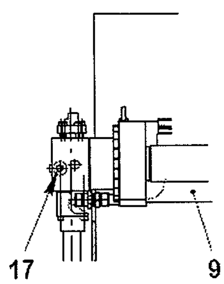
A



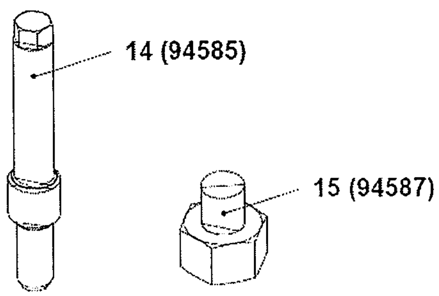
B

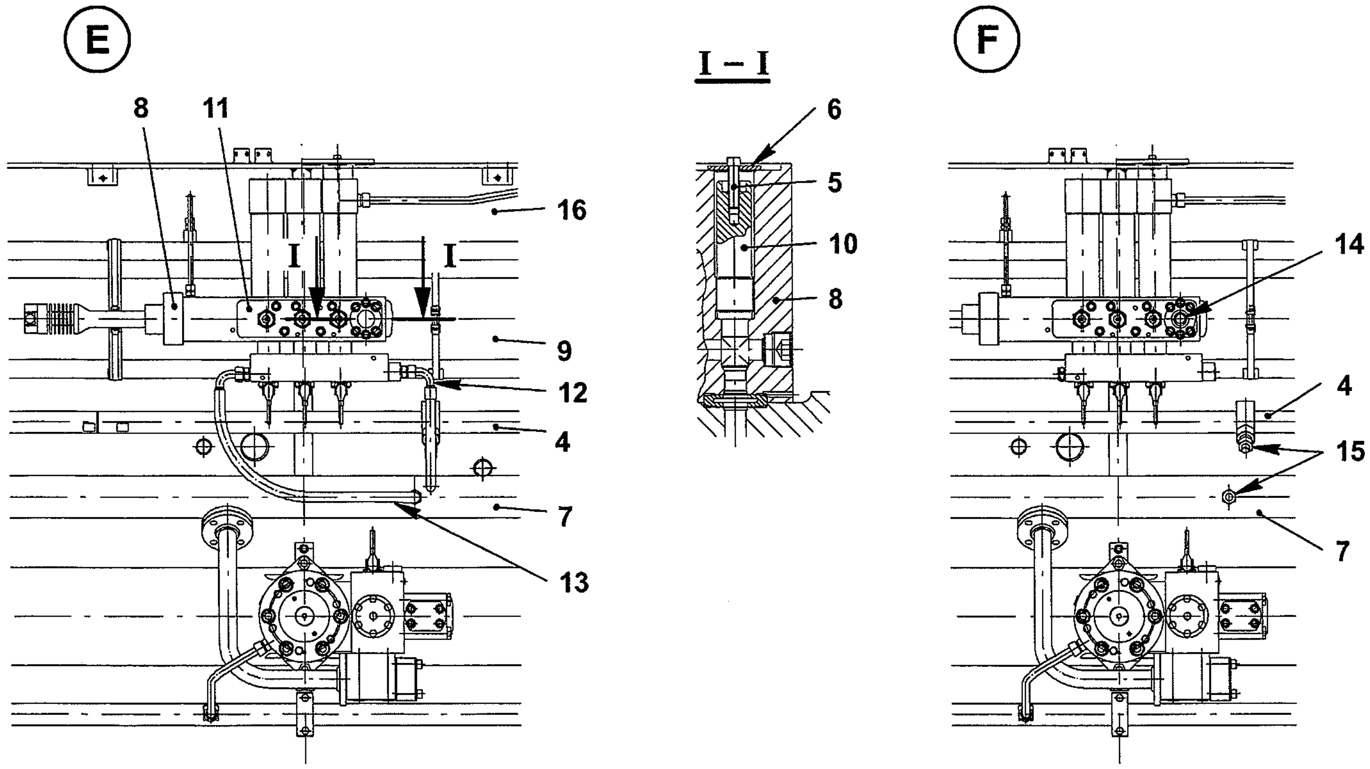


C



D





Key to Illustrations:

'A'	**Control oil rail DE**
'B'	**Control oil rail FE**
'C'	**Fuel rail DE**
'D'	**Screw plug and nut with conical plug (tools)**
'E'	**Injection control unit**
'F'	**Shut off injection control unit**

1	Valve block	10	Plug 3.35
2	Drain (screw) valve 3.68	11	Valve block
3	Drain (screw) valve 3.68	12	Flexible pipe
4	Control oil rail 3.75	13	Flexible pipe (control oil return 3.45)
5	Screw	14	Screw plug (tool 94585)
6	Washer	15	Nut with conical plug (tool 94587)
7	Servo & control oil return piping 4.63	16	Rail unit
8	Injection control unit 3.02	17	Drain screw
9	Fuel rail 3.05		

2. Restarting of injection

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

2.1 Exchange of shut off injection control unit

WARNING: The control oil rail (4) and fuel rail (9) must be pressureless.

Procedure:

⇒ Stop the engine.

⇒ Switch off fuel booster pump (3.15) and bearing oil pump.

⇒ Open drain screw (2) or (3) by about two turns for pressure relief in the control oil system (see Fig. 'A' and 'B').

⇒ Loosen drain screw (17) by about two turns for pressure relief in the fuel rail (see Fig. 'C').

⇒ The shut off injection control unit can now be replaced.

Remark : Screw plug (14) (tool 94585) must be removed from the defective injection control unit and replaced by plug (10) including screw (5) and washer (6). Connection nipple in valve block (11) (control oil outlet) is used for the new injection control unit and must therefore also be removed.

⇒ Remove nut with conical plug (15) (tool 94587) from servo & control oil return piping (7). Fit and tighten connection nipple in valve block (11).
Install flexible pipe (13) and tighten its connections (see Fig. 'E' and 'F').

⇒ Remove nut with conical plug (15) (tool 94587) from the connection of control oil rail (4). Install flexible pipe (12) and tighten its connections (see Fig. 'E' and 'F').

⇒ Close drain screw (2) or (3) and tighten it with a torque of 200 Nm.

⇒ Close drain screw (17) and tighten it with a torque of 200 Nm.

CHECK Switch on fuel booster pump (3.15) and bearing oil pump and carry out a leakage check.

⇒ Adjust the lubricating oil feed rate for the respective cylinder to the previous settings (see 7218-1 'Pump element').

⇒ Cutting in injection of the cylinder concerned with user parameter Inj. RUN in remote control.

⇒ Reconnect the plugs to the rail valves.

2.2 Exchange of defective HP piping to injection valves

Replace defective HP piping at the first opportunity (see Fuel Pressure Piping 8733-1 in the Maintenance Manual).

Remark : A defective, leaking HP piping can be localized by means of the drain screws at the flange (see 8019-1 ' Fuel leakage system').

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

Procedure:

⇒ Stop the engine.

⇒ Replace defective HP piping.

Overview

1. Defective fuel pump

1.1 Identification

- Higher regulating shaft positions of the two fuel pump rows at the same output compared with the acceptance report.
- Abnormal noises such as knocking, scraping and ringing.
- Alarm indication by level switch LS3426A and visual examination at leak indication LI3427L (see 8019-1 'Fuel leakage system').

1.2 Causes

- Pump plunger seized, spring broken, regulating sleeve blocked.
- Roller blocked, damage to cam, roller guide seized.
- Breakage of a HP piping.
- Blocked regulating linkage.

1.3 Measures

⇒ Stop the engine.

⇒ Cut out the corresponding fuel pump (see Cutting Out and Cutting In of the Fuel Pump 5556-2).

⇒ Replace defective parts at the first opportunity (see Fuel Pump 5556-1 and Supply Unit 5552-2 in the Maintenance Manual).

2. Defective actuator

2.1 Identification

- If an actuator fails, its regulating output turns to full quantity or remains in position. The regulating shaft position is on maximum or does not react to load changes.
- ***8 to 14 cylinder engines:*** At higher fuel consumption, the intact actuators take over the control of fuel quantity regulation.
- At lower fuel consumption, fuel pressure control valve (3.06) takes over the fuel pressure regulating function.

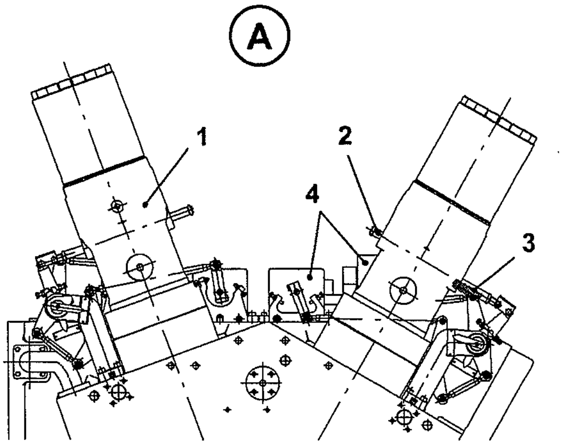
☞ *Remark* : If all actuators fail, their regulating outputs turn to full quantity or remain in position. The regulating shaft positions are on maximum or do not react to load changes. Fuel pressure control valve (3.06) takes over the fuel pressure regulating function over the whole load range. The fuel quantity flowed off is led into the fuel return.

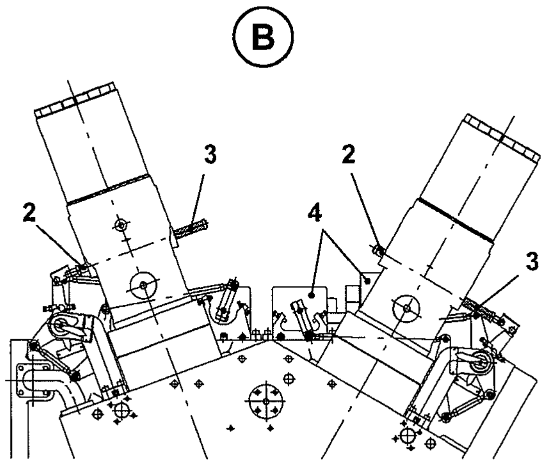
Operation with this regulating functions should be avoided if possible or be maintained only few hours, reduce rail pressure (see 2.3 'Measures' and 5556-1 'Fuel pressure control valve 3.06').
At an overpressure in the HP fuel circuit (failure or malfunction of fuel pressure control valve 3.06), fuel overpressure safety valves (3.52-1 & 2) open and an alarm is triggered by level switch LS3426A.

2.2 Causes

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

2.3 Measures





Failure of one actuator:

⇒ Fit spacer (3) (tool 94555) on regulating rack (2) in position '0' to both fuel pumps with regard to the faulty actuator (Fig. 'A').

⇒ Replace defective actuator at the first opportunity (see Regulating Linkage 5801-1 in the Maintenance Manual).

⇒ Check control signals from WECS–9520 and electric cables, if necessary replace them.

⇒ Ensure that the regulating linkage moves freely.

- Spacer (3) (tool 94555) can also be fitted in position 'max.' depending on the preferential output (i.e. mainly at full load).

⇒ Turn knurled screw at fuel pressure control valve (3.06) (see 5556-1) counter-clockwise till the stop.

Failure of all actuators:

⇒ Fit spacer (3) (tool 94555) on regulating rack (2) in position '0' to all fuel pumps in a row, and in position 'max.' in the other row (Fig. 'B').

- If higher load is required more pumps can be set to position 'max.' instead of '0'.

⇒ Turn knurled screw at fuel pressure control valve (3.06) (see 5556-1) counter-clockwise till the stop.

WARNING

As the regulating linkage can be moved unexpectedly during operation, take care of your hands when fitting the spacers.

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

1 Fuel pump (3.14)
2 Regulating rack
3 Spacer (tool 94555)
4 Actuator 3.21

3. Defective injection control unit

3.1 Identification

- Alarm indication in WECS-9520 (remote control).
- The fuel injection is cut off automatically (Inj. CUT OFF) on the corresponding cylinder, and a SLOW DOWN will be released.
- Leakage at the injection control unit.
- Alarm indication by level switch LS3446C (fuel rail DE) or LS3447C (fuel rail FE) due to leakages at the HP pipings to the injection valves (see 8019-1 'Fuel leakage system').

3.2 Causes

- Fuel quantity sensor defective.
- Fuel quantity piston at the stop (caused by rail valve failure).
- Rail valve defective.
- Crack in the injection control unit.
- Injection control valve seized.
- Fuel quantity piston seized.
- Breakage of a HP piping to the injection valves.

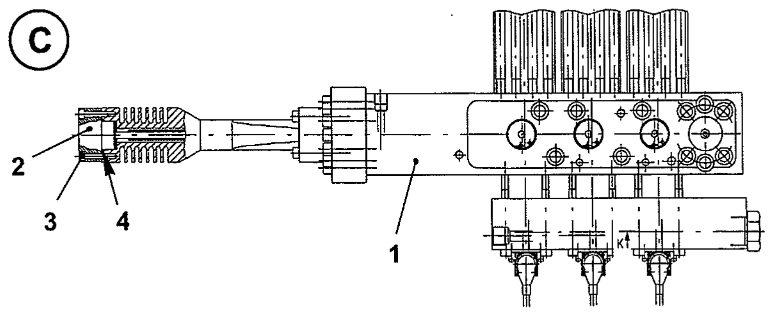
3.3 Measures

Fuel quantity sensor:

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

Replacing defective fuel quantity sensor:

⇒ Remove plug. Do not loose O-ring inside the socket!
⇒ Loosen and remove screws (3).
⇒ Remove fuel quantity sensor (2).
⇒ Oil O-ring (4) and fit new fuel quantity sensor.
⇒ Fit screws and tighten with a torque of 20 Nm.
⇒ Insert plug in the correct position. *Important:* Plug must be tight!



Key to Illustration: 'C'

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

Fuel quantity piston:

⇒ If the fuel quantity piston is at the stop, manually relieve fuel rail pressure shortly at fuel shut-down pilot valve (3.08) (EM. STOP ZV7061S).
This valve is arranged on fuel pressure control valve (3.06) (see 5556-1).

- If the fuel quantity piston sticks in a position, i.e. in most cases this is not a seizure of the piston but a hydraulic locking caused by a rail valve stuck in position 'Inject'.
- See section **Injection control unit**, if the measure taken is unsuccessful.

Rail valve:

- Replace defective rail valve at the first opportunity.

⇒ Stop the engine.

⇒ Switch off bearing oil pump.

⇒ Open drain screw (2) or (3) on valve block 1 by about two turns for pressure relief in the control oil system (see Fig. 'D' and 'E').

⇒ Remove cable (7).

⇒ Loosen screws (6) and remove them together with rail valve (5).

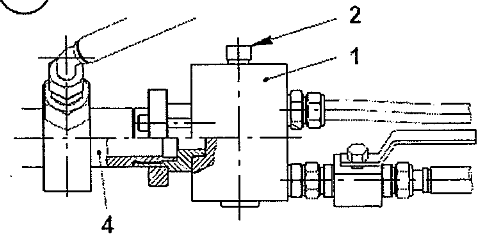
⇒ It is to be ensured that the three O-rings are put in the new rail valve and the surfaces are clean.

⇒ Fit the rail valve with four screws (6) and tighten the latter with a torque of 2.5 Nm (see Fig. 'F' and Injection Control Unit 5564-1 in the Maintenance Manual).

CHECK Pay attention that the bore positions correspond.

⇒ Close drain screw (2) or (3) and tighten it with a torque of 200 Nm.

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

D


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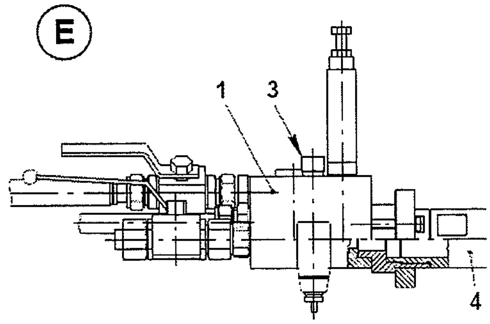

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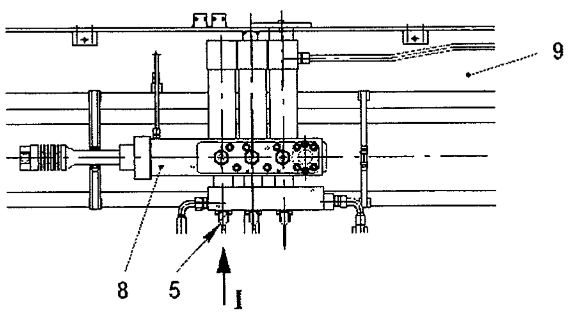
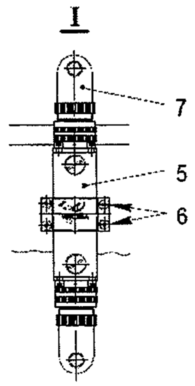




Key to illustrations: **'D' Control oil rail DE**
'E' Control oil rail FE
'F' Injection control unit

1	Valve block	6	Screw
2	Drain (screw) valve (3.68)	7	Cable
3	Drain (screw) valve (3.68)	8	Injection control unit (3.02)
4	Control oil rail (3.75)	9	Rail unit
5	Rail valve (3.76)		

Injection control unit:

The injection control unit must be shut off as an immediate measure in case of:

– injection control unit cracked.
– injection control valve or fuel quantity piston seized.

See 0510–1 'Shut off the injection control unit'.

Remark : With injection control unit shut off or injection cut off (Inj. CUT OFF), the engine can only be operated at reduced load.

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

High pressure piping to injection valves:

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

4. Defective fuel pressure control valve 3.06

4.1 Identification

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

4.2 Causes

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

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

Operation under Abnormal Conditions
Faults in High Pressure Fuel System

4.3 Measures

⇒ Turn knurled screw (4) to the lower stop.

⇒ Overhaul or replace defective fuel pressure control valve (2) at the first opportunity.

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

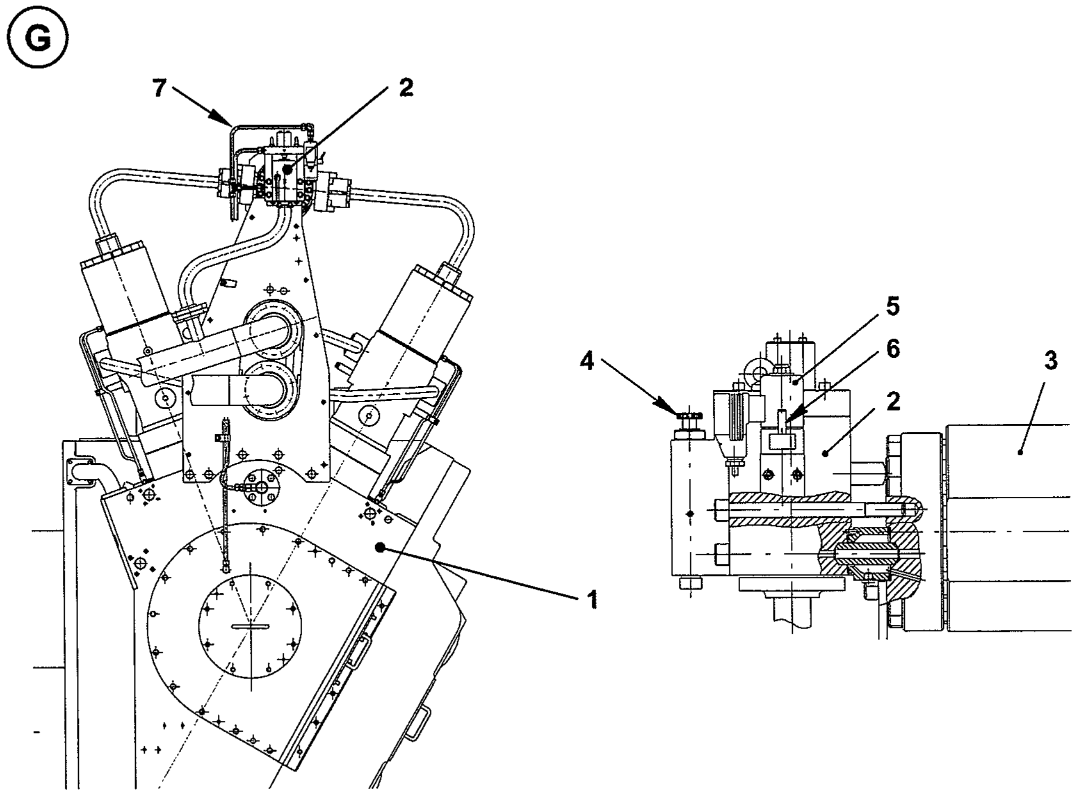
CAUTION

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

The oil supply (7) from bearing oil system and intermediate fuel accumulator (3) must be pressureless.

⇒ Switch off fuel booster pump (3.15) and bearing oil pump.

⇒ Close stop valves (3.62-1 & 2) after intermediate fuel accumulator and relieve pressure with hand lever (6) on fuel shut-down pilot valve (5).



Key to Illustration: 'G'

1	Supply unit G	5	Fuel shut-down pilot valve 3.08
2	Fuel pressure control valve (3.06)	6	Hand lever
3	Intermediate fuel accumulator (3.04)	7	Bearing oil supply
4	Knurled screw		

Operation under Abnormal Conditions
Operation with Exhaust Valve Drive Cut Out

1. General

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

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

CAUTION

In case of cutting out an exhaust valve drive, at the same time, cut out the injection of the corresponding cylinder cutting out an exhaust valve drive.

2. Emergency operation with exhaust valve closed

2.1 Cut out an exhaust valve drive

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

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

⇒ Cut out the injection (see 0510-1 'Measures').

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

WARNING

For safety reasons the plugs must be disconnected from the rail valve of the corresponding cylinder.

Measures to be taken with defective exhaust valve drive:

- In case of heavy leakage to outside.

⇒ Stop the engine.

⇒ Switch off bearing oil pump.

⇒ Open drain screw (2) or (3) by about two turns for pressure relief in the servo and control oil system (see Fig. 'A' and 'B').

⇒ Remove plug (10) from connecting element (11) between servo oil rail (9) and exhaust valve drive (8). Fit shut-off plug (15) (tool 94586) and tighten screws (5) with a torque of 130 Nm (see Fig. 'C' and 'D').

⇒ Remove plug (12) from connection piece (14). Fit shut-off plug (15) (tool 94586) and tighten screws (5) with a torque of 130 Nm (see Fig. 'C' and 'D').

⇒ Close drain screw (2) or (3) and tighten it with a torque of 200 Nm.

Measures to be taken by piping leakages:

⇒ Close stop valve (13) in oil piping (17) to the exhaust valve drive.

2.2 Operation with cut out exhaust valve drive

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

CAUTION

With one or more cut out exhaust valve drive(s), the engine can only be operated at reduced load. Generally the remarks in 0500-1 have to be observed. Furthermore the exhaust gas temperature after cylinders may on no cylinder exceed the **maximum limit of 515 °C.**

2.3 Restarting of exhaust valve drive

Replace defective exhaust valve drive or HP piping at the first opportunity (see Maintenance Manual, Exhaust Valve Drive 5612-1 and Hydraulic Piping for Exhaust Valve Drive 8460-1).

Exchange of shut off exhaust valve drive:

⇒ Stop the engine.

⇒ Switch off bearing oil pump.

⇒ Close stop valve (13) in oil piping (17) to the exhaust valve drive.

⇒ Carefully remove plug (16) for draining the hydraulic piping.

⇒ Open drain screw (2) or (3) by about two turns for pressure relief in the servo and control oil system (see Fig. 'A' and 'B').

⇒ The shut off exhaust valve drive can now be replaced (see 5612-1 in the Maintenance Manual).

Remark : Both shut-off plugs (15) (tool 94586) must be removed from the shut off (defective) exhaust valve drive and replaced with plugs (10) and (12).

⇒ Close drain screw (2) or (3) and tighten it with a torque of 200 Nm.

⇒ Fit and tighten plug (16).

⇒ Reopen stop valve (13).

⇒ Switch on bearing oil pump.

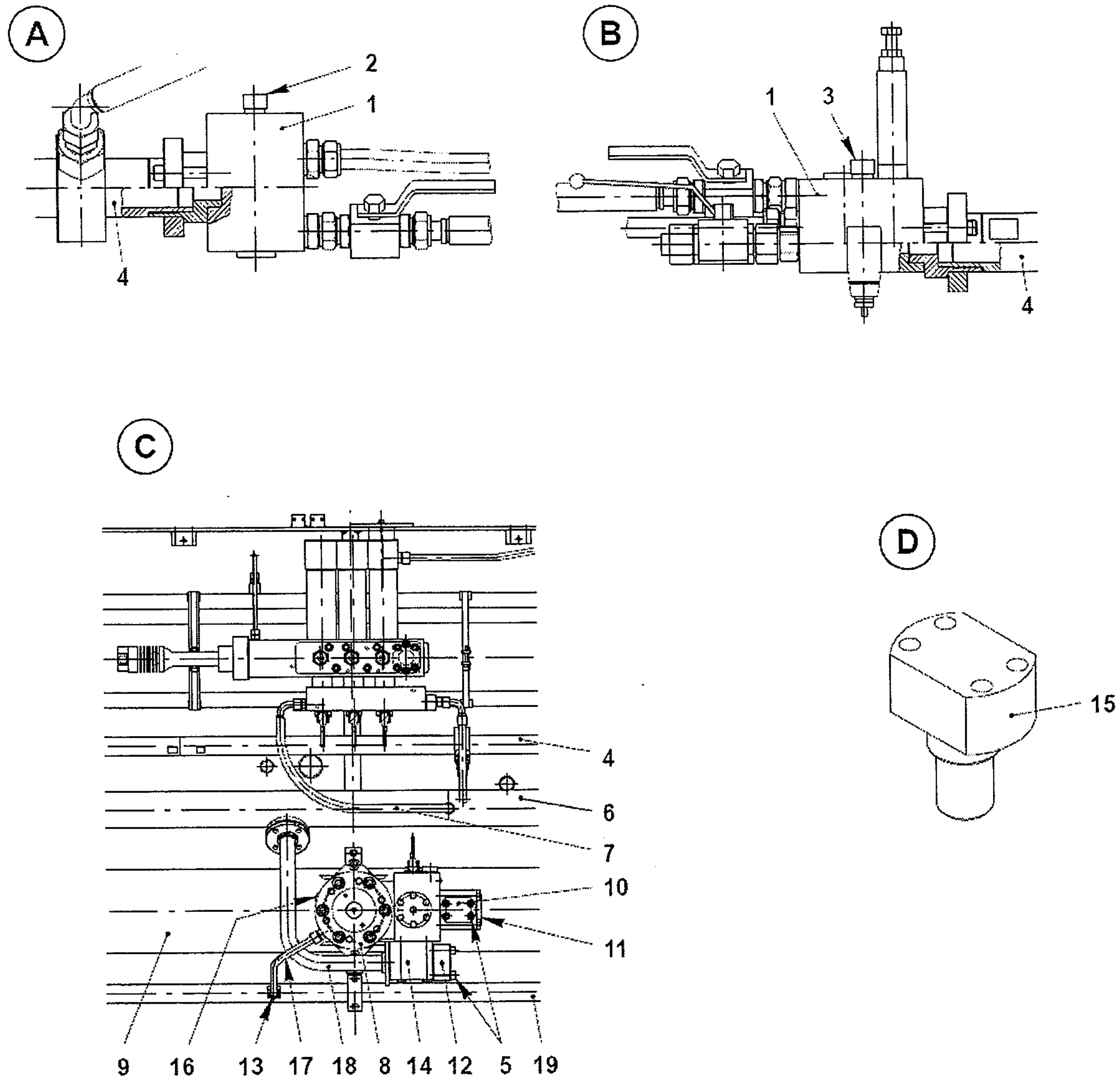
⇒ Set the exhaust valve drive for the cylinder concerned to AUTO with user parameter EXH. VALVE AUTO / MAN. in remote control.

⇒ Reconnect the plugs to the rail valve.

CHECK Carry out a visual leakage test.

Operation under Abnormal Conditions

Operation with Exhaust Valve Drive Cut Out



Key to Illustrations: **'A' Control oil rail DE**
'B' Control oil rail FE
'C' Exhaust valve drive
'D' Shut-off plug (tool 94586)

1	Valve block	11	Connecting element
2	Drain screw (3.68)	12	Plug (4.33)
3	Drain screw (3.68)	13	Stop valve (4.36)
4	Control oil rail (3.75)	14	Connection piece
5	Screw	15	Shut-off plug (tool 94586)
6	Servo and control oil return piping (4.63)	16	Plug 4.34
7	Control oil drain pipe	17	Oil piping to exhaust valve drive
8	Exhaust valve drive (4.10)	18	Servo oil return
9	Servo oil rail (4.11)	19	Oil distributing piping
10	Plug (4.32)		

Exchange of a defective hydraulic piping:

- Injection and exhaust valve drive are cut out (see paragraph 2.1).
- Stop valve (13) closed in oil piping (17) to exhaust valve drive (8).

⇒ Stop the engine.
⇒ Switch off bearing oil pump.
⇒ Carefully remove plug (16) for draining the hydraulic piping (see Fig. 'C').
⇒ Replace defective hydraulic piping (see 8460-1 in the Maintenance Manual).
⇒ Refit and tighten plug (16).
⇒ Reopen stop valve (13).
⇒ Set the exhaust valve drive for the cylinder concerned to AUTO with user parameter EXH. VALVE AUTO / MAN. in remote control.
⇒ Cutting in injection of the cylinder concerned with user parameter Inj. RUN in remote control.
⇒ Switch on bearing oil pump.

3. Emergency operation with exhaust valve opened

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

3.1 Putting an exhaust valve out of service

⇒ Stop the engine.
⇒ Remove screw plugs (1) from lower housing (2) (see Fig. 'E').
⇒ Close venting cock (4.08) in the control air supply $\boxed{A}$. Thereby the air piping to the exhaust valves is vented and the exhaust valve remains open.
⇒ Fit retaining screws (3) (tool 94259) as shown in Fig. 'F'.

WARNING

For safety reasons the plugs must be disconnected from the rail valve of the corresponding cylinder.

⇒ Put back air spring venting (4.08) to operating position after fitting the retaining screw.
⇒ Remove the control signal plug from the starting valve.

Remark : Concerning the reduction in engine load, the same conditions apply as under paragraph 2.2.

4. Re-starting an exhaust valve drive

CAUTION

> After termination of the emergency operation with open exhaust valve, the seat surfaces of exhaust valve and valve seat must be checked for perfect condition(no hard dirt deposits).
> Seat surfaces with heavy deposits must be overhauled according to the 2751-3 and 2751-4 in the Maintenance Manual.

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

⇒ Close venting cock (4.08) in the control air supply $\boxed{A}$. Thereby the air piping to the exhaust valves is vented and the exhaust valve remains open.

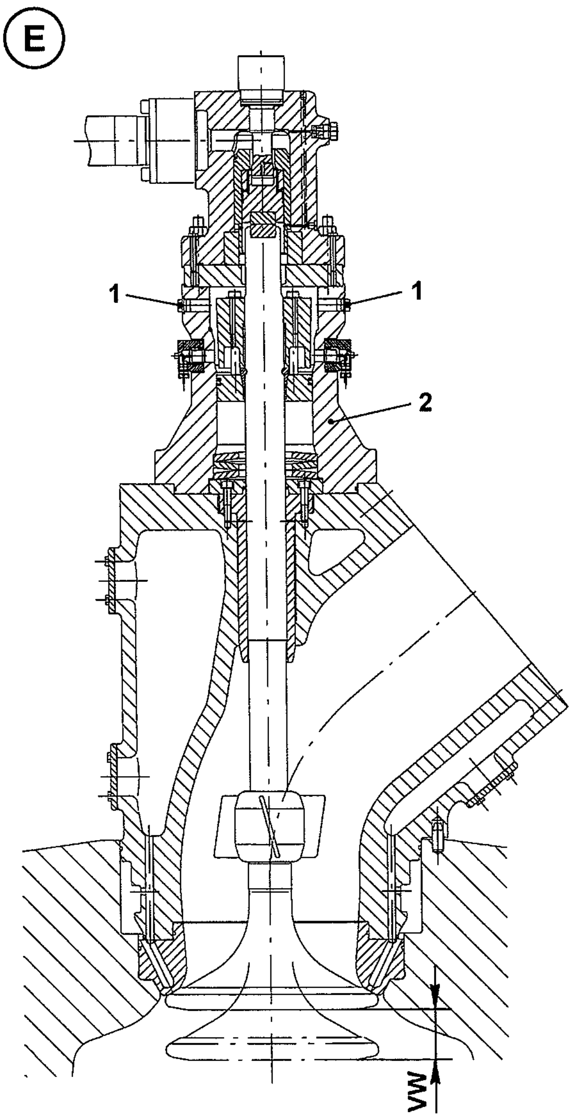
⇒ Unscrew retaining screws (3) (tool 94259) and refit screw plugs (1) (see Fig. 'E' and 'F').

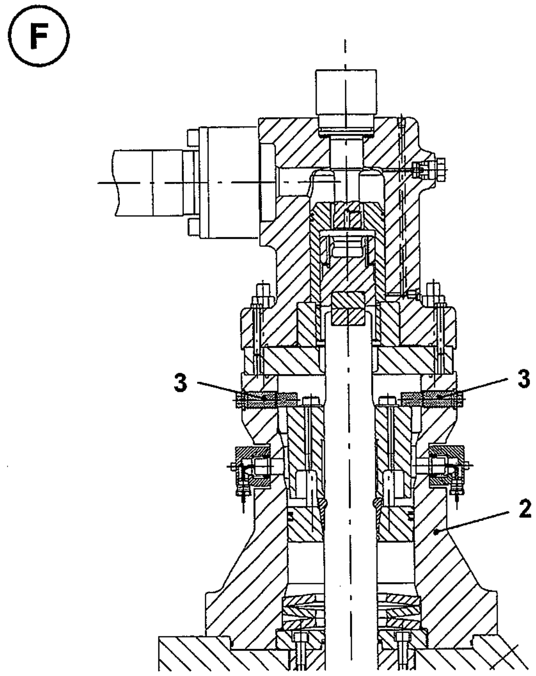
⇒ Cut in the injection (see 0510-1).

⇒ Turn venting cock (4.08) back to operating position.

⇒ Reconnect the plugs to the rail valve.

⇒ Reconnect the control signal plug to the starting valve.





Key to Illustrations: 'E' and 'F'

1 Screw plug
2 Lower housing
3 Retaining screw (tool 94259)

VW Maximum exhaust valve stroke

1. Defective automatic filter

1.1 Identification

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

1.2 Causes

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

1.3 Measures

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

⇒ Clean clogged filter elements manually.

⇒ Examine reason of the clogging.

⇒ Remedy faults (see documentation of automatic filter supplier).

⇒ Check the condition of the system oil (see 0750-1 'Taking oil samples').

⇒ If no flushing cycle is released, investigate reason (no control air, rotating motor, position switch or pneumatic flushing valve defective).

2. Defective servo oil pump

2.1 Identification

- Flow sensors FS2061A ~ FS2066A indicate a pump failure, i.e. an alarm is triggered in alarm and monitoring system ('Servo oil pump #n. flow').

2.2 Causes

- Servo oil pump blocked, carrier at shearable overload protection broken (see Servo Oil Pump 5551-1).
- Failure of the actuators CV7221C ~ CV7226C.
- Failure of control current (cable coupling defective).

2.3 Measures

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

⇒ Replace defective servo oil pump at the first opportunity (see 8016-1 'Filling, draining of servo and control oil system' and Supply Unit 5552-1 in the Maintenance Manual).

CAUTION

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

3. Defective exhaust valve drive

3.1 Identification

- Alarm indication in WECS-9520 (remote control 'Exh. valve late/not opening').
- The fuel injection is cut off automatically (Inj. CUT OFF) on the corresponding cylinder, and a SLOW DOWN will be released.
- Alarm indication by level switches LS3444A or/and LS3445A due to leakages at the HP pipings to the exhaust valves (see 8016-1 'Bearing oil system').

3.2 Causes

- Rail valve defective.
- 3/2-way valve defective.
- Piston in exhaust valve drive seized.
- Breakage of a HP piping to the exhaust valve.

Rail valve:

Replace defective rail valve at the first opportunity.

⇒ Stop the engine.

⇒ Switch off bearing oil pump.

⇒ Open drain screw (2) or (3) on valve block (1) by about two turns for pressure relief in the control oil system (see Fig. 'A' and 'B').

⇒ Remove cable (9).

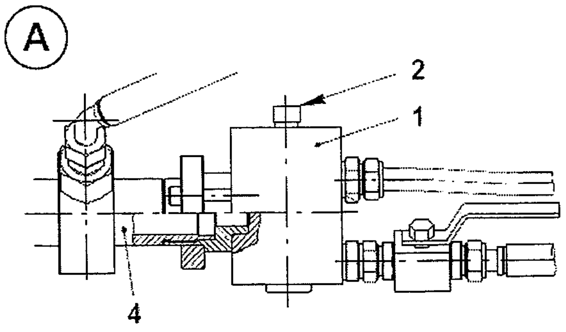
⇒ Loosen screws (8) and remove them together with rail valve (7).

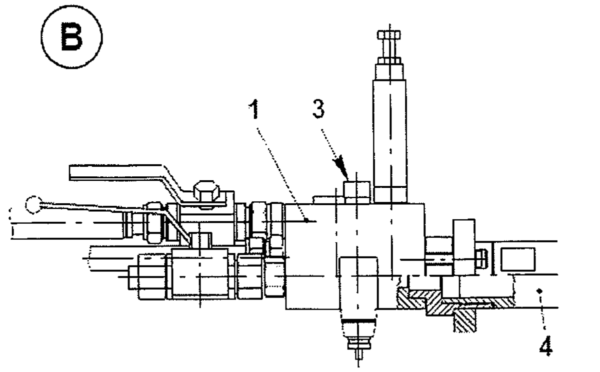
⇒ Take care that the three O-rings are put in the new rail valve and the surfaces are clean.

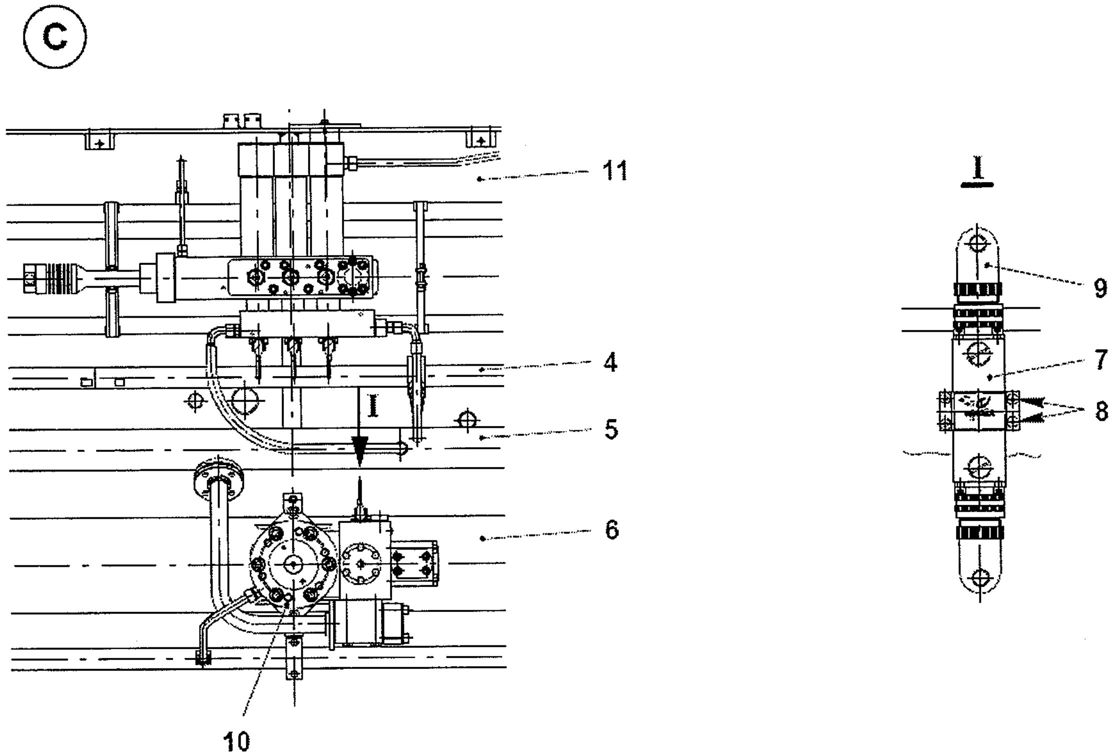
⇒ Fit the rail valve with four screws (8) and tighten the latter with a torque of 2.5 Nm (see Fig. 'C' and Exhaust Valve Drive 5612-1 in the Maintenance Manual).

CHECK Pay attention that the bore positions correspond.

Operation under Abnormal Conditions
Faults in Servo and Control Oil System







Key to Illustrations: 'A' **Control oil rail DE**
'B' **Control oil rail FE**
'C' **Exhaust valve drive**

1	Valve block	7	Rail valve (4.76)
2	Drain screw (3.68)	8	Screw
3	Drain screw (3.68)	9	Cable
4	Control oil rail (3.75)	10	Exhaust valve drive (4.10)
5	Servo and control oil return piping 4.63	11	Rail unit
6	Servo oil rail (4.11)		

Defective exhaust valve drive:

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

– 3/2-way valve defective or piston in exhaust valve drive seized.

See Operation with Exhaust Valve Drive Cut Out 0520-1.

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

⇒ Replace defective exhaust valve drive at the first opportunity (see 0520-1 'Restarting of exhaust valve drive and Exhaust Valve Drive 5612-1 in the Maintenance Manual).

Hydraulic piping to exhaust valve:

⇒ Cut out the injection of the cylinder concerned at a breakage of a hydraulic piping to the exhaust valve (see 0510-1 'Measures').

⇒ Replace defective hydraulic piping at the first opportunity (see 0520-1 'Exchange of a defective hydraulic piping' and 8460-1 in Maintenance Manual).

4. Defective control oil pump

4.1 Identification

- In WECS-9520 (remote control) alarm indication 'Control oil pump 1/2 fails' or 'Control oil pressure low'.
- Control oil pressure drop at failure of both control oil pumps.
- Slow-down actuated.

4.2 Causes

- Control or power supply failed.
- Electric motor, coupling or pump defective.
- Pressure retaining valve (3.73-1A) or (3.73-2A) defective.
- Safety valve (3.73-1B) or (3.73-2B) open.
- Failed current measuring transducer in starter box.

4.3 Measures

- Upon failure of a control oil pump the second pump ensures the correct pressure. The engine remains in operation.
- Replace defective control oil pump or failed current measuring transducer at the first opportunity.

CAUTION

> If both control oil pumps fail during operation, the servo oil system ensures the correct control oil pressure. However, in this case the engine should only be operated in emergency.
> The engine can not be restarted without control oil pressure.

Operation under Abnormal Conditions
Operation without Crosshead Lubricating Oil Pump

1. General

Upon failure of the crosshead lubricating oil pump, the crosshead bearing oil system is being operated at the lower pressure of the main bearing oil.

At reduced load the operation may be continued for the short time until the crosshead bearing oil pump is either repaired or replaced.

CAUTION

- 40% engine power may not be exceeded
(see 0820-1 'Crosshead bearing oil pressure drops').
- This mode of operation may **not be regarded as continuous.**
The booster pump must be repaired/replaced as soon as possible and started up.

Operation under Abnormal Conditions
Operation with Running Gear Partially or Totally Removed

1. General

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

2. Piston removed

Brakedown cases:

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

2.1 Measures

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

⇒ Cut out the injection (see 0510-1 'Measures').
⇒ Cut out the exhaust valve drive (see 0520-1 'Emergency operation with exhaust valve closed').
⇒ Remove control air pipe (7) from bend (6) (Fig. 'A').
⇒ Remove the bend from starting air pipe (5) and fit blank flange (8) (tool 94831).
⇒ Remove control signal plug (11) from the starting valve.
⇒ Fit cover plate (9) (tool 94345d) in place of the piston rod gland.
⇒ Mount cover and lifting plate (10) (tool 94324) onto the crosshead.
⇒ If necessary, close cooling water feed and return piping of the relevant cylinder.
⇒ Stop the lubrication of the respective cylinder forcibly. (see 7218-5 section 3.4 'Procedure for Stop Injection Forcibly').

☞ *Remark* The engine can only be operated at low load. Generally the remarks in 0500-1 have to be observed.
Furthermore the exhaust gas temperature after cylinders may on no cylinder exceed the **maximum limit of 515°C**

3. Piston, crosshead and connecting rod removed

Brakedown cases:

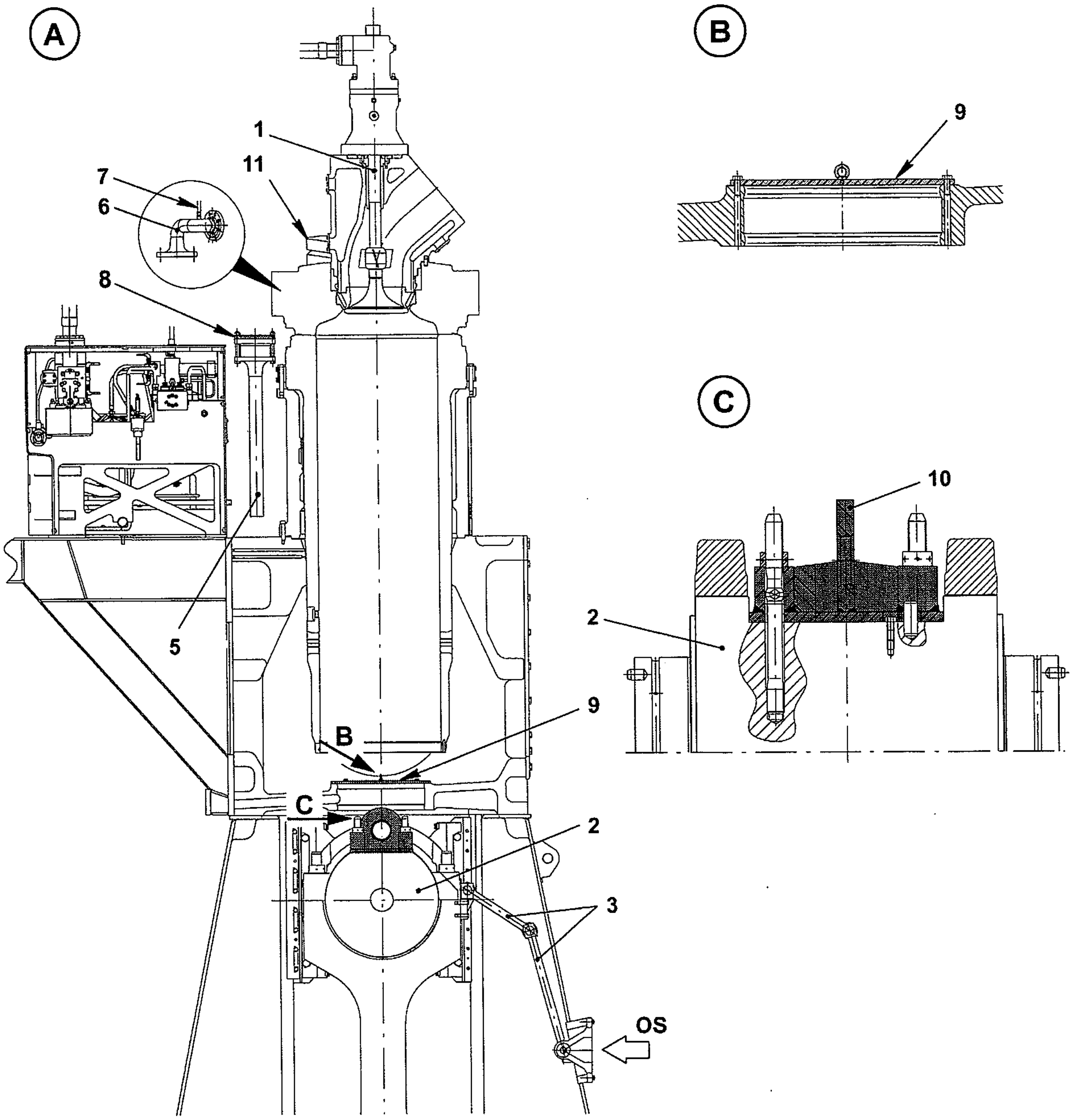
– Defects to crosshead or guide shoes
– Connecting rod bearing badly damaged
– Defects on crosshead pin or on the connecting rod

3.1 Measures

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

☞ *Remark* : Concerning the reduction in engine load, the same conditions apply as under paragraph 2.1.

Operation under Abnormal Conditions
Operation with Running Gear Partially or Totally Removed



Key to Illustrations : **'A' Searing off the cylinder**
'B' Covering for the grand box bore
'C' Searing off the crosshead

1 Exhaust valve
2 Crosshead
3 Toggle lever

5 Starting air pipe
6 Bend (starting air inlet)
7 Control air pipe

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

OS Oil supply

Operation under Abnormal Conditions
Operation with Water Leakage into the Combustion Chamber

1. General

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

2. Measure

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

⇒ Close the valves "V_1" and "V_2" to the cooling water inlet and outlet from the affected cylinder (disconnect from the cooling system) and open the vent valve "V_3". Then, drain the cooling water via the drain piping.

⇒ Operation with injection cut out (see 0510-1).

⇒ Operation with exhaust valve drive cut out (see 0520-1 'Emergency operation with exhaust valve opened").

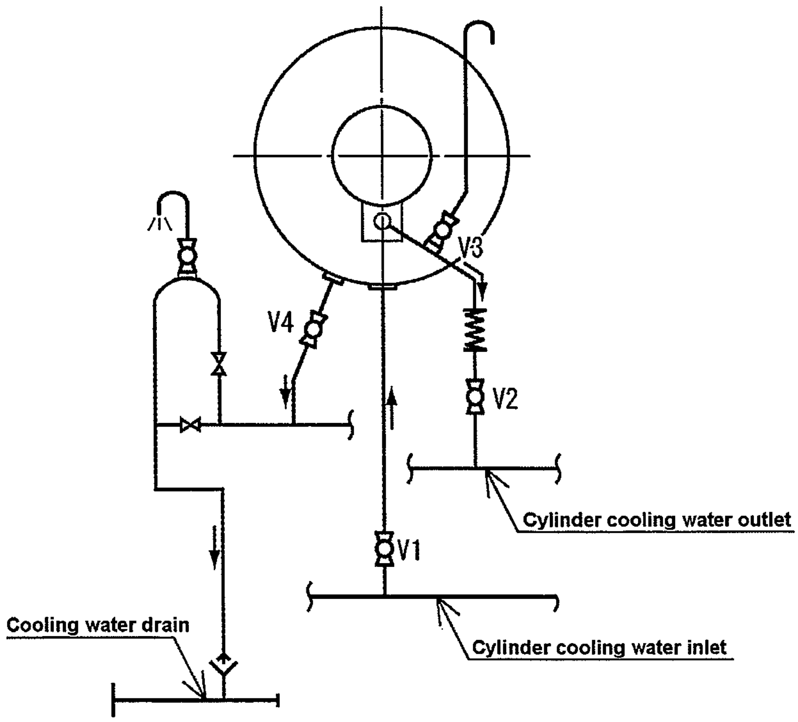
CAUTION

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

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

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

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



Operation under Abnormal Conditions

Scavenge Air Cooler Out of Service / Failure of Auxiliary Blower

1. Scavenge air cooler out of service

When a scavenge air cooler is defective, water can enter the scavenge air receiver and escape through the drain pipe.

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

Remark : Should at engine standstill and running sea-water pumps the escape of water be observed at the sight glass in the drain pipe, a check for a cooler defect must be made as soon as possible.

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

⇒ Where operation permits, repair the defective cooler as soon as possible. In case of emergency individual, defective cooler pipes may be blanked off.

⇒ Shutting down and draining the defective cooler

- The individual cooling water supply and return pipes of the effective cooler have to be closed off and the vent and drain cocks opened and left open. Leakage water entering the receiver automatically flows away through the receiver drain pipe into the collecting pipe.

Remark : When running in this mode, the scavenge air temperature will rise and thus the exhaust gas temperature as well.
The engine may therefore only be so loaded that the normal exhaust gas temperature (measure before the turbine) at service output is not exceeded. The exhaust gas temperature and scavenge air temperature have to be continuously and carefully monitored.
Should the exhaust gas temperature rise too high, the engine speed must be correspondingly reduced (maximum permissible exhaust gas temperatures before turbine and scavenge air temperature, see 0250-1).

2. Failure of auxiliary Blowers

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

When auxiliary blowers fail, starting/operation for the engine shall be as the followings.

3-aux. blowers installation 1 aux. blower failure 2 aux. blower failure	– The engine can start from any control position.
3 aux. blowers failure	– The engine can start from E/S, C/R and W/H only but, it can not be accelerated.

Operation under Abnormal Conditions
Defective Remote Control

1. General

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

Detailed descriptions are given in the groups:

- Starting 0230-1
- Manoeuvring 0260-1
- Shutting Down 0310-1
- Measures to be taken after Stopping 0320-1
- 4003-1 'Engine local control'
- Local Control Panel 4618-1

> **CAUTION**
> This form of engine operation should only be used when absolutely necessary. The engineer must not leave the local control panel. The engine speed must be observed frequently so that immediate action can be taken if large deviations in speed occur.

Operation under Abnormal Conditions
Defective Speed Control System

1. General

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

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

Detailed descriptions are given in the groups:

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

CAUTION

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

Operation under Abnormal Conditions
Turbocharger Out of Service

1. General

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

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

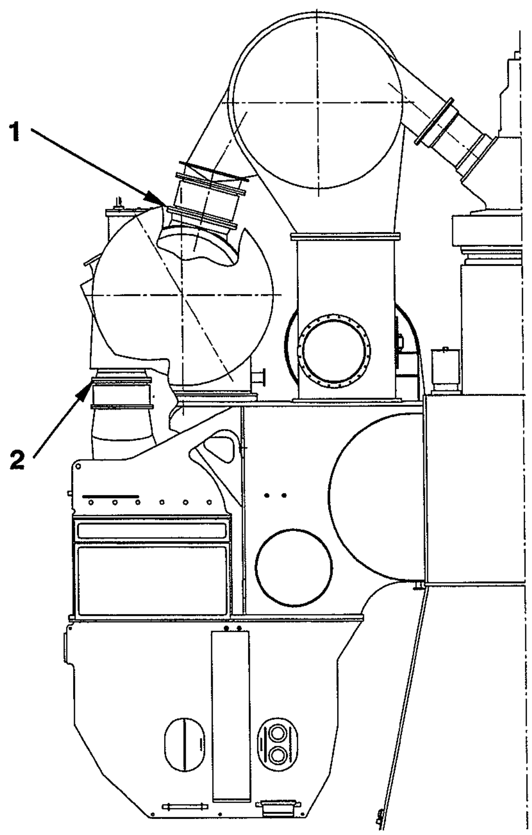
In the mentioned 'Emergency Operation' the engine should basically run only as long as absolutely necessary. (For further instructions see 0500-1 'Reduced power output').

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

2. Breakdown case 1

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

Operable output relative to CMCR:



No. of turbochargers		Operable output in %
fitted on engine	**broken down**	**P**
2	1	about 50
3	1	about 66
3	2	about 33

Measures:

⇒ Remove the distance piece between the expansion joint and the defective turbocharger, and fit blind flange (1).

⇒ Remove the distance piece between the defective turbocharger air outlet and the expansion joint, and fit blind flange (2).

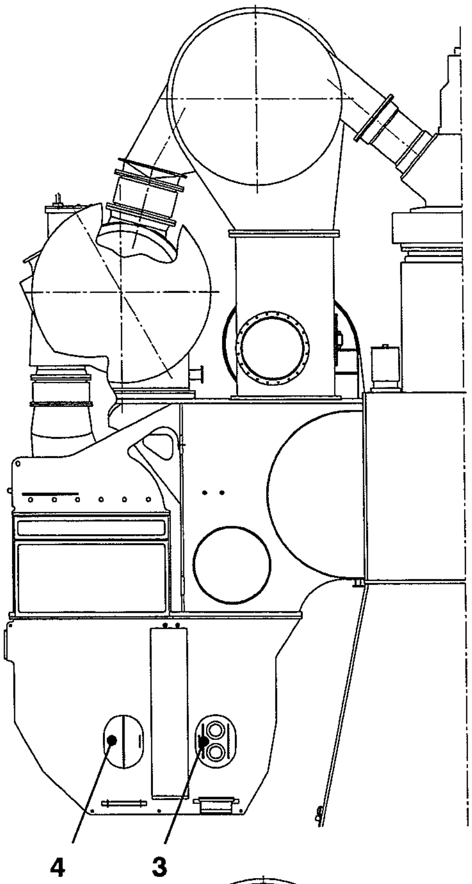
⇒ Check oil supply (pressure) of the other turbochargers. If the pressure has dropped, the supply must be plugged to the defective turbocharger (when restarting turbocharger be sure to reopen lubricating oil supply).

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

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

3. Breakdown case 2

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



Operable output relative to CMCR

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

M***easures:***

⇒ Block the rotors of the defective turbochargers as described in the turbocharger manual. (see the turbocharger maker's instruction)

⇒ In case of lube oil loss the supply must be plugged (when restarting turbochargers be sure to reopen lubricating oil supply).

⇒ Open covers (3) on all air ducts

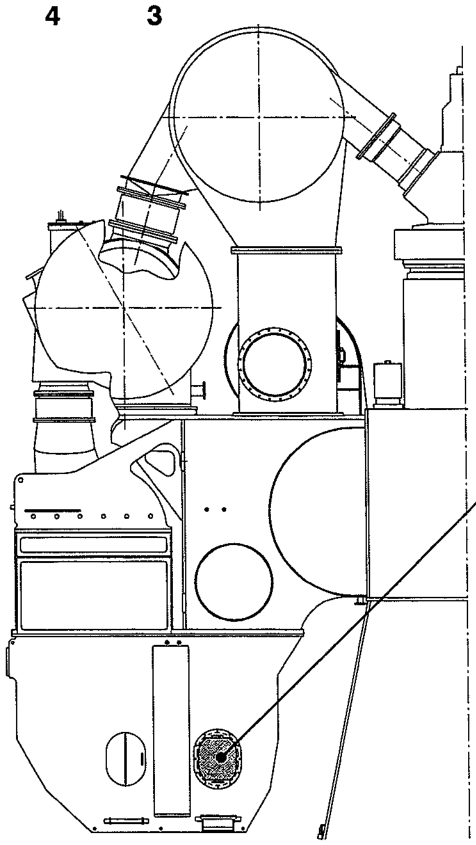
CAUTION

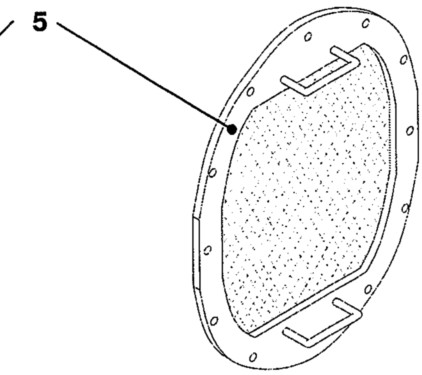
Open only fuel side covers (3). It is not necessary to open the exhaust side covers (4).

⇒ Set wire net covers (5) on the receiver.

⇒ Auxiliary blowers must run during operation.

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





Special Measures before and after Operation
Preparations before Starting after a Prolonged Shut-down Period or an Overhaul

1. General

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

2. Special measures

- A function check of the engine control system has to be carried out according to Control System Checking 4003-1.
- If bearings or parts of the running gear had been replaced or removed for checking, then the lubricating oil supply must be checked at normal oil pressure (see Operating Data Sheet 0250-1). Check visually through open running gear doors whether sufficient oil flows out of every bearing point.
- In the course of the following operating period it is recommended to watch these parts for abnormal heating. For this check stop the engine after its start, at first in short intervals, later in longer intervals, and compare the temperature of the respective parts with the one of those parts which had not been freshly fitted (see 0210-1 'Temperature sensing').
- With regard to running-in new pistons, piston rings and cylinder liners, see 0410-1.
- After draining the servo oil system, check whether the drain screw (43) (4.72) in the collector block (3) (4.52) is tightened. If, however , only the servo oil rail (9) (4.11) has been drained, check whether the drain screws (24) and (24a) in the valve blocks before the servo oil rail are tightened (see 8016-1 'Filling, draining of the servo and control oil system')
- Check to ensure that there is free passage for the scavenge air and exhaust gas.
- If the cooling water for the scavenge air cooler has been drained, refill and vent the system.
- Close drains in the exhaust gas manifold and on the exhaust gas pipe if these have been opened.
- Analyze the lubricating oil quality (see Lubricating Oils 0750-1) after a prolonged shut-down period (several months).

Special Measures before and after Operation
Measures to be taken before Putting Out of Service for Extended Period

1. General

In principle, the same preparations have to be made as required before starting after the engine has been shut down for a few days (see Preparation before Taking into Service 0110-1).

2. Precautions

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

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

- The operating position must be in the "STOP" position (in both the control room and at the engine).

⇒ Close stop valves on the starting air receivers.

⇒ Bring handwheel (2.10) on shut-off valve for starting air (2.03) in position CLOSED (closed by hand) and open venting valves (2.21) and (2.27).

⇒ Engage turning gear (in this case the starting system to the engine is vented).

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

CAUTION

The water and oil pumps should be kept running for **at least 20 minutes** after the engine has been stopped so that the cooled engine parts are brought to as even a temperature as possible. However, the engine **must not be cooled down too much.**

⇒ Close off the shipboard supply to the control air supply unit A on the engine and to automatic filter (4.20) in the plant.

⇒ Open the indicator valves on the cylinder covers.

- For post-lubrication of the cylinders, turn the engine, with the indicator cocks open, using the turning gear ; at the same time execute the priming of ECL system.

⇒ Close the stop valves on the fuel tanks.

⇒ Open the drains of the exhaust manifold, the exhaust gas silencer and the exhaust pipe.

- For the scavenge air coolers, **the measures recommended by the cooler manufacturers** should be followed. When such is not available, we recommend that the coolers be completely drained or the cooling water pump run daily for about 30 minutes in the same flow quantity as for normal running conditions.

Special Measures before and after Operation

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

- Keep cylinder cooling water approximately at room temperature (watch for frost risks).
- Cover the silencer of the turbocharger airtight with a plastic sheet in order to prevent air circulation through the engine (risk of condensed water formation).
- With the indicator valves open, turn the engine, using the turning gear ; at the same time execute the priming of ECL system, at intervals which should not be too long (weekly in dry and daily in damp climates).

  At the same time where possible, start up the oil pumps.

Remark : The oil pressure cannot be completely built up if the exhaust valves are open or without air spring air.

⇒ Remedy all the damage and leaks discovered during the previous running period and the checks made after shut down.

⇒ Carry out any scheduled overhauls, observing the safety regulations (see 0012-1 in the Maintenance Manual).

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

Cylinder Lubricating Oil
Preparations Procedure before Engine Start

1. General

It should be checked whether the ECL system works certainly before re-starting the engine.

2. Priming Procedure of Cylinder Lubricating Oil

⇒ If the middle pressure pump is not operated, start a pump.
⇒ After verifying that the middle pressure pump is starting, turn on the power of the oil heater.
⇒ Warm up cylinder lubricating oil until the main pipe pressure becomes $8^{+0.05}_{-0.0}$ MPa and main pipe temperature becomes 45 to 60 degrees C.

Remark In general, when the main pipe pressure is lower than 7MPa, the controller does not permit to execute the priming.
But, only for the purpose of flushing the lubricating branch pipe, priming can be executed according to the procedure described in section 3 even if the main pipe pressure is lower than 7MPa.

⇒ Push the button of "PRIMING ON" on the control panel.
Each distributor starts and continues priming until the number of times of priming becomes specified number.

Remark During the priming, system A and system B are not synchronized. It is not unusual operation that injection timing of both systems is not same.
It is possible to execute the priming at a single cylinder. (Refer to section 4)

⇒ It is possible to stop the priming forcibly by pushing the button of "PRIMING OFF" on the control panel.

Remark During the priming, the quantity of injection is automatically set below normal lubrication to prevent the incorrect action of the flow limiter.
For the above reason, if air venting of the lubricating branch pipes is not perfect, the lubrication from an ECL-SIP valve may not be performed for several minutes.

3. Procedure for Lubricating Branch Pipes Flushing

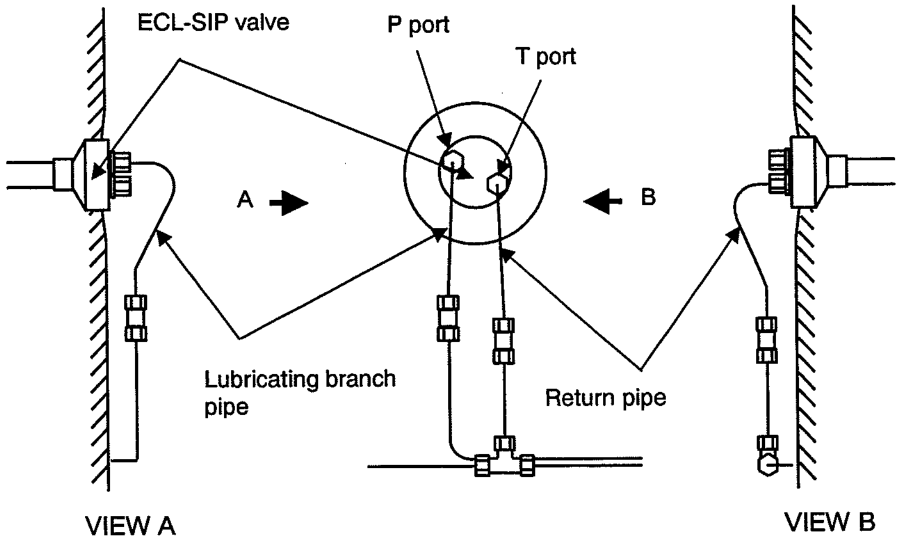
If ECL-SIP valves are clogged frequently because of lubricating branch pipes contamination or the lubricating branch pipes are broken, the lubricating branch pipes should be replaced.
The new lubricating branch pipes should be flushed according to the following procedure.

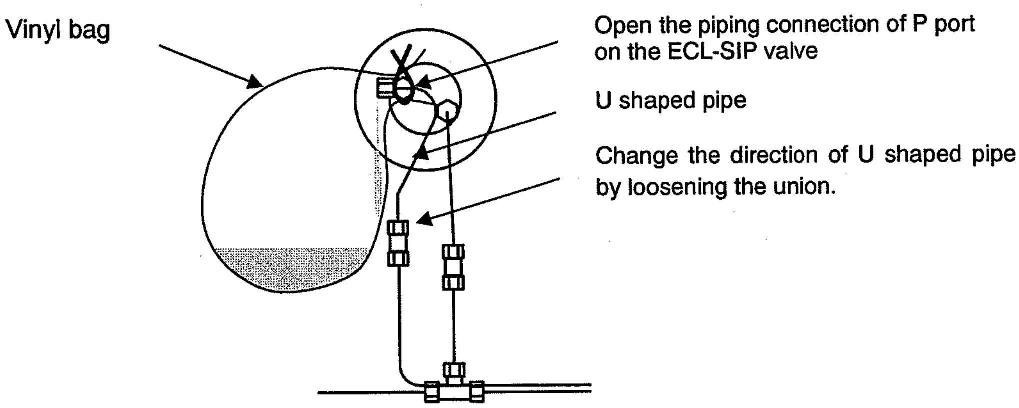
⇒ Prior to flushing of lubricating branch pipes, open all piping connection of pressure ports on the ECL-SIP valves.
⇒ Cover the open end of the lubricating branch pipes with the vinyl bags to collect the contaminated lubricating oil.
⇒ To switch to FLUSHING MODE, the value of the following ten-key address should be changed into 1 from 0.
⇒ Lower the main pipe pressure to 4MPa by opening the bypass valve of pressure relief valve midway.
⇒ Start the flushing by pushing the button of "PRIMING ON" on the control panel.
⇒ When each vinyl bag collects the contaminated lubricating oil more than 200 gram, stop the priming.
⇒ Remove the vinyl bags and restore all piping connection of pressure ports on the lubricating valves.
⇒ Open the end of the pressure detecting pipe in the distributor unit. And, execute the priming until bubble free from the open end of the pressure detecting pipe.
⇒ Restore the value of the following ten-key address.

Address of flushing mode is shown in the following table.

Address	LCD comment	Setting range
140	Flushing Mode	0 : Normal 1 : Flushing mode

Remark Regarding the operating instructions of the ten-key on the operation panel, refer to 7218-5/ A1 "ECL System Control System".
Prior to change these above data, cancel protection with a password.
For more details refer to "Operating Manual Section 3.4".





4. Change Procedure of Number of Times of Priming

It is possible to change the number of times of priming with the ten-key on the control panel.

Regarding the operating instructions of the ten-key on the operation panel, refer to 7218-5/ A1 "ECL System Control System".

Address of Number of times of priming is shown in the following table.

Address	LCD comment	Setting range
114	PRIMING Num.	20 to 500 (times) by 1

5. Procedure of Priming with a Single Cylinder

It is possible to execute the priming at a single cylinder.

Regarding the operating instructions of the ten-key on the operation panel, refer to 7218-5/ A1 "ECL System Control System".

If you want to execute the priming at a single cylinder, the relevant cylinder number should be input into address '115' with the ten-key on the control panel.

Address	LCD comment	Setting range
115	PRIMING CYL.NO.	0 to 12 by 1 CAUTION If you want to execute the priming at all cylinder simultaneously, input '0' to address '115'

Overview

1. General

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

Gas oils and diesel oils (distillates) can be used in all our engines. Whether a specific engine type is suited to run on heavy fuel and up to what grade, can be found in the "Quality specification for heavy fuel oils" (see table on sheet 0710-1-4/6). In case of fuels with very low sulphur content care must be taken, particularly when running-in new piston rings and cylinder liners.

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

The attached table under section 2 (see table on sheet 0710-1-2/6) summarizes the characteristic values of marine fuel oil available on the market.

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

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

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

The following table under section 2 (see table on sheet 0710-1-2/6) may be used as a guide for first classification of fuels according to certain characteristic values.

2. Characteristic values of marine fuel oils

(This summary does not represent a quality specification)

Properties	Marine Gas Oil	Marine Diesel Oil	Intermediate Fuel Oils	Bunker Fuel Oil
Density at 15° C [kg/m^3]	820 ~ 870	850 ~ 920	900 ~ 991	up to 1010
Viscosity at 40° C mm^2/s [cSt]	1.5 ~ 7	4 ~ 14	—	—
at 50° C mm^2/s [cSt]	—	—	30 ~ 420	up to 700
	High viscosity fuels must be heated to reduce the viscosity to the recommended value at engine inlet.			
Pour point [° C]	-6 ~ +6	-6 ~ +6	0 ~ 20	up to 30
	The fuel can no longer be pumped in the vicinity of the pour point and heating devices are necessary for tanks and pipes at corresponding ambient temperatures.			
Sulphur [%]	0.2 ~ 2	0.2 ~ 2	1 ~ 5	1 ~ 5
	During combustion the sulphur of the fuel burns to form sulphur oxides which in turn form sulphuric acids. These acids are very corrosive to the cylinder liner walls and the piston rings primarily if temperatures of these components are below the dew point. The corrosive attack can be combated by using a cylinder oil with sufficient alkalinity, expressed by its BN (Base Number). Regarding the selection of the BN in relation to the sulphur content of the fuel, reference is made to instructions 0750–1 'Cylinder lubricating oil'. Experience shows that also an excessive BN can have detrimental effects such as forming hard deposits in the combustion chamber of the engine.			
Carbon residue MCR [%]	up to 0.20	up to 2.5	up to18	up to 20
	A high conradson figure shows that the fuel tends to form deposits during combustion, and thus favours the fouling of nozzles, piston ring grooves, gas outlet ducts and scavengeports.			
Ash content [%]	up to 0.01	up to 0.02	up to 0.15	up to 0.2
	Ash grinds piston rings, cylinders and valves, and can also promote fouling and burn-off especially with a high vanadium and sodium content. The sodium content should beless than 1/3 of the vanadium content.			
Water content [%]	0 ~ 0.1	0 ~ 0.25	0.1 ~ 1	0.1 ~ 1
Ignition quantity Cetane number/index	~ 40	40 ~ 50	–	–
CCAI			870	870
	see 0710-1-6/6 section 3 and paragraph 4.9			
Flash point [° C]	Min. 60° C			

Note:
This summary gives only a very general survey of available fuel oils but does not indicate their suitability. Regarding the respective permissible limiting value, see quality requirements under sections 3 and 4.
It is not necessarily complete, other properties may also influence the engine performance.
Marine Diesel Oil can be pure distillates or may be blended. Some properties of blended oil may exceed the fuel quality requirements for specific engine types.

3. Heavy fuel oil

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

Marine fuels are usually differentiated by viscosity. The viscosity is indicated in centistokes (cSt) at 50 °C. The fuels are classified according to ISO 8217:1996, e.g. ISO–F–RMK55.

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

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

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

The values in the column 'Bunker limit' (RMK55) indicate the minimum quality of heavy fuel as bunkered, i.e. as supplied to the ship/installation. Good operating results have been achieved with commercially available fuels within these limits.

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

The fuel oil as bunkered must be processed before it enters the engine. For the design of the fuel treatment plant, it is recommended to follow the relevant recommendations of Wärtsilä Switzerland Ltd. The difference between the recommended fuel quality of bunker and at engine inlet is an approximate indication of the improvement that must be achieved by fuel oil treatment. If catalyst fines are present they must be removed. The fuel oil should contain no foreign substances or chemical waste, hazardous to the safety of the ship or detrimental to the performance of machinery.
(see Mitsubishi Service Information MSI-0007E)
(see Mitsubishi Service Information MSI-0204E)
(see Mitsubishi Service Information MSI-9601E)

MITSUBISHI-SULZER Diesel Engine
Recommended Values of Heavy Fuel Oil Properties
at Bunkering and Engine Inlet

Item			Heavy fuel oil		
			Limit value	Recommended fuel quality	
				Bunker	Engine inlet
Dencity at 15° C		[kg/m³]	≦ 991	≦ 991	≦ 991
Viscosity (4.1)	at 50° C	[cSt]	≦ 700	≦ 700	13 ~ 17
	at 100° C	[cSt]	≦ 55	≦ 55	13 ~ 17
Carbon residue (4.2)		Wt. [%]	≦ 22	≦ 15	≦ 15
Sulphur (4.3)		Wt. [%]	≦ 5.0	1.5 ~ 3.5	1.5 ~ 3.5
Ash content (4.4)		Wt. [%]	≦ 0.20	≦ 0.05	≦ 0.05
Aluminium+Silicon (4.5)		[mg/kg]	≦ 80	≦ 30	≦ 10*
Water content (4.6)		Vol. [%]	≦ 1.0	≦ 0.5	≦ 0.2
Flash point (4.7)		[°C]	≧ 60	≧ 60	≧ 60
Vanadium		[mg/kg]	≦ 600	≦ 100	≦ 100
Sodium		[mg/kg]	≦ 50	≦ 30	≦ 30
Total sediment, pot.		Wt. [%]	≦ 0.1	≦ 0.05	≦ 0.05
Pour point		[°C]	≧ 30	≧ 30	≧ 30

*: Catalytic fines are less than 10 μm.

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

4.1 Viscosity

The maximum admissible viscosity of the fuel that can be used in an installation depends on the heating and fuel preparation facilities available. As a guidance, the necessary preheating temperature for a given nominal viscosity can be taken from the Viscosity-Temperature diagram (0270-2). The recommended viscosity range before engine is: 13 ~ 17 cSt [mm2/s].

4.2 Carbon residue, asphaltenes, sediment

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

For judging the stability of a type of heavy fuel oil the SHF test (sediment by hot filtration) is generally applied. For a safe stability criterion, the fuel must not exceed 0.10% sediments in the hot filtration test (SHF).

4.3 Sulphur

The alkalinity (BN) of the cylinder lubricating oil should be selected with regard to the sulphur level of the fuel in use.
Indications for the selection of the BN of lubricating oil in relation to the sulphur content of the fuel oil are found in group 0750-1.

4.4 Ash and trace metals

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

Since sodium compounds (oxides, sulphates) depress the melting point of the vanadium, which is very corrosive in the liquid phase, the sodium content should be as low as possible. With certain ratios of the vanadium to sodium content, the compounds form a eutectic with a minimum melting point which must be avoided. High sodium levels at engine inlet can cause fouling of turbocharger components. The maximum sodium content must not exceed 100 ppm (mg/kg) to avoid fouling of turbocharger components.

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

4.5 Aluminium, Silicon

Aluminium and silicon found in appreciable concentrations in the fuel oil are regarded as an indication of the presence of so-called catalytic fines (cat fines). These are particles of hard oxides which cause high abrasive wear to piston rings and cylinder liners. This material is used as a catalyst in certain processes in petroleum refining and can find its way into marine fuels. The most dangerous cat fines are of the size 10 to 20 microns. They tend to be attracted to water droplets and are very difficult to remove from the fuel oil. Practical experience has shown that with proper treatment in the fuel separator a sum of aluminium and silicon of 80 ppm (mg/kg) can be reduced to less than 10 ppm (mg/kg) which may be considered as just tolerable.
Proper treatment means reduced throughput in the separator and a fuel temperature of as close as possible to 98 °C.
(see Mitsubishi Service Information MSI-9601E)

4.6 Water

The water content of the fuel oil must be further reduced by careful purification.
This is accomplished most effectively by centrifuging and by use of proper draining arrangements on the settling and service tanks. The fuel is often contaminated by sea water containing sodium. A thorough removal of water is strongly recommended, to reduce the content of cat fines and sodium in the fuel oil. A practical guiding value to aim for is 0.2% water content after the separator.
Cat fines potentially reside in the water droplets and marine fuel oil is often contaminated with sea water containing sodium, 1.0% sea water in the fuel oil corresponds to 100 ppm sodium.

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

4.7 Flash point

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

4.8 Pour point

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

4.9 Ignition quantity (CCAI)

The CCAI = **C**alculated **C**arbon **A**romaticity **I**ndex (ISO 8217:1996) is a function of viscosity and density, and is an indication of the ignition quality for medium and high speed diesel engines. In low speed engines ignition delay as given by the CCAI is of minor importance. There is no rigidly applicable limit for this quantity, but good results have been obtained with commercially available fuels which have CCAI values up to 850.

Operation Media
Fuel Treatment, Fuel Oil System

1. General

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

2. Treatment of heavy fuel oils and treatment plant

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

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

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

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

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

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

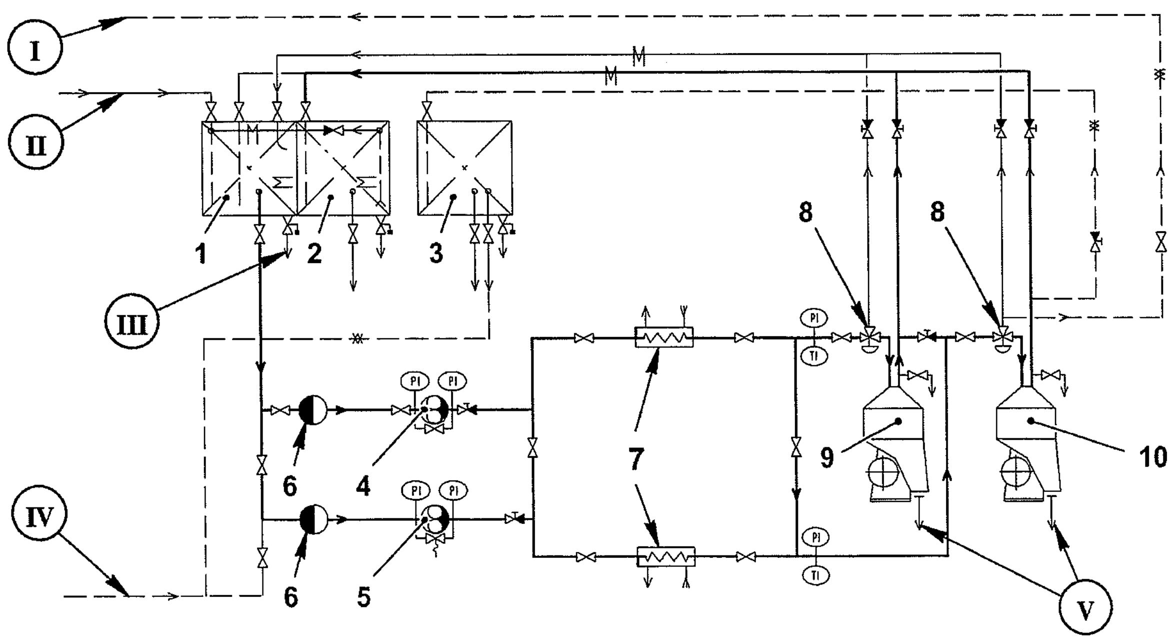
3. Heavy fuel oil and diesel fuel oil separation (see Fig. 'A')

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

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

This necessitates heating the heavy fuel oil before it enters the centrifuge and maintaining the working temperature at a constant level within a tolerance of ±2 °C. The separation temperature is to be as close as possible to at 98 °C.
It is important when processing heavy fuel oils that strict adherence is made to the separator maker's instructions!

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



4. Layout of the fuel oil system (see Fig. 'B')

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

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

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

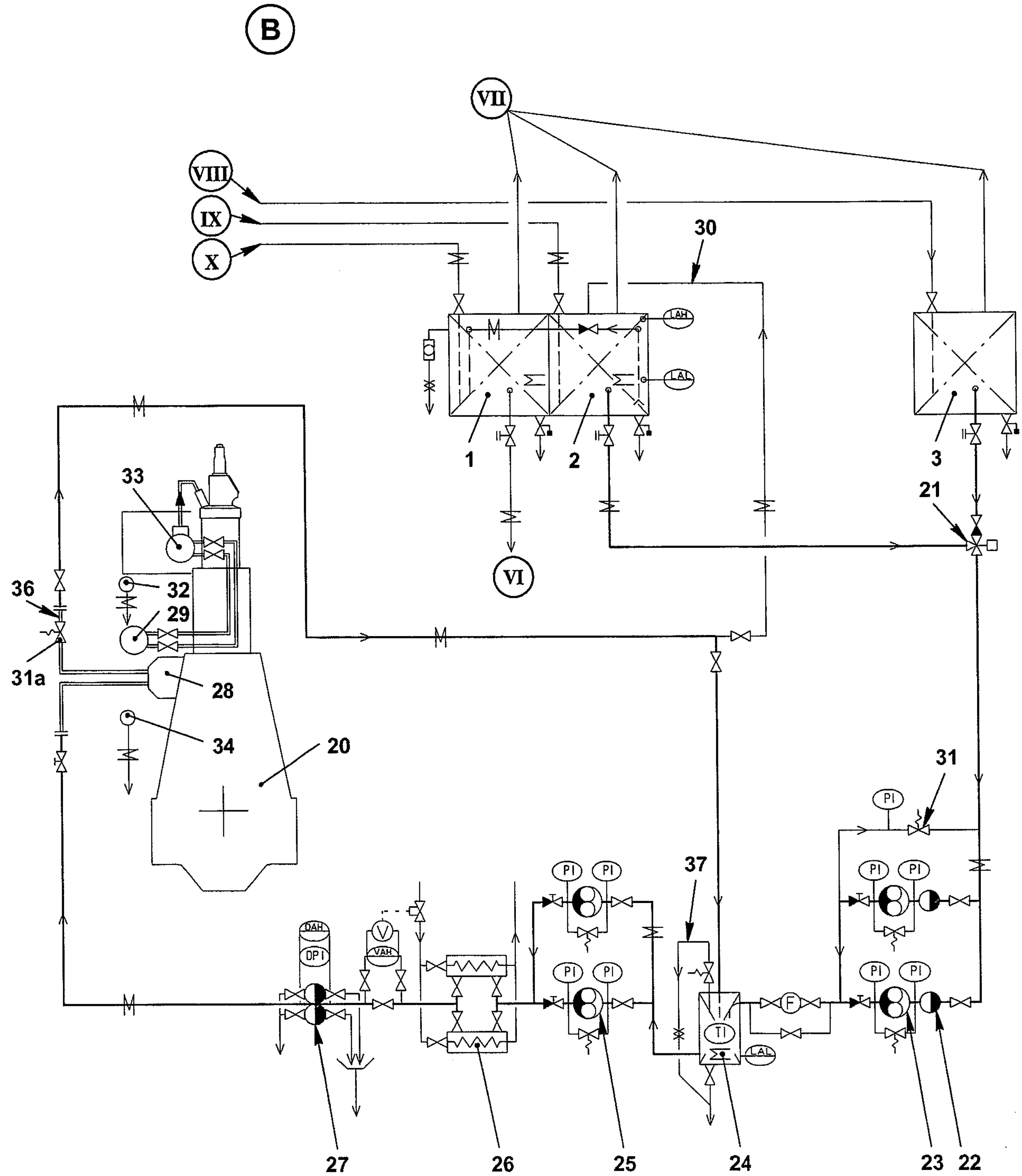
The pump (23) supplies only as much fuel from the daily tank (2) as the engine consumes. The contents of the heavy fuel oil daily tank (2) must be heated, if necessary. However, the official safety regulations limit the temperature to which it can be heated.

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

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

CAUTION

All tanks must be drained off water and sludge at periodically interval.


B
VII
VIII
IX
X
30
LAH
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1
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21
VI
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31a
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DAH
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LAL
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22

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

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

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

-(F)-	Flow indicator	PI	Pressure gauge
	Heated & insulated pipes	TI	Thermometer
	Insulated pipes	DAH	Differential pressure alarm high
	Pressure regulating valve	DPI	Differential pressure indication
	Sight glass	LAL	Fluid level alarm, low
-(V)-	Viscosimeter	LAH	Fluid level alarm high
		VAH	Viscosity alarm high

Operating Media
Scavenge Air and Compressed Air

1. Measures

The air required for scavenging and charging of the cylinders is drawn in and compressed (see Turbocharging 6500-1) by the turbocharger either from the engine room or from outside, depending on the installation.
The aspirated air must be as clean as possible, to keep the wear of cylinder liner, piston rings, compressor wheel of the turbocharger etc. small. For this purpose silencers are fitted to the suction part, which must be serviced and or cleaned (see Cleaning the Turbocharger in Operation 6510-1).

CAUTION

Vibration in service can cause the creation of gaps in the filter through which unfiltered air can be sucked in.

2. Starting air / control air

2.1 Starting air

The starting air required for starting the engine (max. 2.45 MPa) is pumped into the starting air bottles by compressors. For starting the air enters the cylinder directly. It must therefore be clean and dry. The starting air bottles must be drained periodically of accumulated condensed water (see Starting Air Diagram 8018-1).

2.2 Control air

The control air required for the engine control is taken from the shipboard system. To safeguard of control air supply unit A, additional compressed air, available at reduced pressure from the starting air, takes over in case the air supply fails (see Control Diagram 4003-2).

1. General

The engine has separate systems for lubricating certain items. Each system puts special demands on its lubricant which can best be fulfilled by a lubricating oil developed for that particular purpose.

For reference, we recommend use of oil brands shown in sheet 0750-1-4/4.

2. System oil

The system oil (bearing oil) provides lubrication for the bearings and the running parts of the engine and via the crosshead lubricating oil pump (4) also for the crosshead assembly. In addition, it also activates the hydraulic fluid in the servo and control oil system of the engine (see 8016-1).

For marine crosshead engines with oil-cooled pistons, an additive-type crankcase oil (HD type (BN = 5 ~ 14 mgKOH/g)) of the SAE 30 viscosity grade must be used as system oil. Good thermal stability, anticorrosion and antifoam properties and good demulsifying performance are further requirements.

2.1 Oil care

System oil:

In order to always maintain the lubricating oil in good condition over a long period of time, effective oil treatment is absolutely necessary. This is achieved by using a self-cleaning, centrifugal separator working as purifier in by-pass, by circulating the oil from the oil tank through the separator. Should there be the intention to “Water-wash” the oil it is essential that the oil supplier be consulted beforehand.

Solid contaminants (dirt) and water must be removed from the oil in use as completely as possible. There is always the risk that water can enter the system and cause corrosive attack on engine parts, particularly with sea water. Water contamination can also lead to bacterial infection of the oil resulting in loss of lubrication capability and heavy corrosion of the system. Good housekeeping is the most effective precaution against this, meaning in practice to keep water out of the oil. The water content of the lubricating oil should not exceed 0.2 vol.% by mass over an extended period of time. If higher water contamination is observed, special measures such as intensified treatment in the separator or in a renovating tank must be considered.

To ascertain the good condition of the lubricating oil, oil samples must be taken periodically and analyzed. Relevant instructions in the Maintenance Manual must be followed (see sheet 0420-1). For oil analysis it is recommended to utilized the technical services of the oil supplier.

Servo and control oil system:

In order to prolong the lifetime of the sliding parts, fine filtered oil is used in these systems. Branched off from the system oil it passes an additional automatic filter with a mesh size of 6 μm, which flushes back to the system oil.

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

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

2.2 Taking oil samples

The analysis values of the lubricating oil should remain within following characteristic which be taken as guidance values ;

Type of oil		HD type	
Viscosity (Change % of the new oil)	cSt at 40 °C	+ 30 % / - 10 %	(max. 160 cSt)
Flash point	°C	min. 190	
Water	vol.%	max. 0.2	
Solvent insolubles	wt.%	advice be sought from the oil supplier	
Total base number	KOH mg/g	min. 2.0	

Should one of these values be reached, remedial action must be taken to bring the oil charge back to the normal conditions. This can be achieved by intensified separation, treatment in a renovating tank (setting tank) or by a partial exchange of the oil charge. It is recommended that the oil supplier be consulted.

3. Cylinder lubricating oil

Under normal running conditions a high-alkaline cylinder lubricating oil of SAE 50 viscosity grade is recommended. The alkalinity of the oil is indicated by its Base Number (BN, unit: mgKOH/g). The alkalinity of the lubricating oil must be chosen with regard to the sulphur content of the fuel, the higher the sulphur content, the higher the lubricating oil's alkalinity (BN) must be.

Remark : The "Base Number" (BN) was formerly known as "Total Base Number" (TBN). Only the name has changed, values remain identical.

The following relation is indicated for guidance:

Fuel oil type		Distillate	Residual
Fuel sulphur	[%]	0.5 ~ 1.0	more than 1.0
TBN of cylinder oil	[mgKOH/g]	10 ~ 25	more than 70

If the engine is run continuously with a fuel of high sulphur content, the application of a cylinder lubricating oil with BN higher than 70 [mmKOH/g] can also considered.

CAUTION

When running the engine continuously on a fuel having a very low sulfur content, i.e. sulfur content below 0.5% by weight, an excessively alkaline cylinder lubricating oil must be avoided.

Such a combination can easily lead to scuffing of the piston ring and cylinder liners, particularly after a piston overhaul (new rings). In practice, lubricating oils having a BN of about 15mgKOH/g have proven successful in service. Running-in of new piston rings and cylinder liners should never by done with a highly alkaline cylinder lubricating oil.

CAUTION

Running-in of new piston rings and cylinder liners should never by done with a highty alkaline cylinder lubricating oil.

CAUTION

When different brand cylinder lubricating oils are to be mixed unavoidably when cylinder oil is changed to other brand, it is recommended to limit the mixing ratio which should be less than 10%. (see Mitsubishi Service Information MSI-0006E)

4. Turbocharger oil (MET type)

Installing MET type turbocharger, turbocharger oil is as well as system oil.

5 Turning gear oil

Planetary gear oil
EP gear oil (loading stage : FZG12)
Viscosity: ISO VG220

Operating Media
Luubricating Oils

Lubricating Oils for MITSUBISHI-SULZER RTA Marine Diesel Engines

	System Oil	Cylinder Oil		Turning Gear		
	Alkaline System Oil	Sea Trial & MDF	MFO	Gear Oil	Compound	Grease
BP	Enargol OE-HT30 Energol DL-MP-30	Energol CL 155	Energol CLO 50M Energol CL 706	Energol GR-XP150 Energol GR-XP220	Energrease OG	Energrease MM-EP2
CALTEX	Veritas 800 Marine (SAE 30)	Delo 1000 Marine (SAE 50)	Super DCL Special Super DCL Extra	Meropa 150 Meropa 220	Crater 2X Crater Fluid M	Multifak EP2
CASTROL	CASTROL CDX 30 CASTROL MLC 30	CASTROL MLC 50	CASTROL S/DZ 70 CASTROLCyltech 80	CASTROL ALPHA SP 150 ALPHA SP 220	CASTROL SPHEEROL SX 2	CASTROL SPHEEROL EPL 2
CHEVRON	Veritas 800 Marine Oil (SAE 30)	Delo 1000 Marine (SAE 50)	Delo Cyloil Special	Gear Compound EP 150 EP 220	Open Gear Lubricant 250NC	Dura-Lith Grease EP 2
COSMO	COSMO MARINE 3005 COSMO MARINE 3010	COSMO MARINE 5020	COSMO MARINE 5070	COSMO GEAR SE 150 SE 220	COSMO GEAR COMPOUND No.2	COSMO GREASE DYNAMAX EP No.2
ELF	ATLANTA MARINED 3005 DISOLA M3015	DISOLA M 5015	TALUSIA XT 70 TALUSIA HR 70	EPONA Z 150 EPONA Z 220	CARDREXA DC1	EPEXA 2
ESSO	EXXMAR XA EXXMAR 12 TP 30	EXXMAR 12 TP 50	EXXMAR X 70	SPARTAN EP 150 SPARTAN EP 220	SURETT FLUID 4k	LITHTAN EP 2
FUJI	FUKKOL SEA ACE 307 FUKKOL MARINE 312	FUKKOL MARINE 512 FUKKOL MARINE 520	FUKKOL MARINE CYLINDER 5070	FUKKOL MILD EP GEAR 150 GEAR 220	FUKKOL OPEN GEAR 2	MULTI-PURPOSE GREASE 2
GENERAL	GEMICO MARINE SD 30 DX 103	GEMICO MARINE DX 105	GEMICO MARINE DX 705	GENERAL SP GEAROL 150 GEAROL 220	GENERAL GEAR COMPOUND 2	GEMICO GREASE ME 2
IDEMITSU	Daphne Marine Oil SS 30 Oil SX 30	Daphne Marine Oil SS 50	Daphne Sea Master A 50 (New)	Daphne Super Gear Oil 150 Oil 220	Daphne Open Gear Oil No.2	Daphne Eponex Grease EP2
JAPAN ENERGY	JOMO Atlanta Marine D3005 Disola M3010 / M3015		JOMO Talusia XT 70 Talusia HR 70	JOMO Reductus 150 Reductus 220	JOMO Gear Compound No.2	JOMO Lisonix Grease No.2
Nippon Oil	MARINE S 30 T 103	MARINE BRAKE-IN OIL CLS 15	MARINE C 705	BONNOC M 150 BONNOC M 220	CRANOC COMPOUND 2	EPNOC GREASE AP2
MOBIL	Mobilgard 300	Mobilgard 512	Mobilgard 570	Mobilgear 629 Mobilgear 630	Mobiltac 375NC (Open Gear Oil)	Mobilux EP 2
PETROFINA	ALCANO 308	CAPRANO 512	VEGANO 570	GIRAN 150 GIRAN 220	CABLILE 2750 FL	MARSON EPL 2
SHELL	Melina S 30 Melina 30	Alexia D	Alexia 50 Alexia X	Omala 150 Omala 220	Malleus Fluid RL	Alvania Grease 2
TEXACO	DORO AR 30		TARO Special 70	Meropa 150 Meropa 220	Crater 2X Crater Fluid M	Multifak EP 2

1. General

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

2. Cooling water treatment

The purpose of the recommendation to treat the cooling water is to prevent operational difficulties which directly (corrosion) or indirectly (contamination and resultant inadequate heat transfer) could be attributable to the cooling water. The following information applies to closed circuits.

- When normal tap water is used there is the risk of lime scale build up which reduces the heat transfer rate.
- When completely desalinated water, i.e. distilled water,or softened water is used there is a great risk of corrosion since the water contains no corrosion-retarding hardness forming constituents.
  When using sea-water there is an extreme danger of corrosion and contamination, even if only small quantities of it enter the system.

When appropriate water treatment is applied, lime deposits are prevented on the one hand and corrosion attack can be eliminated on the other. In order to fulfill these conditions we recommend:

- The use of desalinated water, e.g. from fresh water generators or condensate from steam driven ancillary equipment, with the addition to this water of a corrosion inhibitor.
- Where no totally desalinated water is available,normal drinking water may be used as an exception, and if possible only for the first filling of the system.
- The hardness of this water may not exceed the German hardness degree of 10 (1° dH =10 mg CaO/liter). Should the hardness of the available water exceed 10 German hardness degrees, it must be softened.
  The softening of the water does not influence the content of chlorides and sulphates which are present in large quantities in the water of many coastal regions. In the absence of an inhibitor these accelerate corrosion attack. For this reason the chloride may not exceed 100 ppm (100mg/liter) and sulphate content of the water may not exceed 50 ppm (50mg/liter).

  To enable the inhibitor added to the water to be at its most effective, the surface exposed to the water should be cleaned the before system is put into operation. This also applies when inhibitor is replaced.
- For the cleaning of the system, as well as the treatment and regular supervision of the cooling water, we refer you to the instructions supplied by specialist firms.

- As a rule products from well known firms specializing in water treatment should be used. Their instructions must be strictly adhered to.
- In operation, the quality must be checked regularly or better still, have it checked by a specialist firm. This applies especially when incompletely desalinated water is used.
- The condition of the system should be checked at regular intervals. Evaporation losses must be made up exclusively with untreated water otherwise the inhibitor concentrations would rise too high.
Leakage losses, however, are to be made up with inhibited water.

3. Cleaning the cooling water system

The metal surfaces which, during the operation of the engine, come in contact with water have to be cleaned **before filling up** the system with fresh coolant. Contamination in the **cylinder cooling system** which occur **during operation** settle mainly in locations where the water velocity is lowest.

The contaminations impair the heat transfer.

If sediments are found the whole system must be cleaned.

For the thorough cleaning of the cooling spaces only experienced firms should be engaged, who can offer a good service and who possess the necessary equipment.

4. Cooling water standard

Basically, use deionized water (distilled water) or city water. When cooling water is collected overseas in particular, for example, analyze the water quality as soon as possible with care given to water quality, and check the following values.

Parameter	Value
PH value	8 ~ 10
Total hardness compornents	up to 30 mg/liter (as CaO)
Content of chlorides	up to 100 ppm (100mg/liter)
Content of sulphur	up to 50 ppm (50mg/liter)

A much severer water quality regulation may be required, depending on corrosion inhibitor (rust preventive agent) used.
It should be noted that, if it should exceed its standard value, the rust preventive effect is significantly reduced or a deposit may possibly be produced into scale.

For marine crosshead engines with oil-cooled pistons, an additive-type crankcase oil (HD type (BN = 5 ~ 14 mgKOH/g)) of the SAE 30 viscosity grade must be used as system oil. Good thermal stability, antifoam properties and good demulsifying performance are further requirements.

5. Corrosion inhibitor (Rust Preventive Agent) brand

Among the nitrite rust preventive agents used in general, the use of following brands is recommended.

Brand	Maker	Density(ppm)	Standard for water quality
POLYCRIN I-175 (Liquid type)	KURITA WATER IND. LTD.	*1 2,500～3,000	Total hardness element: 30mg/liter or less (as CaO) Cl^-ion : 100ppm or less (chlorides) SO_4^{--}ion : 50ppm or less (sulphates) The above standard is to be strictly observed
POLYCRIN I-172 (Powder type)		2,500～3,000	
HI-MOL AM-5	TAIHO IND. CO.,LTD.	2,000～2,500	
YUNIPROT PC-200	NIPPON YUKA KOGYO CO.,LTD.	*2 3,000～3,500	
NEOS PN106	NEOS	2,000～3,000	
RUSMIN MK-45	KYOEISHA YUSHI KAGAKU KOGYO CO.,LTD.	2,000～2,500	
DEWT-NC	DREW AMEROID JAPAN CO., LTD.	3,000～4,500	Total hardness element: 30 mg/liter or less (as CaO) Cl^-ion : 50ppm or less (chlorides) SO_4^{--}ion : 50ppm or less A great care is to be taken not to exceed the above criteria.
DIESEL GUARD NB (Powder)	UNITOR CHEMICALS (UNITOR SHIPS SERVICE CO.,LTD.)	1,080～2,340	Total hardness element: 30mg/liter or less (as CaO) Cl^-ion : 50ppm or less (chlorides) A great care is to be taken not to exceed the above criteria.
DIESEL GUARD NB (Liquid)			

Note:

*1: This inhibitor is solution type and dosage concentration of solution is 8,500 to 12,000 ppm. The concentration (as NO_2) shown in the above table is reference values.

*2: The concentration at initial dosage is 3,500 ppm.

6. Control of rust preventive agent concentration

In order to add rust preventive agent, do not forget to dissolve the specified amount of rust preventive agent completely in another tank in advance, and charge it into the cooling water system as water solution.
Next, circulate the solution sufficiently inside the system and check the condition when the concentration is uniform then, check specified concentration.

Normally, at the earlier stages in which new water is applied, rust preventive agent will be consumed substantially and the concentration may lower; it is therefore necessary to check the condition frequently (Start with measurement every day, for example), and additionally apply it as needed. After that, since the concentration change becomes stable gradually, ascertain its tendency sufficiently and adjust the amount of solution added and interval.

Check the concentration in a stable condition at least once per one or two weeks, and make sure that the concentration falls within a proper value. Then, record the concentration, and use this record to find an abnormality at earlier stages if it should occur.

7. pH control

Make arrangements so that the pH value of cooling water can be maintained within the range of **8 to 10**. If it deviates from this ranges, the rust preventing effect is reduced. When the rust preventive agent concentration is checked, therefore, also be sure to check the pH value. To adjust the pH value, supply new water added with caustic soda when pH is 8 or less, and discharging cooling water by 10 to 20% and refill with new water when it is 10 or more.

8. Complete replacement of cooling water

In the following cases, replace the entire amount of cooling water newly:

- When the pH value falls below 6
- When sea water intrudes due to damage in the hydraustatic water cooler, for example.
- When the rust preventive agent brand is replaced with another brand.
- When abnormal suspended matter or sediment occurs inside the cooling water system.
- When the parts around the combustion chamber, such as the cylinder cover, linerand piston are cracked even for one cylinder and combustion gas intrudes into the cooling water, replace the whole amount of cooling water promptly.
- Even in other cases than the above, replace the cooling water newly at intervals of approx. 2 years.

9. Others

Concentration measuring instrument:

Use an instrument recommended by the rust preventive agent manufacturer. To check the measured value in the ship, it is recommended that you should ask the rust preventive agent manufacturer for a sample periodically.

Suspended matter inside cooling water system:

If the cooling water is stored at a normal temperature (40 °C or below) over a long period of time (approx. 10 days or longer), gelatinuous suspended matter, fibrous suspended matter or agar-like suspended matter (a kind of mould) on remarkable may be produced in cooling water.

Once suspended matter occurs, it cannot be removed even by temperature increase or circulation, while the rust preventive agent concentration may also lower remarkably.

Therefore, when the cooling water is re-used after leaving it for a long time, check the condition of the bottom section in the header tank and sub tank inside the cooling water system.

If suspended matter is found, replace the cooling water with a new charge after cleaning.

Cooling water discharge:

When the cooling water containing the rust preventive agent is discharged, it may conflict with the drain pollution regulations within the harbor.

Accordingly, for the disposal procedure in such a case, contact the rust preventive agent manufacturer.

Cooling water path clogging:

The water line of cylinder liner, cylinder cover and exhaust valve is narrow, and it is also considered that water flow may become partially stagnant. In this case, precipitation in cooling water may deposit gradually, until at least it may cause the water path to become clogged.

Therefore, completely control the water quality and rust preventive agent concentration and also check the condition carefully when the parts are overhauled.

1. General

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

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

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

1.1 Troubles during starting, reversing and stopping (see 0810–1)

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

1.2 Irregularities during operation (see 0820–1)

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

- Scavenge air pressure drops
- Scavenge air pressure rises
- Exhaust temperature before turbocharger rises
- Exhaust temperature of individual cylinder rises
- Exhaust temperature of individual cylinder drops
- Engine speed drops
- Exhaust smoky
- Engine runs irregularly or misfires at times (individual or all cylinders)
- Engine stops by itself (without indications of shut-downs)
- Irregularities in the cylinder cooling water system
- Crosshead bearing oil pressure drops to main bearing oil pressure
- Cylinder lubrication fails
- Trouble with exhaust valve
- Surging of turbochargers
- Oil mist detector gives alarm

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

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

1.4 Failure and defects of WECS components (see 0850-1)

- WECS passive failure
- WECS common failure
- WECS cylinder failure
- WECS pressure failure
- WECS critical failure

Operating Troubles
Troubles during Starting and Stopping

1. Trouble during starting

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

Case of trouble	Possible cases	Remedial measures
Engine does not turn when starting	Shut-off valves on starting air bottles are closed	Open shut-off valves
	Starting air pressure is too low	Fill air bottles
	Oil pressure, water pressure or air pressure for air spring are too low, pressure switches have triggered a SHUT-DOWN	Reset SHUT-DOWN
Starting from control room:	Inactive control stand	Press corresponding button for mode transfer or to take over the control
	Failure in remote control system/ telegraph system	Check Remote Control System or contact supplier
	Starting interlock by RCS	Check indication of starting interlock in RCS (turning gear, shut-down, auxiliary blower), release interlock
	Signal interruption from RCS to WECS-9520	Check plugs, activity of CAN-BUS, for loose or broken wires
Starting at the engine:	Inactive control stand	Press corresponding button for mode transfer or to take over the control
	Turning gear is engaged, blocking valve (2.13) prevents passage of control air to v. unit $\boxed{E}$	Disengage turning gear
	Control valve (2.05) to starting air shut-off valve is either jammed or does not open fully.	Clean control valve (2.05)
	Solenoid valves ZV7013C and ZV7014C fail in valve unit $\boxed{E}$	Clean or replace, check wiring
	Plug(s) removed from solenoid valve(s) in valve unit $\boxed{E}$	Plug in
	Shut-off valve for starting air is in position CLOSED (closed by hand)	Turn shut-off valve to position AUTOMAT
	Shut-off valve for starting air does not open, being stuck; non-return valve is jammed and does not fully open	Clean and overhaul shut-off valve completely
	Auxiliary blowers do not run	Start auxiliary blowers
	Air flaps in scavenge air receiver defective (no pressure can be built up by the auxiliary blowers)	Overhaul or replace air flaps

Operating Troubles
Troubles during Starting and Stopping

Case of trouble	Possible cases	Remedial measures
	No air spring pressure or pressure too low	Open shut-off cock (4.08) in control air supply unit check pressure (see 4003-1 'Control air supply unit')
	Starting valves jammed or plug not connected	Overhaul starting valves or reconnect plug
	Different causes	Try to start in opposite running direction
Engine oscillates on starting or fails to come up to speed	Individual cylinders receive either no, or insufficient starting air (restriction in starting air piping, solenoid valve(s) ZV7241C (to 54C) seized, wiring interrupted to FCM–20 module)	Check starting air piping, flame arrester and remedy restriction, clean or replace corresponding solenoid valve(s), check electric signal
	Starting air pressure too low	Fill air bottles
	Stop valve (4.36) before exhaust valve drive closed (oil supply)	Open stop valve (4.36)
	Wrong positions of shut-off valves and ball cocks in servo and control oil system	Check positions (see 0130-1)
Engine turns on starting air but receives no fuel oil, regulation of fuel injection quantity is in Pos. 'zero' %	Speed control system is defective, does not release regulation of fuel injection quantity	See documentation of remote control supplier. Check electric signal from speed control system to WECS-9520
Engine turns on starting air but receives no fuel oil	Fuel rail pressure too low, connection between actuators and regulating linkage disconnected	Fit connecting rods (see Maintenance Manual 5801-1)
	Fuel rail pressure too low, regulating linkage blocked in position 'zero'	Check regulating linkage, repair damage
	Fuel rail pressure too low, knurled screw of fuel pressure control valve 3.06 not at lower stop	Check fuel pressure control valve 3.06 (see 0515-1)
	Piston or control slide in injection control unit (3.02), piston in rail valve ZV7201 seized	Replace injection control unit or rail valve (see 0515-1)
	Shut-off valves in high pressure circuit on engine (fuel) closed	Open shut-off valves (see 0120-1)
	Heavy leakage in high pressure circuit (fuel) on engine	Check for leakage, see 8019-1 'Fuel leakage system'
	Fuel booster pressure is insufficient, pressure retaining valve is set too low, booster pump does not discharge	Adjust fuel booster pressure
	Shut-off valves before engine closed	Open shut-off valves

Case of trouble	Possible cases	Remedial measures
No ignitions when starting	Injected fuel quantity is too small, speed setting is in too low a position	Readjust speed setting
	Fuel oil is either unsuitable or its viscosity is too high	Prepare fuel oil system (see 0120-1)
	Starting air pressure is insufficient to turn engine over fast enough	Fill air bottles
	Auxiliary blower or air flaps in scavenge air receiver defective	Overhaul or replace auxiliary blower or air flaps
	Compression pressures are too low, piston rings in poor condition, exhaust valves do not close properly	Replace piston rings, grind seating surfaces of valve head and valve seat
	High pressure circuit leaking (fuel pump, intermediate fuel accumulator, rising pipe, fuel rail, injection control unit)	Investigate and remedy leakage with control oil pump in service; pipe (tool 94583) between fuel rail and control oil rail connected
Individual cylinders do not fire or do not fire properly when starting	Injection control unit cut out by WECS-9520 (function)	Switch on injection in remote control (user parameter 'Inj. RUN')
	Connections leaking on injection control unit	Tighten properly, regrind sealing faces
	Rail valve(s) ZV7201C (to H) defective	Replace defective rail valve(s)
	No electric signal to rail valve(s) ZV7201C (to H)	Check wiring, check LEDs on FCM-20 module, if necessary replace it
	Exhaust valve malfunction, no electric signal to rail valve(s) ZV7201A/B (to 14A/B)	Check wiring, check LEDs on FCM-20 module, if necessary replace it
	Injection nozzles leaking, nozzle needles sticking	Replace injection nozzles
	Individual holes in injection nozzle blocked	Replace nozzle tip
	Compression pressure in cylinder insufficient to ignite fuel oil	Replace piston rings, grind seating surfaces of valve head and valve seat
	Exhaust valve spindle seized	Replace defective parts
	FCM-20 module, power supply interrupted, plug removed or wrongly connected, internal failure	Switch on power supply, connect plug, replace FCM-20 module
	Piston in exhaust valve drive (actuator) (4.10), slide rod in 3/2-way valve or piston in rail valve ZV7201 seized	Replace whole unit
	Shut off exhaust valve drive closed with shutoff plugs (tools 94586) or stop valve (4.36)	Replace tools 94586 by plugs (4.32 & 4.33) (original) or open stop valve (4.36), see 0520-1
	Starting valves do not open, either being stuck or damaged or getting no signal	Overhaul or replace starting valves, check wiring

Operating Troubles
Troubles during Starting and Stopping

Case of trouble	Possible cases	Remedial measures
Violent firing when starting	Fuel rail pressure too high, fuel regulation fails	Check power supply, wiring, regulating linkage
	Cylinders were over-lubricated before starting, accumulation of cylinder oil in combustion spaces	Reduce speed setting (fuel injection quantity) till oil accumulation has burned, avoid over-lubrication
	Auxiliary blowers were not running during previous starting attempts, accumulation of fuel oil in combustion space	Reduce speed setting (fuel injection quantity)
	Fuel injection quantity (start fuel charge) is set too high	Reduce speed setting (fuel injection quantity)
	Fuel limiter is set too high	Readjust setting to standard value

2. Troubles with stopping

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

Operating Troubles
Irregularities During Operation

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

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

Case of trouble	Possible cases	Remedial measures
Engine speed drops	Speed setting from speed control system reduce or limited	Check speed control system
	Fuel injection quantity from speed control system limited to avoid overload at heavy sea	Normal situation
	Hull resistance increased due to growth/ageing, propeller damaged	See Interrelationship between Engine and Propeller 0070-1
	Defect in an injection control unit, defective HP piping to injection valve	Shut off or replace (see 0510-1 and 0515-1)
	Fouling of air and exhaust gas passages	See section 1 'Scavenge air pressure drops'
Exhaust smoky	Air deficiency! Fouling of either gas or air side of turbocharger, scavenge air cooler, air flaps in receiver, scavenge ports in cylinder liners or fouling in exhaust boiler	See section 1 'Scavenge air pressure drops'
	Engine overloaded	Reduce fuel injection quantity
	Engine runs with excessive cylinder lubricating oil	See 7218-1 and 7218-2
	Injection nozzles atomize fuel oil incompletely, e.g. due to trumpet formation, eroded or blocked spray holes	Clean, check and readjust or replace
	Fuel oil unsuitable or of too high a viscosity, insufficiently pre-heated	See 0270–1 'Recommended viscosity before fuel pumps'
	Compression pressure too low, piston rings leaking, exhaust valve leaking	Replace piston rings, grind valve seat and head
	Bores in vent screw for upper housing of exhaust valve choked up, exhaust valves close too late	Check and clean
	Servo oil pressure too low, actuating oil pressure supply interrupted, servo oil pump control defective, oil leakage	Check oil flow, investigate and remedy leakage
	No or only one auxiliary blower runs at part load	Switch on auxiliary blowers

Operating Troubles
Irregularities During Operation

Case of trouble	Possible cases	Remedial measures
Engine runs irregularly or misfires at times, individual or all cylinders	High water content in the fuel oil	See 0720-1 'Treatment of heavy fuel oils and treatment plant'
	Fuel oil temperature before fuel pumps too low or too high	See 0270-1 'Recommended viscosity before fuel pumps'
	Pressure in the fuel rail too low, disturbance with fuel pressure control valve (3.06), one or several fuel pumps do not deliver fuel	See 0515-1 'Defective fuel pressure control valve 3.06', check pressure transmitter
Engine stops by itself (without shut-down indication)	Fuel oil daily tank empty or fuel supply interrupted, fuel oil filters choked, booster pump failed, faulty switching, fuel rail pressure too low, regulating linkage defective, fuel leakage	Top up daily tank, clean filter, investigate other causes and remedy them, check regulating linkage, repair fault, investigate and remedy leakage
	Failure in electric power supply to WECS-9520	Remedy causes and restart WECS-9520
	Speed setting system defective, e.g. broken wires	Clear fault
	Engine fails at heavy sea	Switch on Heavy Sea Mode see 4002-3 'User parameters'
Irregularities in cylinder cooling water system ***Pressure fluctuates:***	Air collecting in cooling spaces or in pipes due to insufficient venting	Vent
	Drop of static pressure at inlet to cooling water pump due to throttling in return pipe or draining of expansion tank	See plant instructions
	Exhaust gases blowing into cooling water due to a crack (cylinder liner, cylinder cover, valve cage)	See Operation with Water Leakage into the Combustion Chamber 0545-1
Increased cooling water temperature at outlet of individual cylinders:	Shut-off valves in pipes of affected cylinders shut by mistake or defective	Open or replace
	Cooling spaces insufficiently vented	Vent
	Cooling water pipes or water passages choked, insufficient water flow	See Cooling Water / Cooling Water Treatment 0760-1
	Piston running hot	See Troubles and Damages with Engine Parts 0840-1
	Exhaust gases blowing into cooling water due to a crack (cylinder liner, cylinder cover, valve cage)	See Operation with Water Leakage into the Combustion Chamber 0545-1
Increased cooling water temperature on all cylinders:	Plant side faulty (regulating valve, cooling water cooler etc.)	See plant instructions
Crosshead bearing oil pressure drops to main bearing oil pressure	Crosshead bearing oil pump failed, oil feed effected via non-return valve from main bearing oil system	Reduce engine load to 40% Repair crosshead bearing oil pump as soon as possible, until then raise main bearing pressure as much as possible

Cylinder lubrication (with ECL system)

Regarding the ECL system, see 7218-5.

Case of trouble	Possible cases	Remedial measures
Trouble with exhaust valve	Step piston in exhaust valve defective	Overhaul, replace
Exhaust valve knock:	Oil feed to exhaust valve drive insufficient	Open stop valve (4.36)
	Strainer holes in vent screw to exhaust valve considerably enlarged (erosion)	Replace strainer or vent screw
	Leakage in hydraulic piping	Remedy leakage, replace piping
Exhaust valve does not open:	Heavy leakage in hydraulic valve drive	Remedy, if necessary replace parts
	Non-return valve (4.35) in exhaust valve drive defective	Overhaul, replace
	Piston in exhaust valve drive (4.10), slide rod in 3/2-way valve seized	Replace exhaust valve drive as whole unit
	Rail valve defective or cable plug loose	Rail valve or reconnect cable plug (see 0525-1)
Exhaust valve does not shut:	Air spring pressure too low (< 0.2 MPa)	Investigate cause: leakage, pressure reducing valve, pressure in starting air bottles
	Exhaust valve shank or hydraulic piston seized	Overhaul, replace

Remark : First of all cut out the injection and exhaust valve drive at a not operating exhaust valve (see 0510-1and 0520-1).

Turbocharger

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

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

Case of trouble	Possible cases	Remedial measures
Surging of turbocharger	Overload, air deficiency	See Cleaning the Turbocharger in Operation 6510-1,6606-1 ' Scavenge Air Cooler, Operating Instruction and Cleaning' and Manual of Turbocharger
	Cylinder fails (injection, exhaust valve drive)	Check injection control unit and exhaust valve drive

Oil mist detector

WARNING: Keep away from engine! Particularly avoid areas next to explosion relief valves (see Instruction Concerning the Prevention of Crankcase Explosions 0460–1).

Case of trouble	Possible cases	Remedial measures
Oil mist detector gives alarm	Part of a running gear getting hot	Reduce load (min^{-1}) immediately Stop engine as soon as the situation permits Investigate cause, remedy as far as possible (see General Matters that Demand Special Attention on Operation Troubles 0210-1 & and Damages with Engine Parts 0840-1)

Operating Troubles
Troubles and Damages with Engine Parts

1. Hot running of a piston

Possible indication:

(although the combustion is in order)

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

Possible cases	Remedial measures
Gas blow-by via defective or worn piston rings Scuffing at cylinder liner surface to due lack of cylinder lubricating oil	Cut out injection of affected cylinder for a while (see 0510-1) Increase cylinder lubrication oil feed rate of affected cylinder (see 7218-2) Should temperature still not drop, or rise again after injection is cut in, cut injection out again (see 0510-1) and stop engine as soon as possible, then wait until cylinder and piston have cooled down Check running surface of piston and cylinder liner If the damage is slight, seizure portions can be smoothed out with an oil stone If the damage is heavy, replace piston, piston skirt and cylinder liner Should a replacement of these parts not be feasible for any reason, remove piston, taking necessary precautions (see 0540-1)

1. Hot running of running gear parts

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

Overview

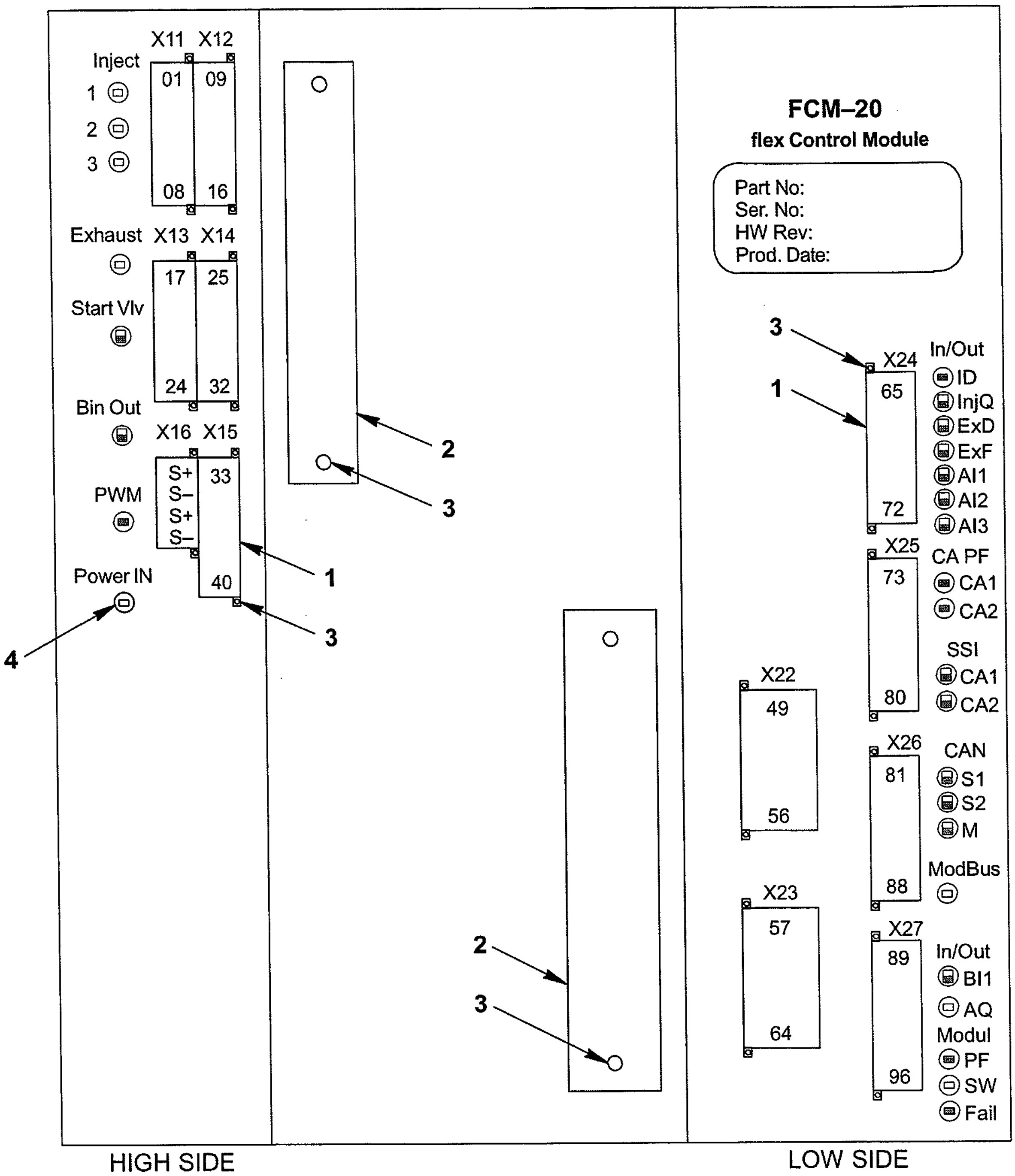
1. General

Failures and defects of WECS components cause failure message in the WECS-9520 which are led to the alarm and monitoring system.

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

Remark : The screws (3) of connectors (1) and cable supports (2) must always be tightened!

2. LED indications on FCM-20 Module



Key :

1 Connector
2 Cable support
3 Screw
4 LEDs

3. Failure indications

3.1 Failure grouping

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

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

3.2 Blink code

RED LED Fail.:

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

Remark : Before the blink interval of a failure starts on YELLOW LEDs, the failure status is indicated by the RED LED Fail. according to the following table.

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

CAUTION

Due to the location of control boxes E95.01 to E95.14, danger of mistakes exist with the view of the LEDs on FCM-20 modules. Therefore, always make sure that the corresponding LEDs are checked!

3.3 WECS passive failure

Designation	LED	Blink interval	Fault finding, causes	FCM-20 No.
ME charge air pressure sensor #1 meas. fail.	AI2 YELLOW	1	· Check pressure transmitter PT4043C · Check supply voltage 24 VDC on plug X27 and cabling in E95.03 · FCM-20 #3 switched off in E85?	3
ME charge air pressure sensor #2 meas. fail.	AI2 YELLOW	1	· Check pressure transmitter PT4044C · Check supply voltage 24 VDC on plug X27 and cabling in E95.04 · FCM-20 #4 switched off in E85?	4
ME servo oil pressure sensor #1, meas. fail.	AI2 YELLOW	1	· Check servo oil pressure indication of pressure transmitter PT2071C · Check pressure transmitter PT2071C of servo oil rail · Check supply voltage 24 VDC on plug X27 and cabling to E95.01 · FCM-20 #1 switched off in E85?	1
ME servo oil pressure sensor #2, meas. fail.	AI2 YELLOW	1	· Check servo oil pressure indication of pressure transmitter PT2072C · Check pressure transmitter PT2072C of servo oil rail · Check supply voltage 24 VDC on plug X27 and cabling to E95.02 FCM-20 #2 switched off in E85?	2
ME fuel rail pressure sensor #1, meas. fail.	AI1 YELLOW	1	· Check fuel rail pressure indication of pressure transmitter PT3461C · Check pressure transmitter PT3461C of fuel rail · Check supply voltage 24 VDC on plug X25 and cabling to E95.03 FCM-20 #3 switched off in E85?	3
ME fuel rail pressure sensor #2, meas. fail.	AI1 YELLOW	1	· Check fuel rail pressure indication of pressure transmitter PT3462C · Check pressure transmitter PT3462C of fuel rail · Check supply voltage 24 VDC on plug X25 and cabling to E95.04 · FCM-20 #4 switched off in E85?	4
WECS module FCM-20 #00 fail.	Fail RED	none	· Engine can remain in operation · Check cabling on plugs X22 and X23 · Replace FCM-20 'Online Spare' module if necessary · Power supply switched off in E85? (in this case no LEDs light up)	00 (E90)

Operation Toubles

Fauilres and Defects of WECS Components

Designation	LED	Blink interval	Fault finding, causes	FCM-20 No.
WECS any FCM-20 module Cyl. ID lost	ID RED	none	· Corresponding cylinder remains in operation, however, after a restarting of FCM-20 modules corresponding cylinder is cut out · Check cabling address on plug X25 of corresponding FCM-20 module	00 to 11
WECS CAN S-Bus Connection fail. FCM-20 #00 CAN System Bus #1 Fail.	S1 RED	none	· Check cable connection in FCM-20 'Online Spare' module (plug X22)	00 (E90)
WECS CAN S-Bus Connection fail. FCM-20 #00 CAN System Bus #2 Fail.	S2 RED	none	· Check cable connection in FCM-20 'Online Spare' module (plug X23)	00 (E90)
WECS CAN S-/SSI-Bus connection fail. FCM-20 #n	S1 RED SSI CA1 RED	none 1	· Check cable connection in corresponding FCM-20 module (plug X22) · Replace FCM-20 module, if failure appears on one module only	1 to 11
WECS CAN S-/SSI-Bus connection fail. FCM-20 #n	S2 RED SSI CA2 RED	none 1	· Check cable connection in corresponding FCM-20 module (plug X23) · Replace FCM-20 module, if failure appears on one module only	1 to 11
WECS CAN S1-bus fail.	S1 RED	none	· Check CAN system bus cabling in all control boxes E95, if failure appears on several modules	1 to 11
WECS CAN S2-bus fail.	S2 RED	none	· Check CAN system bus cabling in all control boxes E95, if failure appears on several modules	1 to 11
WECS CAN M-bus fail. FCM-20 #n	M RED	none	· Check cable connection in corresponding FCM-20 module (plug X22) · Check cabling and connections in control boxes E90 · Replace FCM-20 module, if failure appears on one module only	1 to 4

Operation Toubles
Fauilres and Defects of WECS Components

Designation	LED	Blink interval	Fault finding, causes	FCM-20 No.
ME crank angle #1 fail.	SSI CA1 RED	1	· Crank angle sensor (GT5126C) failed or FCM-20 module (last cylinder) switched off · If failure is indicated on all active modules, check sensor (GT5126C) and replace it if necessary · Otherwise check SSI-bus terminating resistors on plug X22 of FCM-20 #1 · If failure is indicated on one module only, check on corresponding module, whether cable connections are ok on plug X22 · Replace FCM-20 module if necessary	1 to 11
ME crank angle #2 fail.	SSI CA2 RED	1	· Crank angle sensor (GT5127C) failed or FCM-20 module (penultimate cylinder) switched off · If failure is indicated on all active modules, check sensor (GT5127C) and replace it if necessary · Otherwise check SSI-bus terminating resistors on plug X23 of FCM-20 #1 · If failure is indicated on one module only, check on corresponding module, whether cable connections are ok on plug X23 · Replace FCM-20 module if necessary	1 to 11
ME exhaust valve #n position meas. fail.	Ex.D or Ex.F YELLOW	1	· Check plug in terminal box at cylinder cover, corresponding cabling to sensor and FCM-20 module · Replace sensor if necessary · If failure appears periodically, remove plug from faulty sensor in terminal box	1 to 11
ME start pilot valve #n loop fail	Start Vlv RED	none	· Check cabling between corresponding solenoid valve and FCM-20 module (plug X15)	1 to 11

Operation Toubles
Fauilres and Defects of WECS Components

3.4 WECS common failure

Designation	LED	Blink interval	Fault finding, causes	FCM-20 No.
ME charge air pressure sensor #1+2 meas. fail.	AI2 YELLOW	2	· Check pressure transmitters PT4043C & 44C · Check supply voltage 24 VDC on plugs (X27) and cabling in transmitter, E95.03 and E95.04	3 and 4
ME charge air pressure meas. fail. diff. high	AI2 YELLOW	3	· Compare both charge air pressure indications in 'Operator interface' with pressure gauge to detect differing pressure transmitter · Check cabling in transmitter, E95.03 and E95.04 · Readjust transmitter or replace it if necessary	3 and 4
ME control oil pressure meas. fail.	AI1 YELLOW	1	· Check pressure transmitter PT2081C · Check cabling to E95.05 (plug X25) · Pressure transmitter or cable defective	5
ME control oil pressure low	AI1 YELLOW	5	· Is at least one pump in operation? In case of too low pressure, 2nd pump should start · Check oil supply of bearing oil system and pressure after automatic filter · Is drain valve (3.68) (control oil rail DE or FE) open or exists leakage in control oil system? · Check power supply to electric motor	5
ME control oil pump #1 fail.	Bin Out YELLOW	1	· Check on starter control box: Current sensing relais, overload trip, is pump hot? · Check cable connection between starter control box, E90 and FCM-20 module (plug X15) · If there is no pressure but pumps are running, check valves in distributor block, leakage alarm from LS2085A?	1
ME control oil pump #2 fail.	Bin Out YELLOW	1	· Check on starter control box: Current sensing relais, overload trip, is pump hot? · Check cable connection between starter control box, E90 and FCM-20 module (plug X15) · If there is no pressure but pumps are running, check valves in distributor block, leakage alarm from LS2085A?	2
ME servo oil pressure sensor #1+2, meas. fail.	AI2 YELLOW	2	· Check pressure transmitters PT2071C and PT2072C of servo oil rail · Check cable connection (plug X27) · Check supply voltage 24 VDC on plugs X27 and cabling in E95.01 and E95.02	1 and 2

Operation Toubles
Fauilres and Defects of WECS Components

Designation	LED	Blink interval	Fault finding, causes	FCM-20 No.
ME servo oil pressure meas. fail. diff. high	AI2 YELLOW	3	· Compare both servo oil pressure indications. If possible, change engine load through a wider range and verify which sensor does not follow linearly to the changing servo oil pressure · Check cabling of differing pressure transmitter (plug X27) · Replace pressure transmitter if necessary	1 and 2
ME servo oil pressure high	AI2 YELLOW	4	· Pressure controllers not adjusted in servo oil pumps after overhaul	1 and 2
ME servo oil pressure low	AI2 YELLOW	5	· Check oil pressure after automatic filter · Check control signals and cabling to servo oil pumps · Safety valve (4.23) or drain valve (4.72) open (leakage alarm)? · Stop valves before servo oil rail closed? · Pump drive, carrier 4.50 broken at predetermined breaking point or pump defective	1 and 2
ME servo oil pump #1 fail.	PWM RED	1	· Check cable connections between pump #1 and E95.03 · Check plug connection on CV7221C · FCM-20 #3 in E85 switched off or CAN M-Bus failed	3
ME servo oil pump #2 fail.	PWM RED	1	· Check cable connections between pump #2 and E95.04 · Check plug connection on CV7222C · FCM-20 #4 in E85 switched off or CAN M-Bus failed	4
ME servo oil pump #3 fail.	PWM RED	1	· Check cable connections between pump #3 and E95.05 · Check plug connection on CV7223C · FCM-20 #5 in E85 switched off or CAN M-Bus failed	5
ME servo oil pump #4 fail.	PWM RED	1	· Check cable connections between pump #4 and E95.06 · Check plug connection on CV7224C · FCM-20 #6 in E85 switched off or CAN M-Bus failed	6
ME servo oil pump #5 fail.	PWM RED	1	· Check cable connections between pump #5 and E95.07 · Check plug connection on CV7225C · FCM-20 #7 in E85 switched off or CAN M-Bus failed	7

Operation Toubles

Fauilres and Defects of WECS Components

Designation	LED	Blink interval	Fault finding, causes	FCM-20 No.
ME fuel rail pressure sensor #1+2, meas. fail.	AI1 YELLOW	2	· Check pressure transmitters PT3461C and PT3462C of fuel rail · Check supply voltage 24 VDC on plugs X25 and cabling to E95.03 and E95.04	3 and 4
ME fuel rail pressure meas. fail diff. high	AI1 YELLOW	3	· Compare both fuel rail pressure indications. If possible change engine load to range, where fuel rail pressure varies with load and verify which sensor does not follow linearly · Check cabling of differing pressure transmitter (plug X25) · Replace pressure transmitter if necessary	3 and 4
ME fuel rail pressure high	AI1 YELLOW	4	· Check regulating linkage for free movement · Check whether fuel pump actuators are switched on and act properly · Assembly mistake of fuel pump after overhaul? · Check actuator alarms in AMS	3 and 4
ME fuel rail pressure low	AI1 YELLOW	5	· Check regulating linkage for free movement · Check whether fuel pump actuators are switched on and act properly · Check actuator alarms in AMS · Check whether fuel supply pressure of 7~10 bar is ok · Appears a leakage alarm? · Check whether oil supply to fuel pressure control valve (3.06) is ok or valve seat leaky · Check alarms (TE3431~38A) for temperature monitoring	3 and 4
ME crank angle difference between #1 and #2	SSI CA1 RED	3	· LED indication on all modules: Toothed belt shifted or slack · When flywheel is at TDC of Cyl. 1, both sensors must indicate 0 °CA (in 'Operator interface') · Adjust offset parameter or belt position, if necessary · LED indication on one module only: Check SSI-bus cabling on plugs X22 and X23 from corresponding FCM-20 module · Replace FCM-20 module if necessary · LED indication on a successive group of FCMs: Check SSI-bus cabling on plugs X22 and X23 from highest failing Cyl. and to next higher Cyl. without alarm	1 to 11

Operation Toubles

Fauilres and Defects of WECS Components

Designation	LED	Blink interval	Fault finding, causes	FCM-20 No.
ME crank angle #1 / TDC low shift	BI1 YELLOW	2	· Crank angle sensor or toothed belt shifted · TDC offset wrongly adjusted · Possibility of shifted crankshaft	5
ME crank angle #2 / TDC low shift	BI1 YELLOW	4		
ME crank angle #1 / TDC high shift	BI1 YELLOW	3		
ME crank angle #2 / TDC high shift	BI1 YELLOW	5		
ME TDC signal fail.	BI1 YELLOW	1	· Check cabling from pickup ZS5123C to E95.05 and correct distance between pickup and flywheel teeth · Check supply voltage and signal · Replace pickup if necessary · Check cabling on plug X27	5
ME injection quantity sensor #n meas. fail.	InjQ YELLOW	1	· Check signal to corresponding quantity sensor · Check: Plug must be tight! · Make sure whether measuring sleeve is properly mounted on fuel quantity piston · Red LED lights up: Check cabling between corresponding FCM-20 module & quantity sensor · Replace sensor if feedback is instable or disconnect plug temporarily if no spares available	1 to 11
ME injection timing fail. cylinder #n Injection time too short	InjQ YELLOW	5	· Injection time on Cyl. deviates from other Cyl. · Cracked, seized or stuck injection nozzle · Leakage from fuel pressure pipe (alarm) · Too low opening pressure of injection valves · Consequence of rail valve (3.76) failure: Check 'return ON-time' in 'Operator interface' (can occur when operating with temporarily disconnected plug)	1 to 11
ME injection timing fail. cylinder #n Injection time too long	InjQ YELLOW	6		

3.5 WECS cylinder failure

Designation	LED	Blink interval	Fault finding, causes	FCM-20 No.
WECS module FCM-20 #n fail.	Fail RED	none	· Check LEDs on module · Red LED lights up: Check cabling on corresponding FCM-20 module and plugs X22 & X23 · Replace corresponding FCM-20 module, if failure occurs on one module only	1 to 11
ME both CA/TDC low shift	BI1 YELLOW 1)	2 and 4	· Crank angle sensor or toothed belt shifted · TDC offset wrongly adjusted · Possibility of shifted crankshaft in this case see 'TDC low shift' 1)	5
ME exhaust valve #n, fail. Late / not opening	Ex.D YELLOW	2	· Rail valve (4.76) defective · Cable connection between rail valve and corresponding FCM-20 module interrupted · Too high air spring pressure · Oil pressure too low in hydraulic pipe: Check non-return valve (4.35) in oil supply pipe · Mechanical failure of exhaust valve drive or control valve · FCM-20 module defective	1 to 11
ME exhaust valve #n, fail. Early / closing	Ex.D YELLOW	3	· Too high air spring pressure · Oil pressure too low in hydraulic pipe: Check non-return valve (4.35) in oil supply pipe · Mechanical failure of exhaust valve drive or control valve · FCM-20 module defective	1 to 11
ME exhaust valve #n, fail. Late / not closing	Ex.D YELLOW	4	· Rail valve (4.76) defective · Cable connection between rail valve and corresponding FCM-20 module interrupted · Too low air spring pressure · Check non-return valve (4.06) in air spring pipe on cylinder cover · Mechanical failure of exhaust valve drive or control valve · FCM-20 module defective	1 to 11
ME exhaust valve #n, fail. Closing deadtime too long	Ex.D YELLOW	5	· Too low air spring pressure · Check non-return valve (4.06) in air spring pipe on cylinder cover · Mechanical failure of exhaust valve drive or control valve · FCM-20 module defective	1 to 11

Operation Toubles

Fauilres and Defects of WECS Components

<table>
<tr><th>Designation</th><th>LED</th><th>Blink interval</th><th>Fault finding, causes</th><th>FCM-20 No.</th></tr>
<tr><td>ME manual injection cutoff cylinder #n</td><td>none</td><td>none</td><td>· Cut out injection manually (operator) or automatically</td><td>1 to 11</td></tr>
<tr><td>ME injection quantity piston fail. cylinder #n
Late / no return</td><td>InjQ
YELLOW</td><td>2</td><td rowspan="3">· Consequence of rail valve (3.76) failure: Check 'return ON-time' in 'Operator interface'
· Check signal from fuel quantity sensor
· Check:
Plug must be tight!
· Make sure whether measuring sleeve is properly mounted on fuel quantity piston
· Red LED lights up:
Check cabling between corresponding FCM-20 module & quantity sensor
· Replace sensor if feedback is instable or disconnect plug temporarily if no spares available
· Viscosity of fuel too high (after longer engine stop and shut off heating)
· If not recovering:
Press shortly manual lever on fuel shut-down pilot valve (3.08)
· Final check: Can also hint on seized quantity piston, replace injection control unit</td><td rowspan="3">1 to 11</td></tr>
<tr><td>ME injection quantity piston fail. cylinder #n
No movement</td><td>InjQ
YELLOW</td><td>3</td></tr>
<tr><td>ME injection quantity piston fail. cylinder #n
Stuck in max. position</td><td>InjQ
YELLOW</td><td>4</td></tr>
</table>

3.6 WECS pressure failure

Designation	LED	Blink interval	Fault finding, causes	FCM-20 No.
ME charge air overpressure	AI2 YELLOW	4	· Reduce engine power · Take countermeasures (see manual of turbocharger manufacturer)	3 and 4
ME control oil pressure very low	AI1 YELLOW	6	· Is at least one pump in operation? In case of too low pressure, 2nd pump should start · Check oil supply of bearing oil system and pressure after automatic filter · Is drain valve (3.68) (control oil rail DE or FE) open or exists leakage in control oil system · Check power supply to electric motor	5
ME servo oil pressure very low	AI2 YELLOW	6	· Check oil pressure after automatic filter · Check control signals and cabling to servo oil pumps · Safety valve (4.23) or drain valve (4.72) open (leakage alarm)? · Stop valves before servo oil rail closed? · Pump drive, carrier (4.50) broken at predetermined breaking point or pump failure	1 and 2
ME fuel rail pressure very low	AI1 YELLOW 6	6	· Check regulating linkage for free movement · Check whether fuel pump actuators are switched on and acts properly · Check actuator alarms in AMS · Check whether fuel supply pressure of 0.7~1.0 MPa is ok · Appears a leakage alarm? · Check whether oil supply to fuel pressure control valve (3.06) is ok or valve seat leaky · Check alarms (TE3431~38A) for temperature monitoring · Stop valves at intermediate fuel accumulator or fuel rail inlet still closed after maintenance works	3 and 4

3.7 WECS critical failure

Designation	LED	Blink interval	Fault finding, causes	FCM-20 No.
ME crank angle #1+2 fail.	**SSI** CA1 RED and CA2 RED	2	· Check crank angle sensor unit and terminal box E96 for damage · LED also lights up, if FCM-20 module of penultimate cylinder will be switched off (no 'clockmaster') · LED indication on all modules: Check SSI-bus terminating resistors on plug X22 and X23 of FCM-20 #1 · If failure is indicated on one module only, check on corresponding module, whether cable connections are ok on plugs X22 and X23 · Replace FCM-20 module if necessary	1 to 11
ME both CA / TDC high shift	BI1 YELLOW 1)	3 and 5	· Crank angle sensor or toothed belt shifted · TDC offset wrongly adjusted · Possibility of shifted crankshaft in this case see 'TDC high shift' 1)	5
ME excessive engine speed	none	none	· Engine was overspeeding (more than 115% nominal speed) · Reduce engine speed in case of heavy sea · Check separate alarms from CA sensors or FCM-20 modules	-

Group 1

1

1. General

Bearing shell (2) is placed into bearing girder (5) of the bedplate and held in the centre by locating pin (7). The running surface is lined with white metal.

The bearing cover is pressed against the bearing girder by waisted studs (3) and round nuts (4) which are pretensioned hydraulically. The waisted studs (3) are fitted with a non-hardening locking compound.

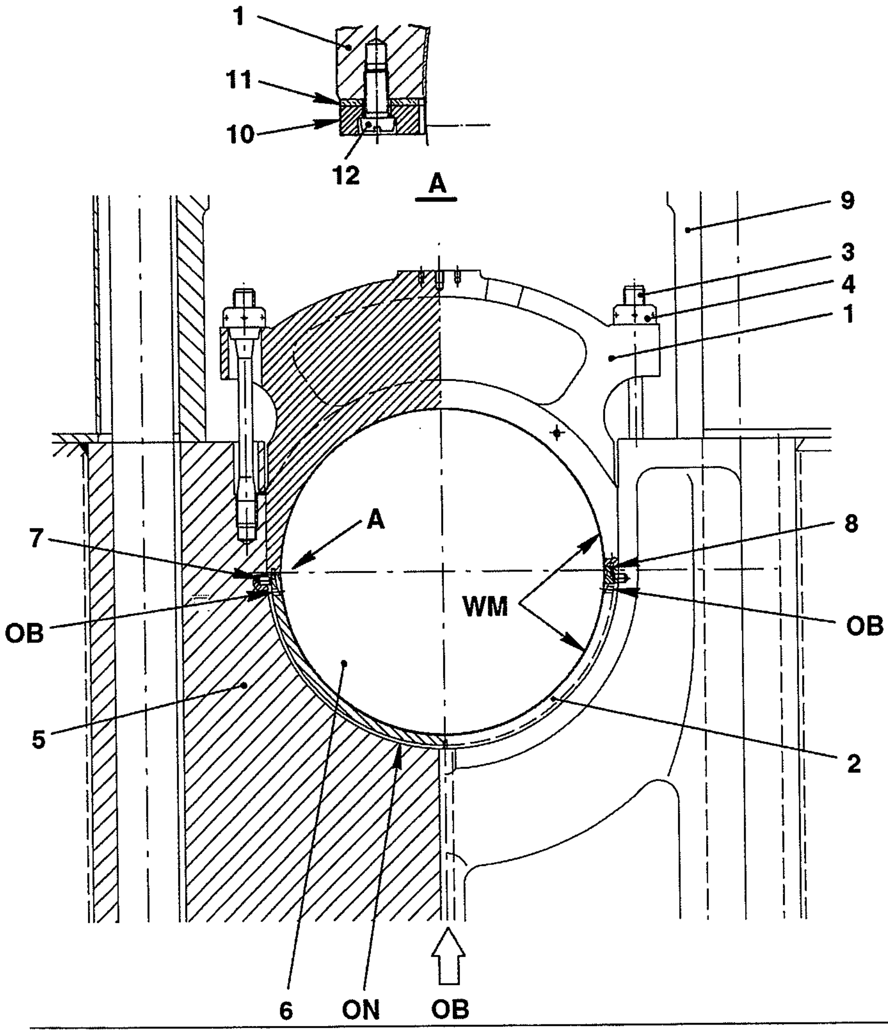
The bearing cover (1) serve at the same time as upper bearing part, therefore, it is also lined with white metal at the inside. Depending on design, to position the bearing cover four locating pins (8) or two keys have been provided in the mating surface of the bearing shell.

Shim (10) and adjusting shim (11) are placed between bearing cover (1) and bearing shell (2) in order to adjust the bearing clearance.

The first main bearing on the driving end and the adjoining main bearings on the camshaft drive for 8 ~ 12 cylinder engines are provided with smaller bearing shells and bearing covers.

2. Lubrication

The main bearings are supplied with oil "OE" from the bedplate side. The oil reaches the bearing running surface through groove "ON" and bores "OB".



Key to Illustration:

1	Bearing cover
2	Bearing shell
3	Waisted stud
4	Round nut
5	Bearing girder
6	Crankshaft
7	Locating pin
8	Key
9	Column
10	Shim
11	Adjusting shim
12	Screw
OB	Bore
OE	Oil inlet
ON	Groove
WM	White metal

1. General

The thrust bearing is situated at the driving end of the engine. The thrust created by the ship's propulsion is transmitted by the thrust flange "DF" of the crankshaft via the thrust pads into bedplate (9).

Arbor support (11) prevent thrust pads from being turned out.
Depending on the sense of rotation of the crankshaft or propeller, thrust pads (2) or (3) take up the axial thrust forces.

In fixed pitch propeller plants the respective execution for right hand or left hand rotating engines has seven thrust pads on either side of the thrust bearing flange, each adapted to the respective sense of rotation.

In controllable pitch propeller plants the thrust bearing is equipped on either side with two thrust pads each for left hand and right hand rotation respectively.

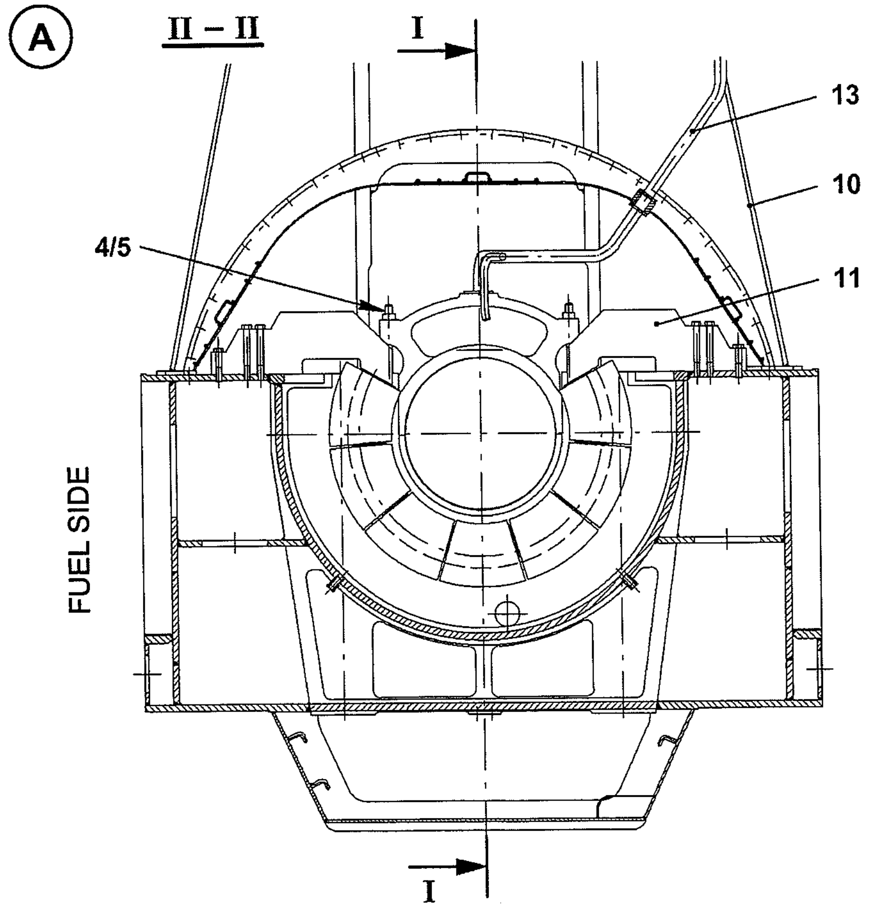
There are seven thrust pads on either side of the thrust bearing flange.

On 6 and 7 cylinder engines the gear wheel on crankshaft (7) is mounted on top of the thrust bearing flange "DF" and drives the intermediate gear wheel for supply unit (8) (see Fig. 'C' and 'D').

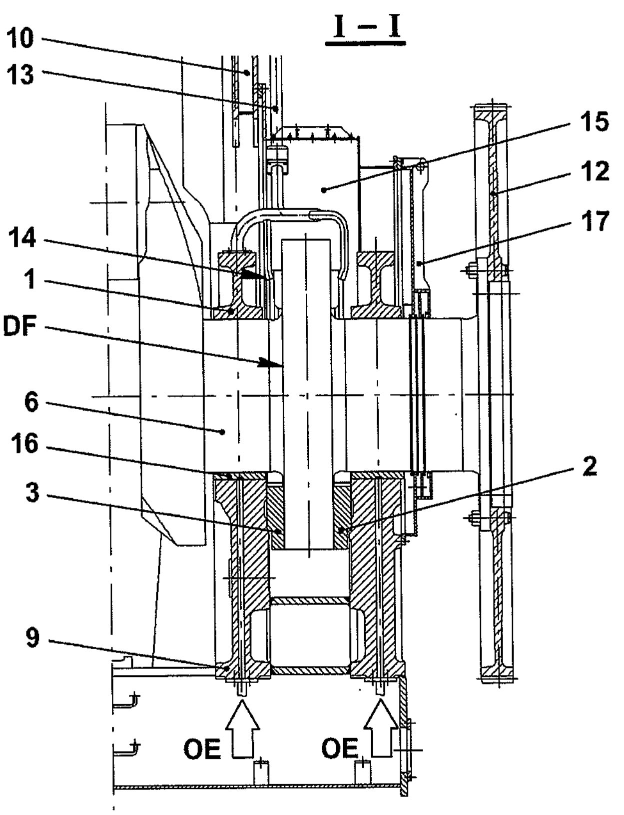
On 8 to 14 cylinder engines the camshaft drive is situated at mid-engine.

2. Lubrication

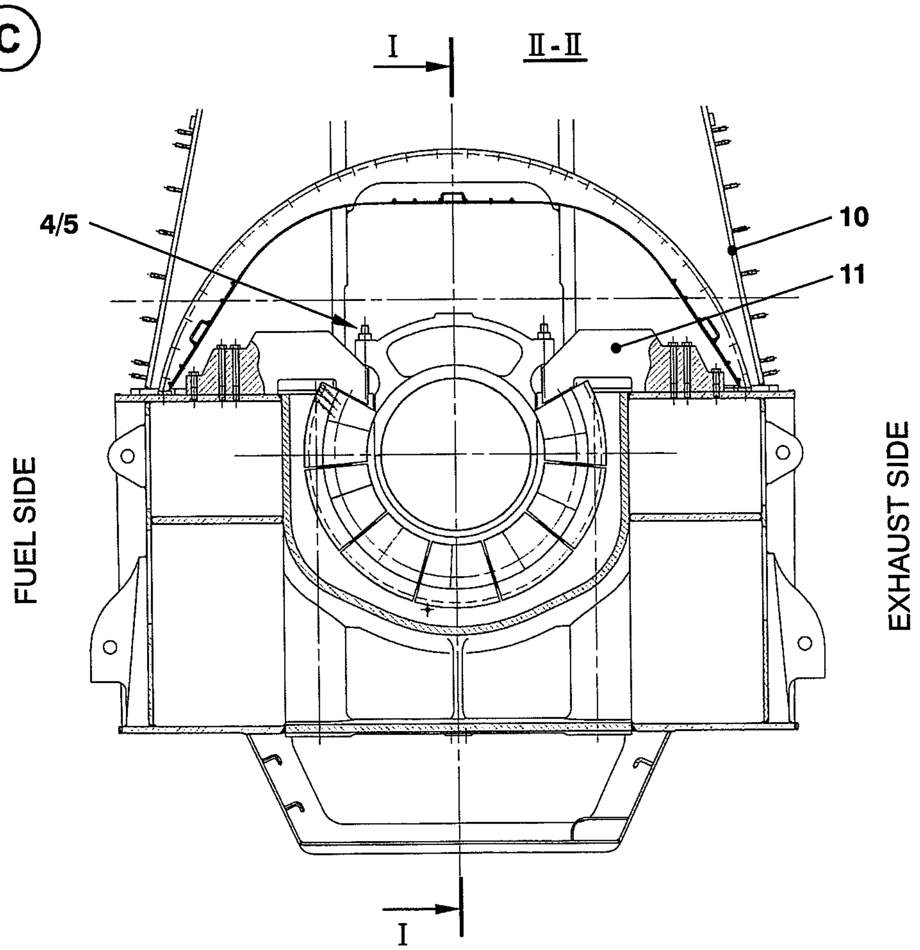
The thrust pads are lubricated with bearing oil which is led by lubricating oil pipe (13) to the spray nozzles (14). The nozzles are dimensioned in such a way that in operation an oil film forms between thrust bearing flange "DF" and thrust pads (hydraulic wedge).



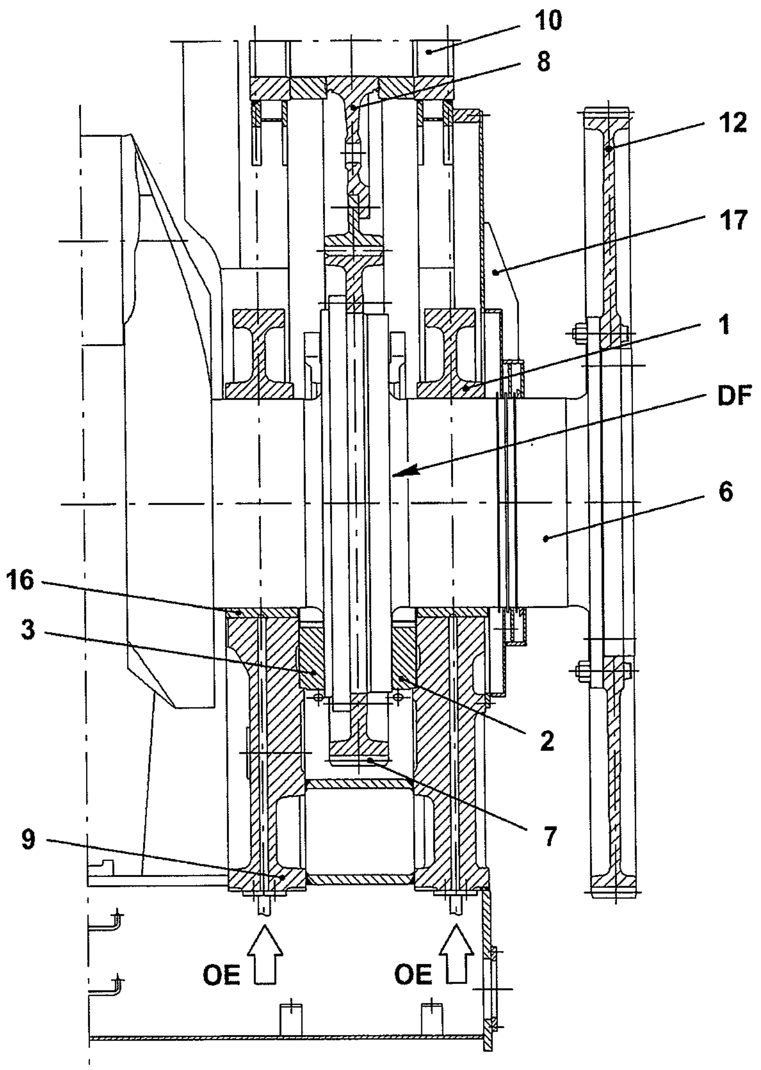
B


I – I
10
13
15
12
17
14
1
DF
6
16
2
3
9
OE
OE

C


I
II - II
4/5
10
11
FUEL SIDE
EXHAUST SIDE
I

(D) I – I



Key to Illustrations :

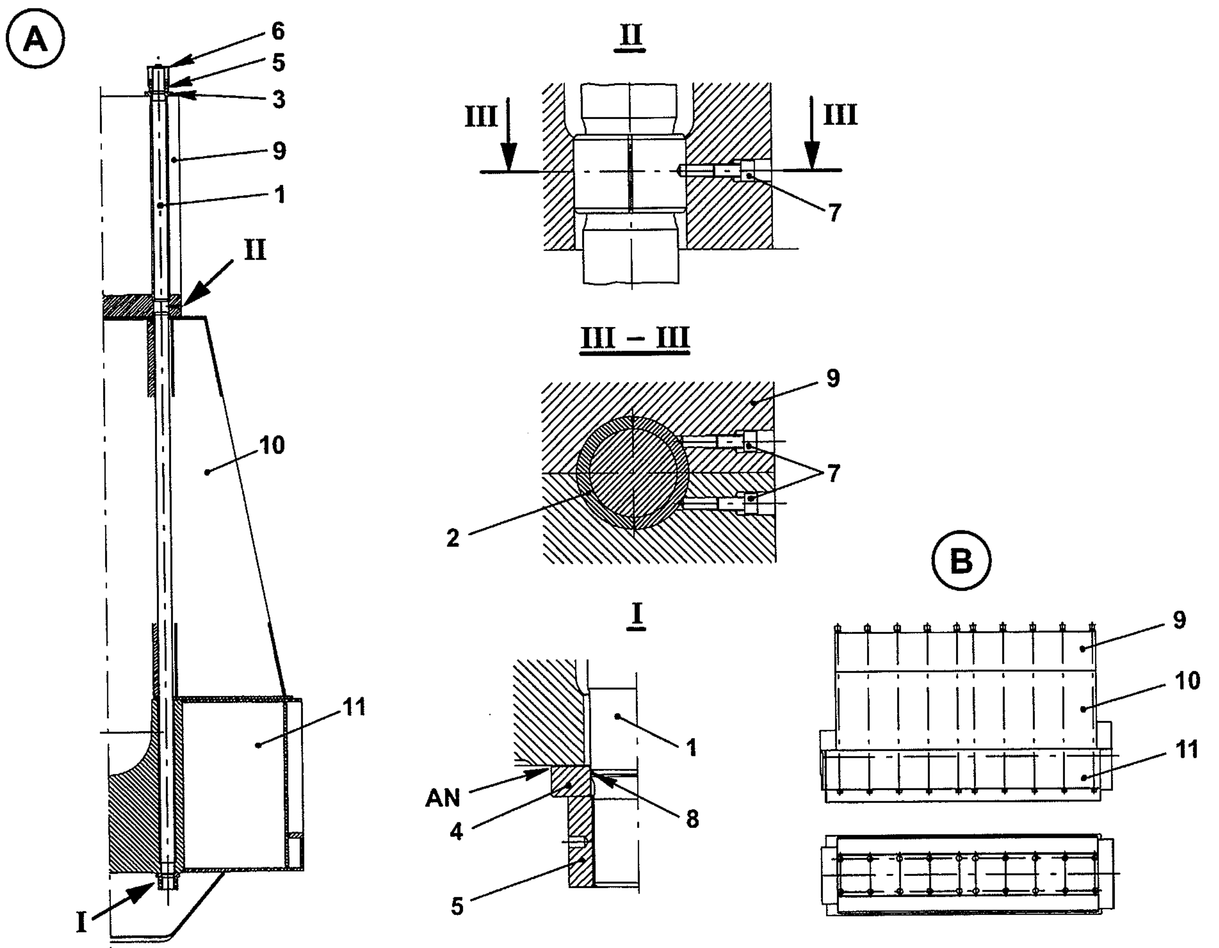
'A'	**Cross section 8 to 14 cylinder**
'B'	**Longitudinal section 8 to 14 cylinder**
'C'	**Cross section 6 and 7 cylinder**
'D'	**Longitudinal section 6 and 7 cylinder**

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

1. General

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

Each tie rod is equipped with a two-part bush (2) which is firmly fastened by the two clamp screws (7) (see detail II) located at the bottom of the cylinder jacket (9). These guide bushes prevent the tie rod from vibrating. For additional vibration damping the space around the lower part of the tie rod till mid-column is filled with oil which enters through a filling bore in way of the crosshead guide plate. The lower thread (detail I) of the intermediate ring is provided with a drain groove “AN”. Through this drain groove some oil and possible condensate water can always drain away (in case of engine standstill).



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

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

Group 2

2

Cylinder Liner and Cylinder Cover — Group 2

1. General

Cylinder liner (1) is fitted into the cylinder jacket (4) with supporting ring (2). The nuts of the waisted studs fasten the cylinder head (6), the cylinder liner (1) and the supporting ring (2) onto the cylinder block (4). Supporting ring (2) is additionally fixed by the three cylindrical screws (8), which ensure that the supporting ring stays attached to the cylinder jacket when the liner is pulled out.

2. Cooling

At connection "KE" the cooling water enters into between water guide ring(11) and supporting ring(2) and is led into water space "WR".
The cooling water rising around cylinder liner (1) and supporting ring (2) flows at the support surface of the cylinder liner into its cooling bores "KB" and is led via the horizontal bores into water guide jacket (3). Via the vertical connecting bores in the water guide jacket, the cooling water flow passes through into the upper ring space "RR" and cools afterwards cylinder head (6) and the exhaust valve cage.

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

fluctuations:

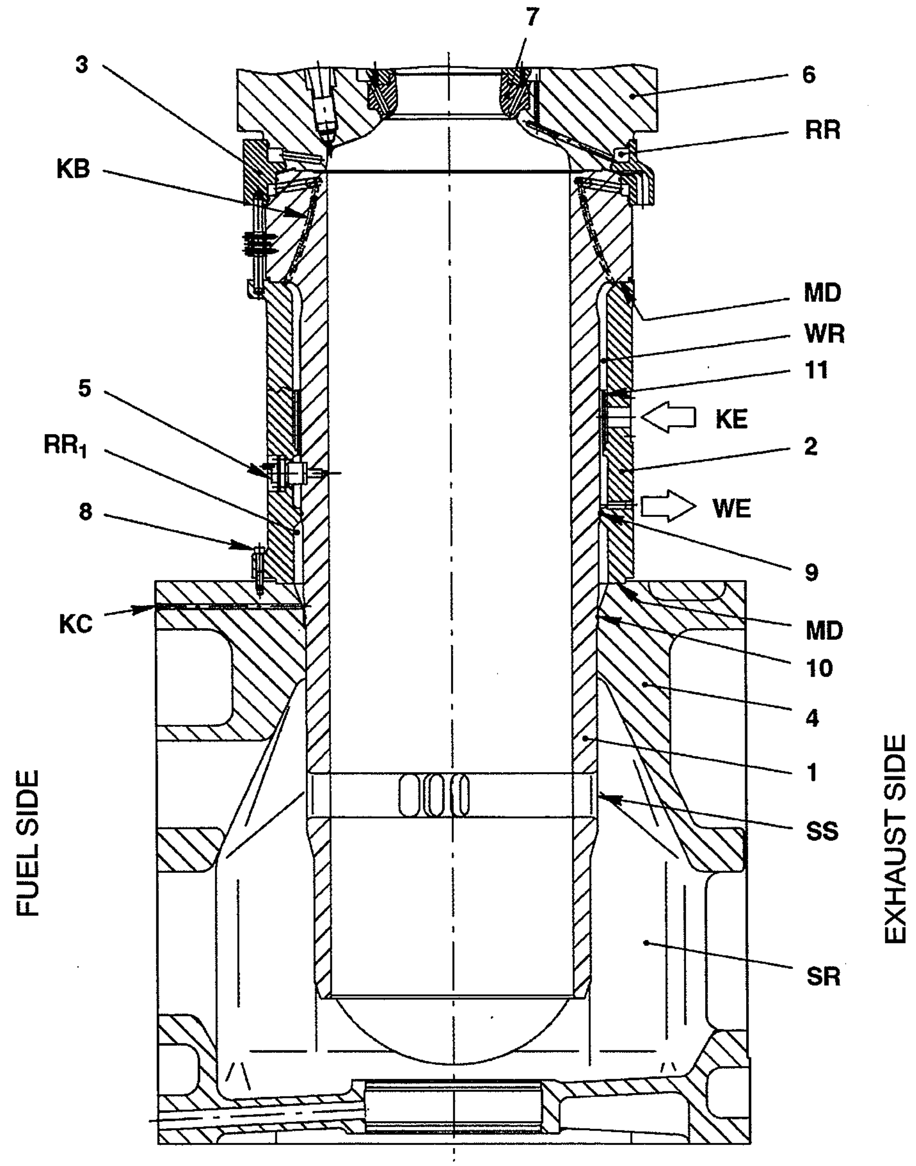
- at constant load : ± 2 °C
- during load changes (transient conditions) : ± 4 °C

The water space "WR" is sealed towards the ring space "RR1" between cylinder liner (1) and supporting ring (2) by the O-ring (9). O-ring (10) prevents the entering of water into the scavenge space "SR" via O-ring (9) by a possible leakage. Should water leak through check bore "KC" or there is an accumulation of cooling water in the scavenge space "SR" then the O-ring must be replaced at the next opportunity. The two sealing surfaces "MD" of support ring (2) are sealing metallically with a non-hardening sealing compound.

3. Lubrication

Cylinder lubricating oil is delivered to the running surface of the cylinder liner through the ten ECL-SIP valves (5).

Exact instructions on the setting of the lubricating oil quantity have been given in 7218-2.



Key to Illustration :

1	Cylinder liner	KB	Cooling bores in the cylinder liner
2	Supporting ring	KC	Check bore
3	Water guide jacket	KE	Cooling water inlet
4	Cylinder jacket	MD	Metallic searing
5	ECL-SIP valve	RR	Annual space
6	Cylinder head	SR	Scavenge space (piston underside)
7	Valve seat for exhaust valve	SS	Scavenge port
8	Screw	WE	Water space drain
9	O-ring	WR	Water space
10	O-ring	RR_1	Annual space void of water
11	Water guide ring		

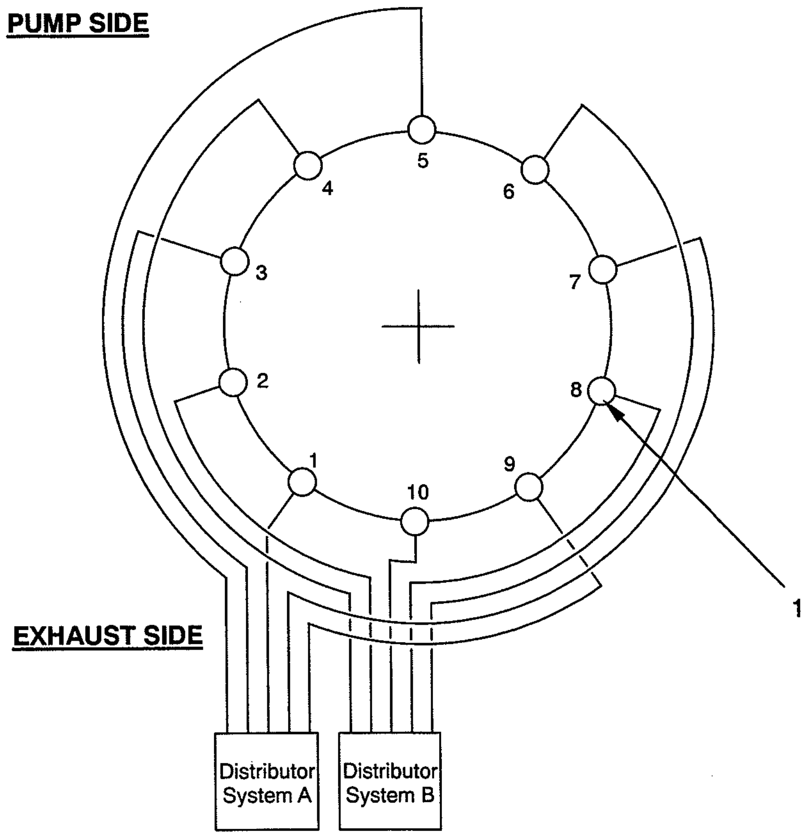
1. General

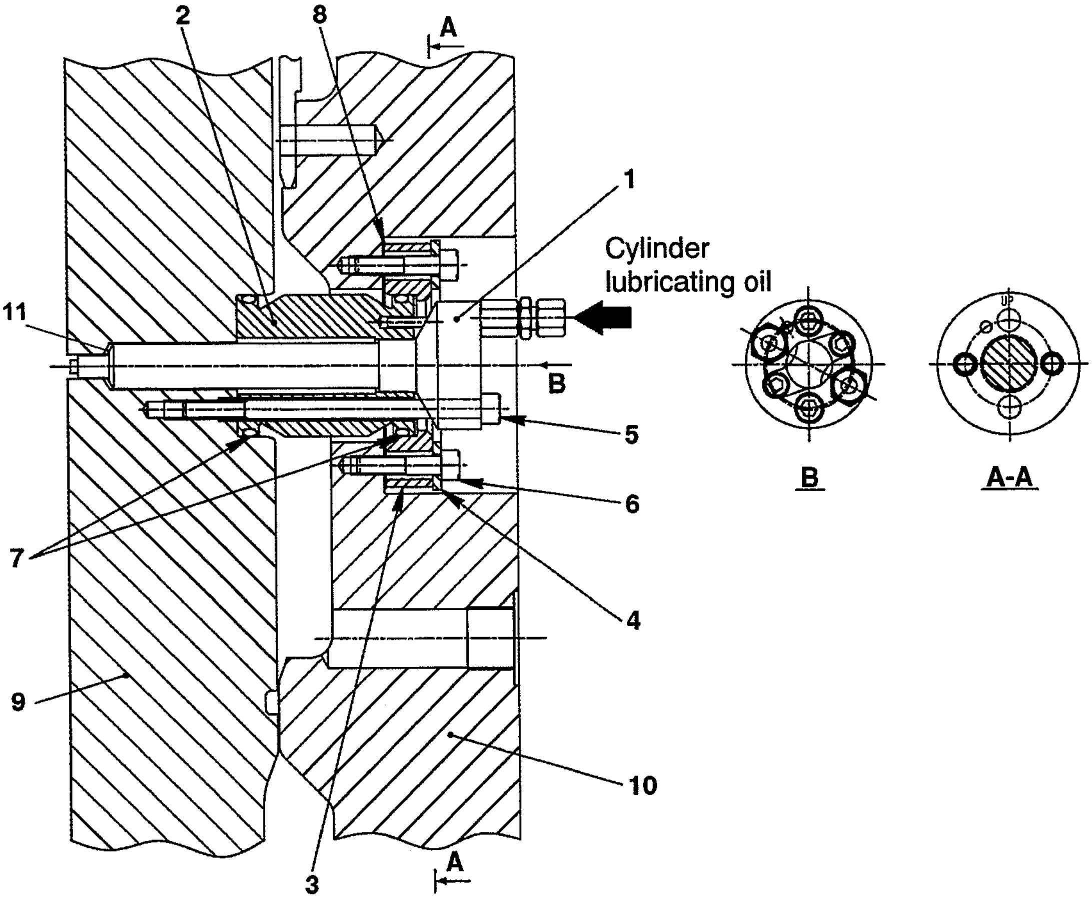
Each cylinder liner has ten ECL-SIP valves on cylinder liner upper part.
The ECL-SIP valves are inserted into the bush (2) to deliver the lubricating oil through supporting ring and water space.
Water space is sealed by bush (2) and flange (3).

The ECL distributor supplies cylinder lubricating oil to the five ECL-SIP valve.
The ECL-SIP valves inject and spread the cylinder lubricating oil on the cylinder liner surface during the compression stroke.

CAUTION

When a piston has been removed, check if the ECL-SIP valves work properly.
Make sure if equivalent lubricating oil flows out from lubricating holes on inner face of a cylinder liner in according to priming procedure (see 0630-1). When oil delivery amounts are not even at each lubricating hole, check whether the opening pressure of each ECL-SIP valve is within the specified value (see 2136-5/A1 of Maintenance manual).





Key to Illustration:

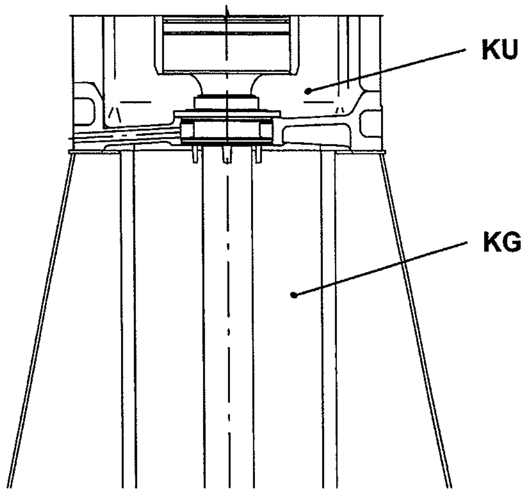
1 ECL-SIP valve
2 Bush
3 Flange
4 Press plate
5 Screw
6 Screw
7 O-ring
8 Gasket
9 Cylinder liner
10 Supporting ring
11 Conical shim

1. General

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

The four protection pins (11) pressed into fixing ring (1) from the side protect the cylinder liner surface from scratching damage, when the piston is removed and/or fitted together with the gland box.

A



2. Function

Scraper ring (2) and the upper oil scraper ring (3) scrape dirty oil from piston rod (10). This dirty oil is collected at the bottom of the cylinder jacket and flow through the drain on the fuel side.

The rest of the dirty oil originating from the top is scraped off by sealing ring (5), then it flows through bores “OB” and is collected on the bottom of the scavenge space “KU”.

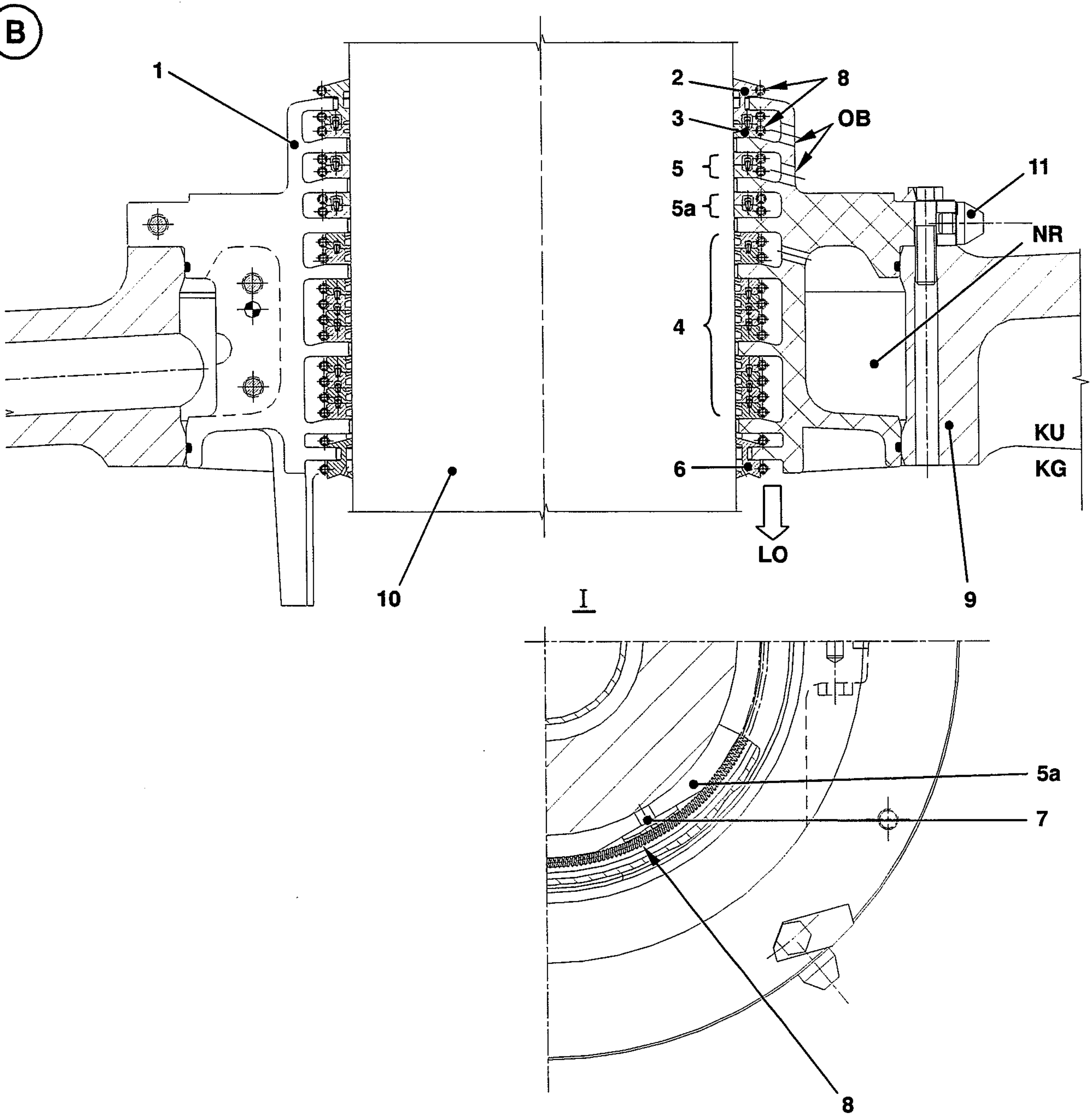
> **WARNING** — The dirty oil drain from the scavenge air space “KU” must always be free (see 0240–1). A major fire risk exists, if the dirty oil does not flow off (see 0450–1)!

The two three-part sealing rings (5) and (5a) with sealing piece (7) at the separation gaps prevent the escape of scavenge air into the crankcase. The low air pressure caused by gap losses is released via a vent in the dirty oil collecting pipe (see 8345–1).

The ten lower oil scraper rings (4) (two-part and four-part units) as well as the scraper ring (6) scrape bearing oil off the piston rod (10) and lead it back to the crankcase “KG” via bore “LO”.

All ring types are pressed against piston rod (10) by a garter spring (8) (standard size).

B



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

1	Housing (2-part)	10	Piston rod
2	Scraper ring (3-part)	11	Protection pin (Nylatron)
3	Upper oil scraper ring (3-part)		
4	Lower oil scraper ring (3-part)	KG	Crankcase
5, 5a	Sealing ring (3-part)	KU	Piston underside (scavenge space)
6	Scraper ring (4-part)	LA	Leakage oil drain from space "NR"(relief of air pressure)
7	Sealing piece	LO	Bearing oil drain
8	Garter spring	NR	Neutral space
9	Cylinder block	OB	Oil bore

1. General

Three injection valve (1) are fitted in each cylinder cover.
Fuel which leaks in consequence of the nozzle needle clearance is drained through leakage fuel pipe (13) via connection "LA" to the leakage fuel pipe from the injection valve (see Fig. 'B' and Fuel Oil System 8019-1).

Remark : A large leakage fuel quantity is normal due to the groove in nozzle needle (4).

Fuel oil which possibly leaks between nozzle body (3) and holder (2) rises and appears at the upper edge of the cylinder cover at "LB".

CAUTION

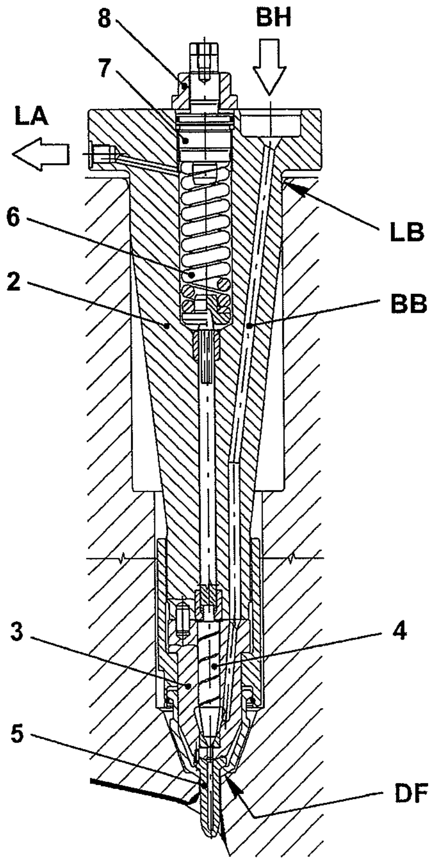
In this case the parts concerned should be overhauled at the next opportunity.
If the sealing face "DF" is leaky, exhaust gas also escapes through gap "LB".

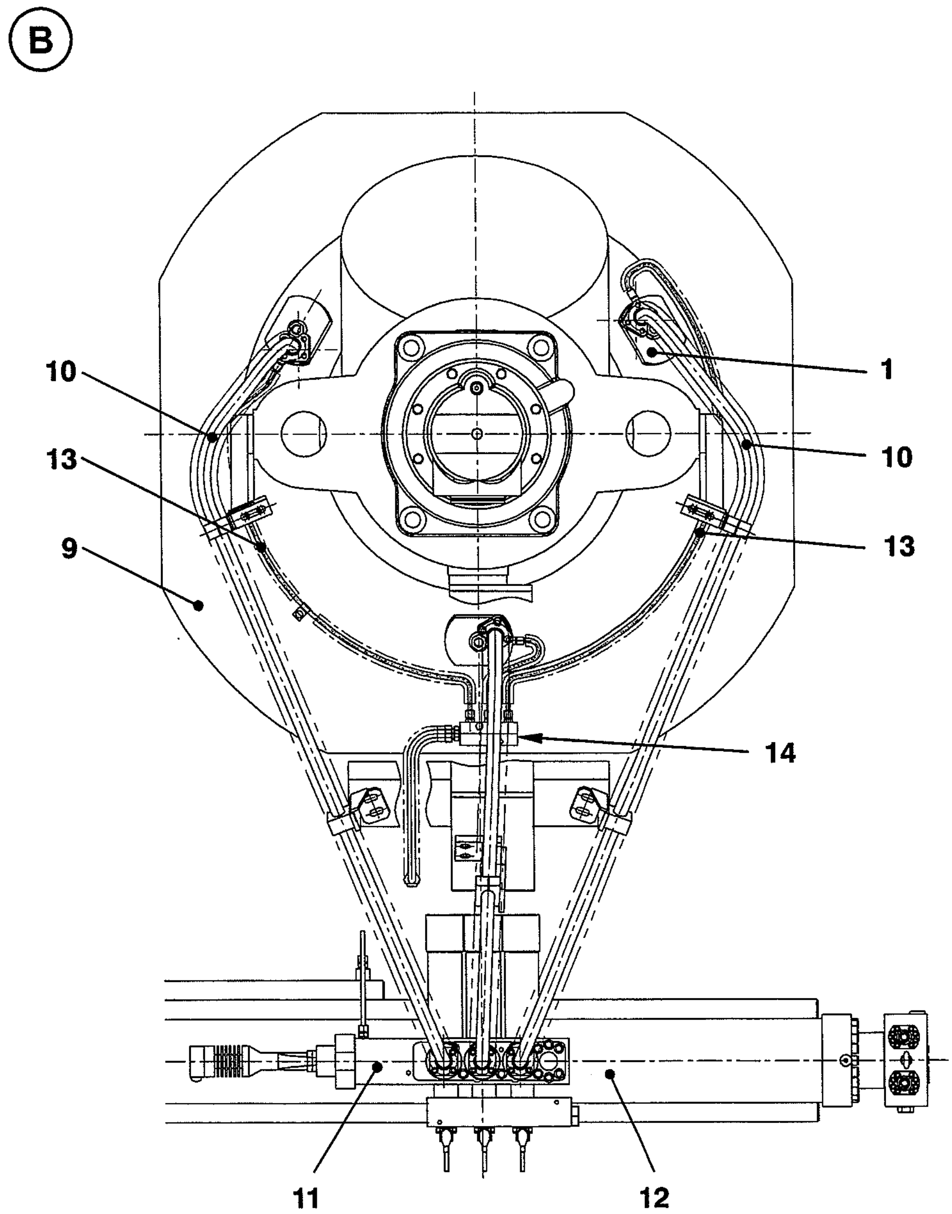
For testing, dismantling, assembling and setting of injection valves see 2722-1 in the Maintenance Manual.

2. Function

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

A





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

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

1. General

Every cylinder cover (7) is provided with a starting valve, which is controlled electrically by the FCM-20 module. With that the engine can be started and when reversing it can be slowed down (see also Manoeuvring 0260-1). I.e. at certain piston positions starting air streams into the cylinder during these processes.

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

In the schematic diagram 4003-2 the starting valve bears number (2.07).

2. Function

Ready for operation:

Space “AL” is charged with starting air pressure. Space “P_3” is charged through bores “EB” and thereby assists spring (5) in the closing of the valve. Connection “SL” is under pressure from the starting air piping. Via valve (8) space “P_2” in housing (4) is connected with supply “SL”. The starting valve is shut.

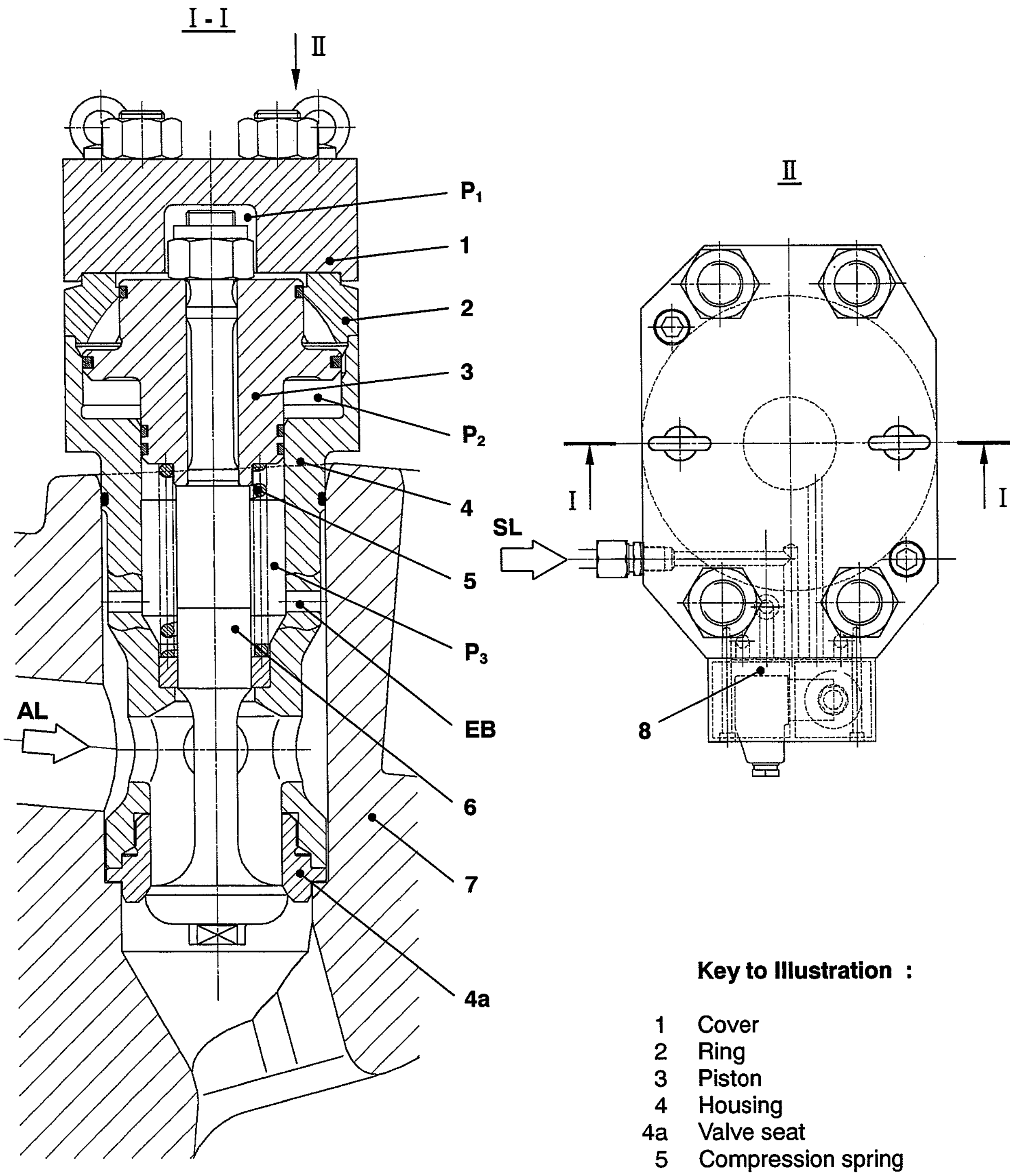
Starting:

The 5/2-way solenoid valve (8) is controlled by the FCM-20 module. Space “P_1” is pressurized, space “P_2” is vented. The valve is opened and starting air flows to the cylinder space. The piston is moved downwards and the engine begins to turn.

When the engine begins firing, a higher pressure (firing pressure) exists in the combustion space and therefore the starting valve remains closed during this high pressure phase.

Slow-down of the engine for reversing:

During reversing, when the ship is still in motion, the engine is ’dragged’ by the propeller in the wrong direction of rotation. The starting valve opens by approx. 90° ∡ before TDC and starting air fills the cylinder space. By compressing this air the engine is braked in order to be re-started in the new direction of rotation. Depending on the ship speed (dragging of the engine by the propeller) this manoeuvre must be delayed (this may take several minutes). I.e. as soon as the engine speed falls below the set limit, the starting valve will be operated via the engine control system in order to release braking air / starting air and thereby initiating a successful engine start.



Key to Illustration :

1	Cover
2	Ring
3	Piston
4	Housing
4a	Valve seat
5	Compression spring
6	valve spindle
7	Cylinder cover
8	5/2-way solenoid valve
AL	Starting air
EB	Connecting bore
P_1 ~ P_3	Air spaces
SL	Control air connection From air spring

1. General

The exhaust valve is screw fastened in the centre of cylinder cover (21). The exhaust valve generally consists of the following parts: Valve drive, valve cage (1), valve spindle (6), valve seat (20) and air spring “LF”.

Stroke sensor (19) monitors and transmits the position OPEN and CLOSED of valve spindle (6) to WECS-9520 control system (Fig. 'B').

For safety reasons disc springs (16) are provided as a damping element to prevent the exhaust valve from being damaged, if the balance of valve opening and the air spring force are disturbed.

2. Function

Opening:

Controlled by the parting piston the exhaust valve drive presses hydraulic oil “HO” through connection (14) into upper housing (3), moving the step piston downwards. Valve spindle (6), with air spring piston (10) fastened to it, is also pushed downwards against the pressure in the air spring “LF”. The exhaust valve opens. The exhaust gas outflow hits rotation wings (17), thereby rotating the valve spindle.

Closing:

When the hydraulic oil pressure from the exhaust valve drive diminishes (i.e. the corresponding relief passages have been opened by the slide rod in 3/2-way valve of the exhaust valve drive) valve spindle (6) is pressed upwards by the pressure in air spring “LF” acting on the air spring piston. The exhaust valve closes. The hydraulic oil in upper housing (3) is pressed back to the exhaust valve drive.

2.1 Venting of the hydraulic system (see Fig. 'B' and 'C')

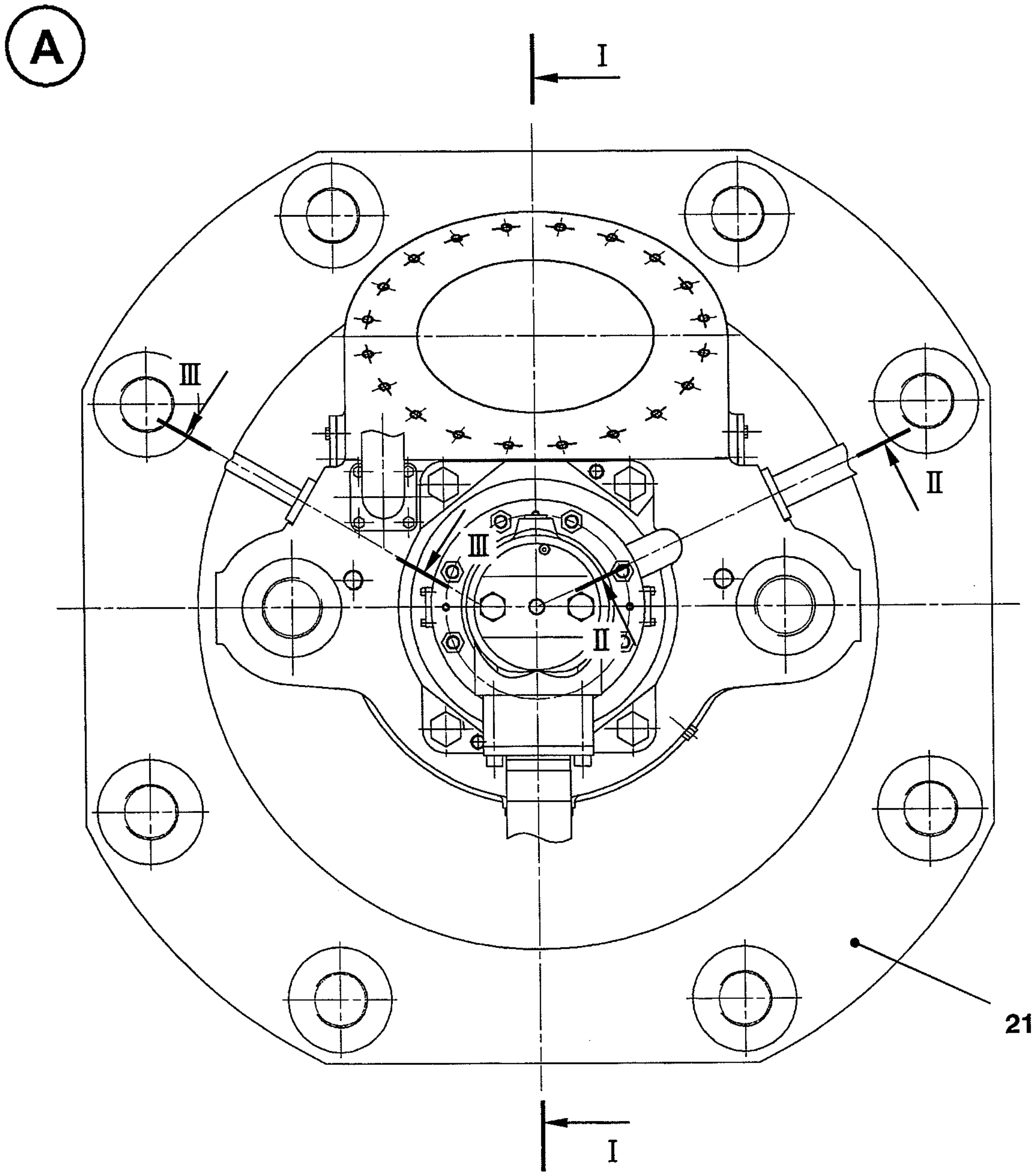
Through vent screw (15) hydraulic oil and any air present in the system is continuously drained into the leakage oil drain “LO” via bores in housing (3), outside and inside piston (item (4), (5)) and leakage oil collecting space “LS”. This oil loss is continuously made up to the hydraulic system by the oil supply which is led to the exhaust valve drive (non-return valve).

2.2 Air supply to the air spring (see Fig. 'D')

Compressed air enters the air spring “LF” through connection “LE” and inlet bore “EB”. When the exhaust valve opens, air spring piston (10) is pushed downwards compressing the air in the air spring housing. Some air flows back into connection “LE” through inlet bore “EB”. After the exhaust valve closes, the air spring space “LF” fills up again.

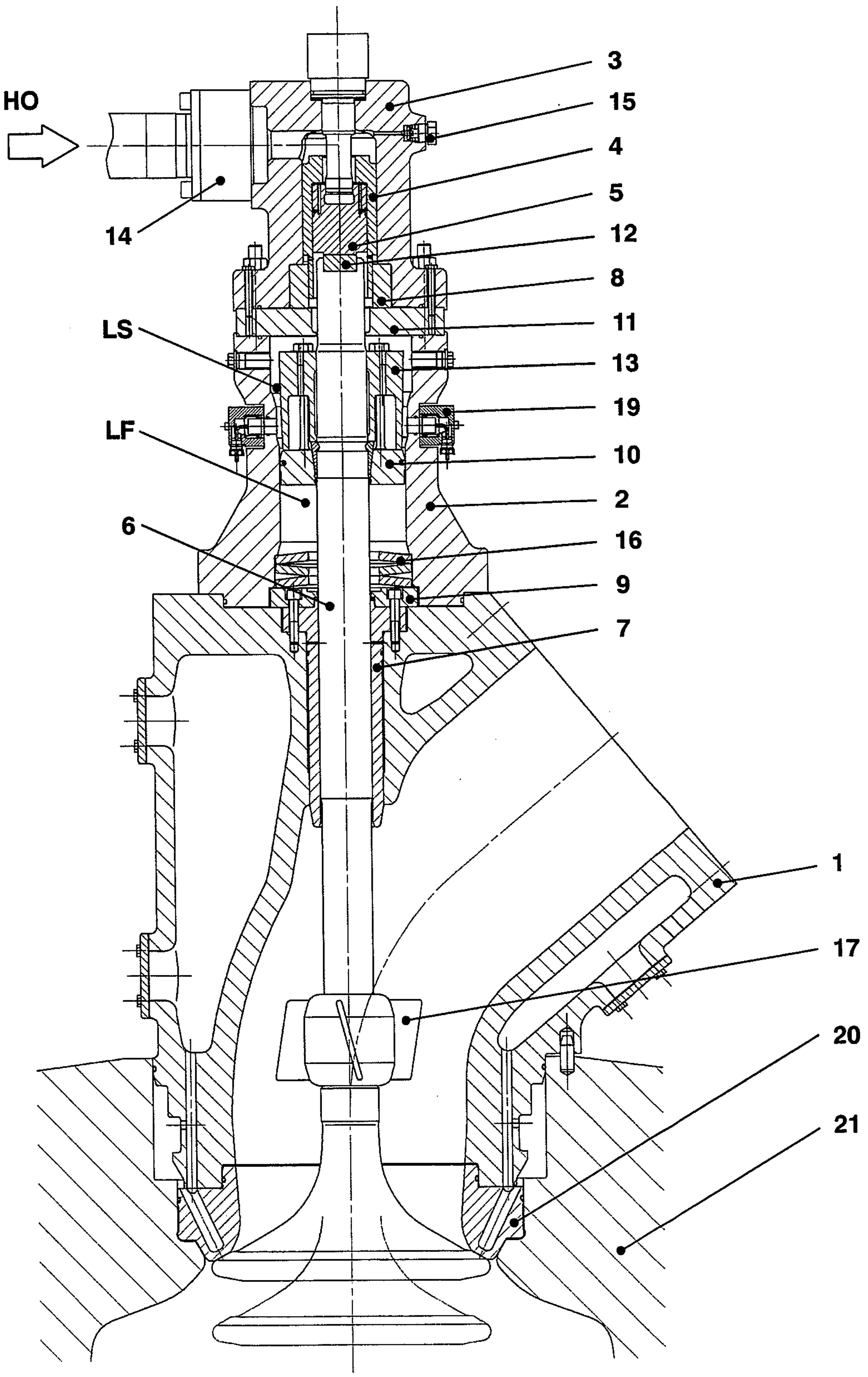
3. **Lubrication** (see Fig. 'B' to 'D')

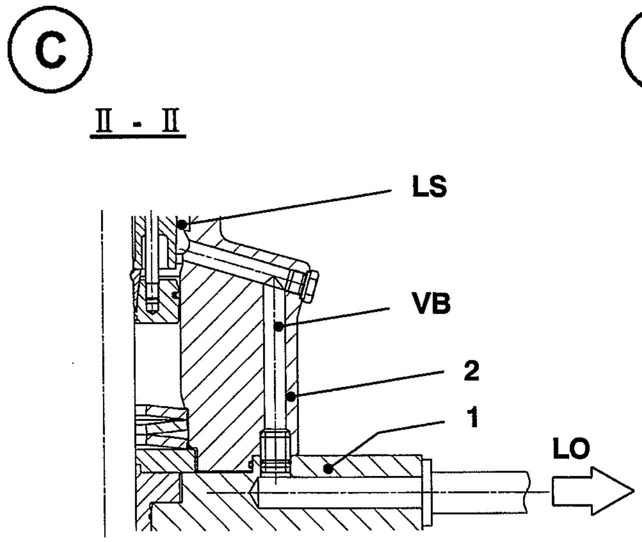
Leak oil from step piston is used to lubricate air spring piston (10). Surplus oil in space "LS" is drained via connecting bore "VB" into leakage oil drain "LO". While the exhaust valve closes oil enters the air spring "LF" via the air spring piston. The oil accumulating on the bottom of the air spring (inlet bore "EB") is atomized by the in-flowing air. This oil mist lubricates the upper part of the valve spindle. Excess oil is pressed out of air spring "LF" when the exhaust valve opens, and is led to an accumulator via the air spring pipe. From time to time the contents of the accumulator are automatically drained to the crankcase via the leakage oil collecting pipe of the exhaust valves.

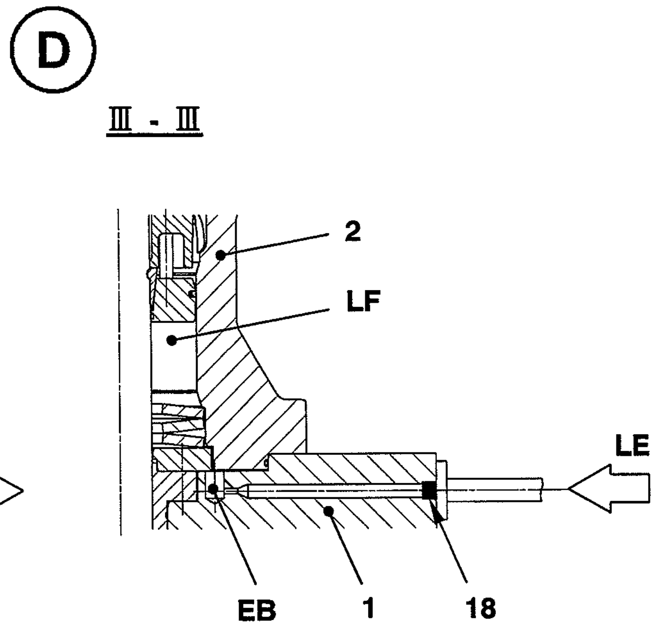


FUEL SIDE

B







Key to Illustration : **'A'** **Arrangement in cylinder cover**
'B' **Exhaust valve**
'C' **Leakage oil drain**
'D' **Air inlet to air spring**

1	Valve cage	16	Disc spring
2	Lower housing	17	Rotation wings
3	Upper housing	18	Non-return valve
4	Outside piston	19	Valve stroke sensor
5	Inside piston	20	Valve seat
6	Valve spindle	21	Cylinder cover
7	Guide bush		
8	Piston guide	EB	Inlet bore to air spring
9	Distance ring	HO	Hydraulic oil (high pressure)
10	Air spring piston	LE	Air inlet to air spring
11	Intermediate flange	LF	Air spring
12	Thrust piece	LO	Leakage oil drain
13	Measuring cone	LS	Leakage oil collecting space
14	Hydraulic oil connection		
15	Vent screw	VB	Connecting bore

Group 3

3

Crankshaft, Connecting Rod and Piston — Group 3

1. General

The engine is equipped with an integrated axial damper. The duty of the axial damper is the reduction of axial vibrations.

The damper consists of an upper (1), and a lower cylindrical part (2), which are both screw fastened to the last bearing girder, and of a damping flange "FK" which is a part of the crankshaft. The oil quantity required for the damping is adjusted by means of a throttling valve.

2. Function

Bearing oil "OE" is supplied via orifices (8) into the spaces "OR" to both sides of flange "FK" on crankshaft (10). The bigger part of the oil, thus imprisoned, can only circulate in case of axial crankshaft movements through throttle valve (3) from one space "OR" to the other. The remaining part of the oil is drained due to the radial and axial clearance of the sealing rings as well as the venting screws.

The optimum damping effect can be adjusted by spindle (4).

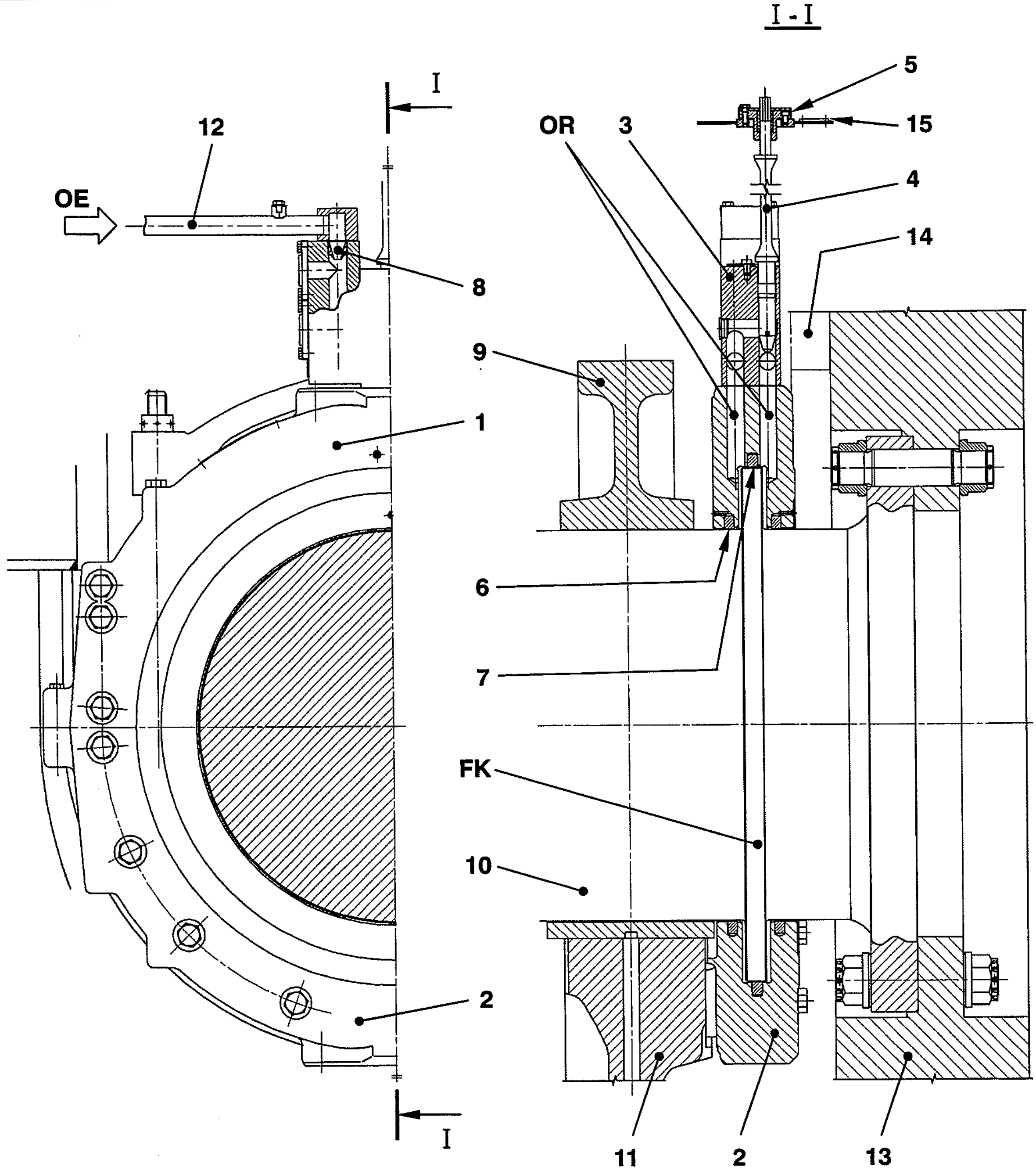
Remark : The adjustment has to be carried out during sea-trials, with the application of special measuring instruments. After the adjustment the setting screws are secured with locking device (5) against unintentional mis-adjustment.

The setting value of the spindle has to be engraved on a nameplate 15 in the immediate
vicinity of the throttle valve.

In order to exceptionally permit taking readings at different throttle positions of the spindle during sea-trials, , the spindle position can be altered
using a spanner outside.

WARNING

Any displacement of this spindle must be avoided!
The engine must **not** be operated with the spindle (4) removed or with the oil supply to the axial damper interrupted!



Key to Illustrations :

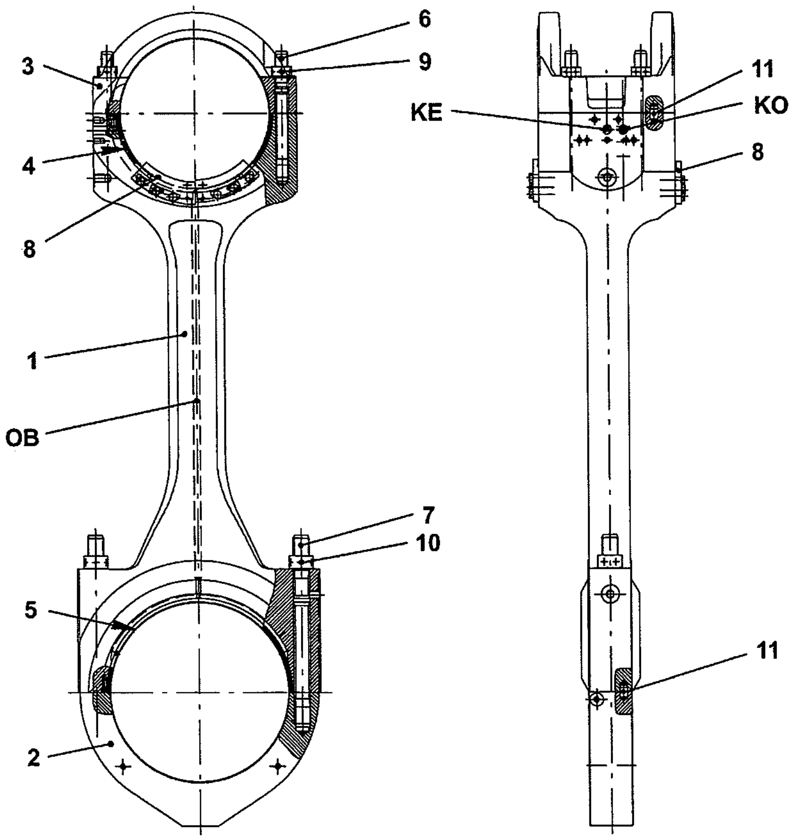
1	Upper part of cylinder	11	Bearing girder (part of bedplate)
2	Lower part of cylinder	12	Oil pipe
3	Throttle valve	13	Damper
4	Spindle	14	Counterweight
5	Locking device	15	Name Plate
6	Small sealing ring		
7	Large sealing ring	FK	Flange on crankshaft
8	Orifices	OE	Oil inlet
9	Bearing cover	OR	Oil spaces
10	Crankshaft		

1. General

The connecting rod connects the crosshead with the crankshaft and converts the linear stroke movement of the piston into a turning movement. Replaceable bearing shells are fitted on the connecting rod (1) for the top and bottom end bearings (items (4) and (5)). The bearing covers for the top and bottom end bearings (items (2) and (3)) are lined with white metal. The locking segments (8) prevent incorrect fitting of the crosshead pin.

2. Lubrication

Crosshead lubricating oil reaches the crosshead bearing through the connection "KE", and drillings in the crosshead pin admit lubricating oil to the guide shoes. Crosshead lubricating oil reaches the bottom end bearing through oil bore "OB" in the connecting rod (1).
Bearing lubricating oil is fed through connection "KO" for piston cooling through corresponding drillings in the crosshead pin and piston rod.



Key to Illustrations :

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

KE Crosshead bearing oil inlet
KO Piston cooling oil inlet
OB Oil bore through connecting rod shank

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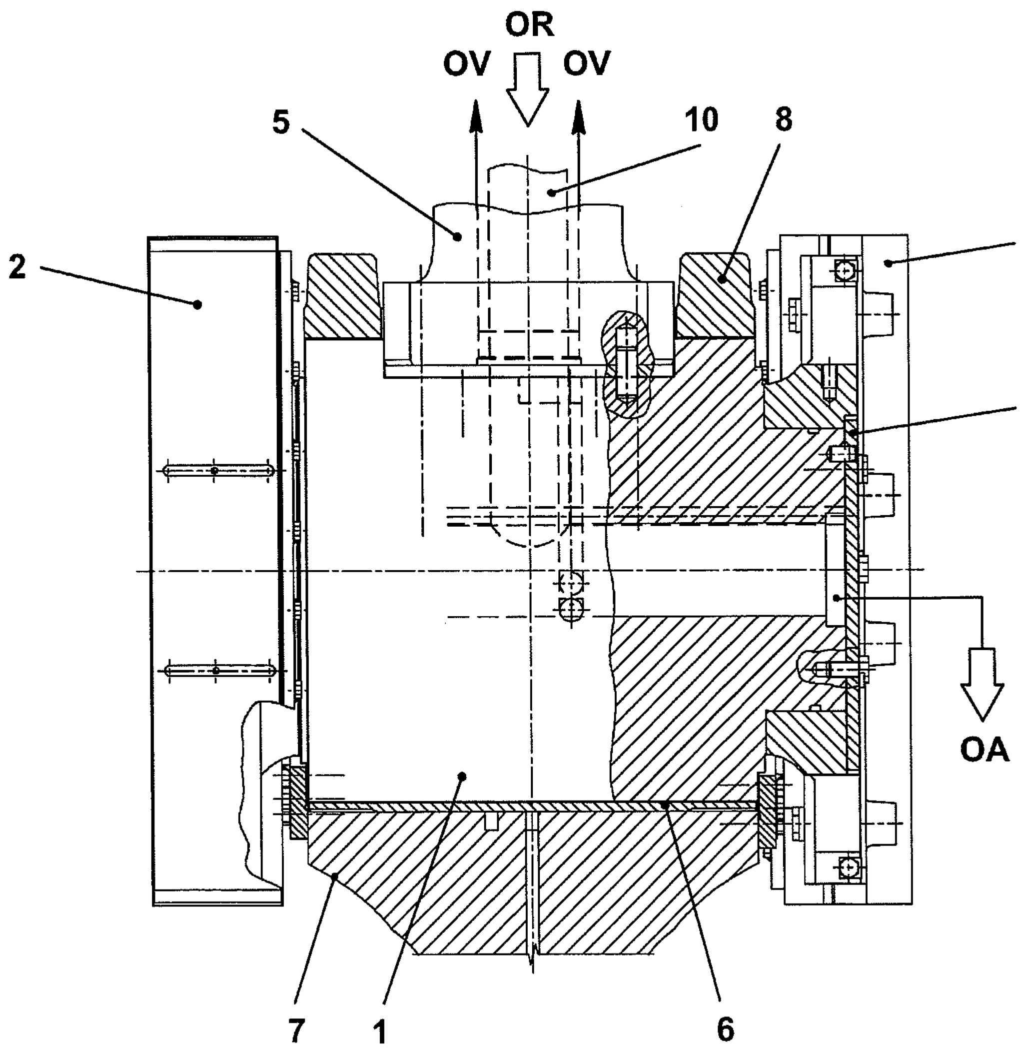
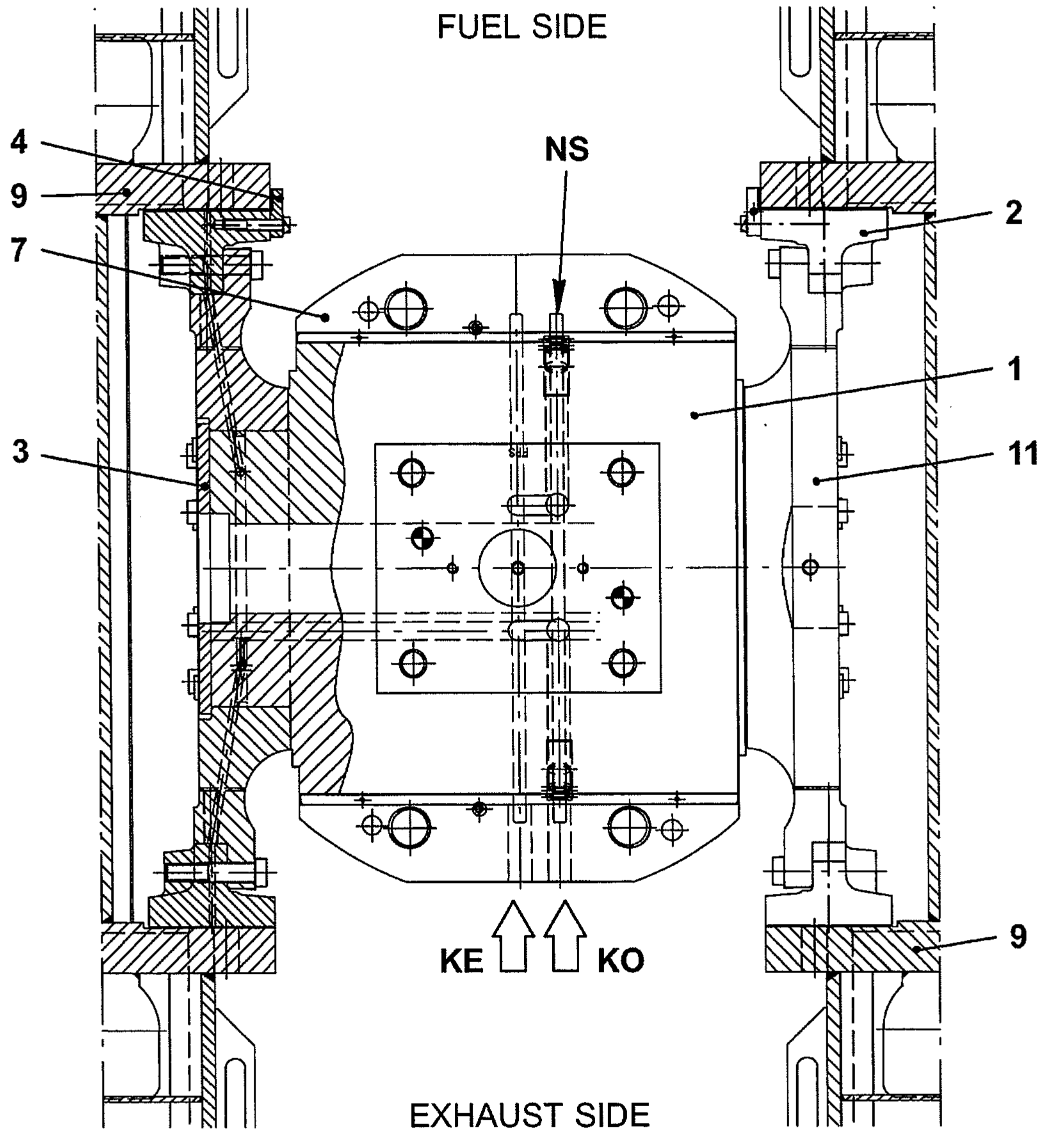
1. General

The crosshead guides piston rod (5) and absorbs the lateral forces originating from connecting rod (7).
The piston rod (5) is screw fastened to the crosshead pin (1). The bearing lubricating oil required for cooling the piston is led through slot "NS" and bore "OV" to the piston.
The oil "OR" flows back to the crosshead pin through the oil pipe (10) and returns to the crankcase through the drain "OA".
The guide shoes (2) rest on the small diameters of the crosshead pin. They are guided in the guide ways of column (9) by guide rails (4).
The retaining covers (3) hold the middle parts (11) to the crosshead pin during removal; they allow only a limited rotating movement.





Key to Illustrations:

1	Crosshead pin	10	Oil pipe to piston
2	Guide shoe	11	Middle part
3	Retaining cover		
4	Guide rail	KE	Crosshead lubricating oil inlet5
5	Piston rod	KO	Oil inlet for piston cooling oil inlet
6	Bearing shell for top end bearing (crosshead)	NS	Slot (groove) in connecting rod
7	Connecting rod	OA	Oil drain into crankcase
8	Upper bearing half for top end bearing	OR	Oil return from piston
9	Column	OV	Oil approach in connecting rod

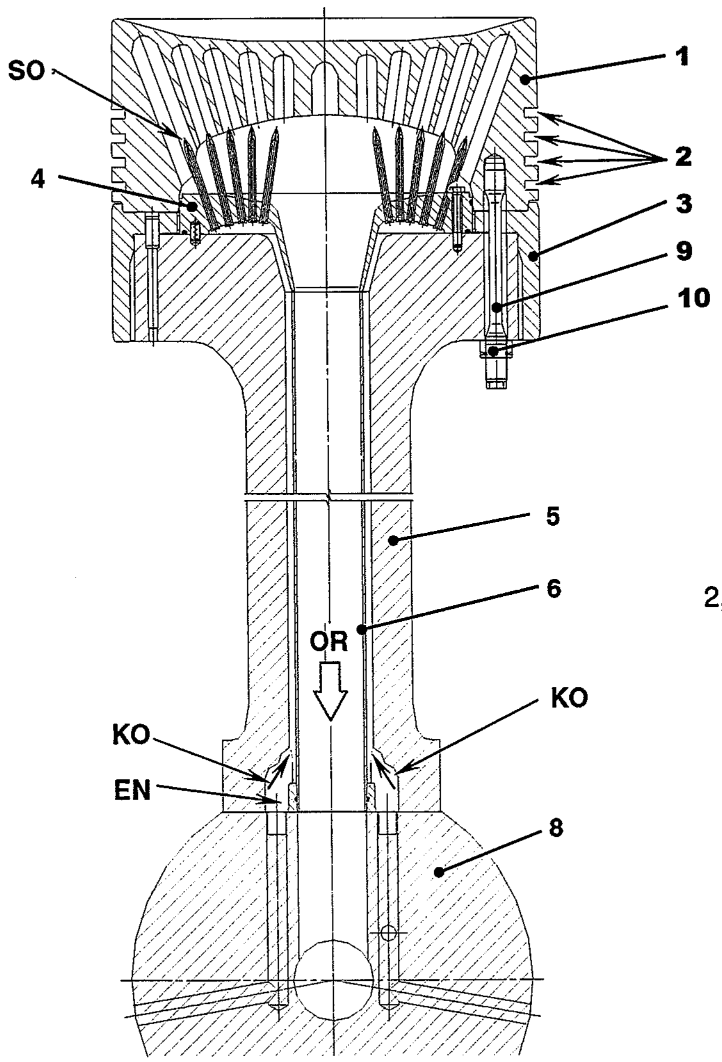
1. General

The piston consists basically of piston crown (1), piston skirt (3), piston rod (5), the oil cooling components and piston rings (2), (2a). Piston crown and piston rod are fixed by means of hydraulically tightened twelve elastic bolts (9) and round nuts (10).
The piston skirt (3) is directly screw fastened to the piston rod (5).
The piston rod (5) is fastened to crosshead pin (8) in a particular position.

Remark : All piston rings have to be fitted with the marking "TOP" upwards. Equipment of the piston rings see Maintenance Manual 3425-1.

2. Piston cooling

The piston crown (1) is cooled by bearing lubricating oil. The piston cooling oil "KO" is fed from crosshead pin (8) into the two inlet slots "EN". From here it flows outside the oil pipe (6) (arranged in the piston rod (5)) till spray plate (4). The cooling oil is sprayed into the cooling bores of the piston crown through nozzles in the spray plate. From there the oil "OR" flows through oil pipe (6) into the crosshead pin from where it emerges sideways.



Key to Illustrations :

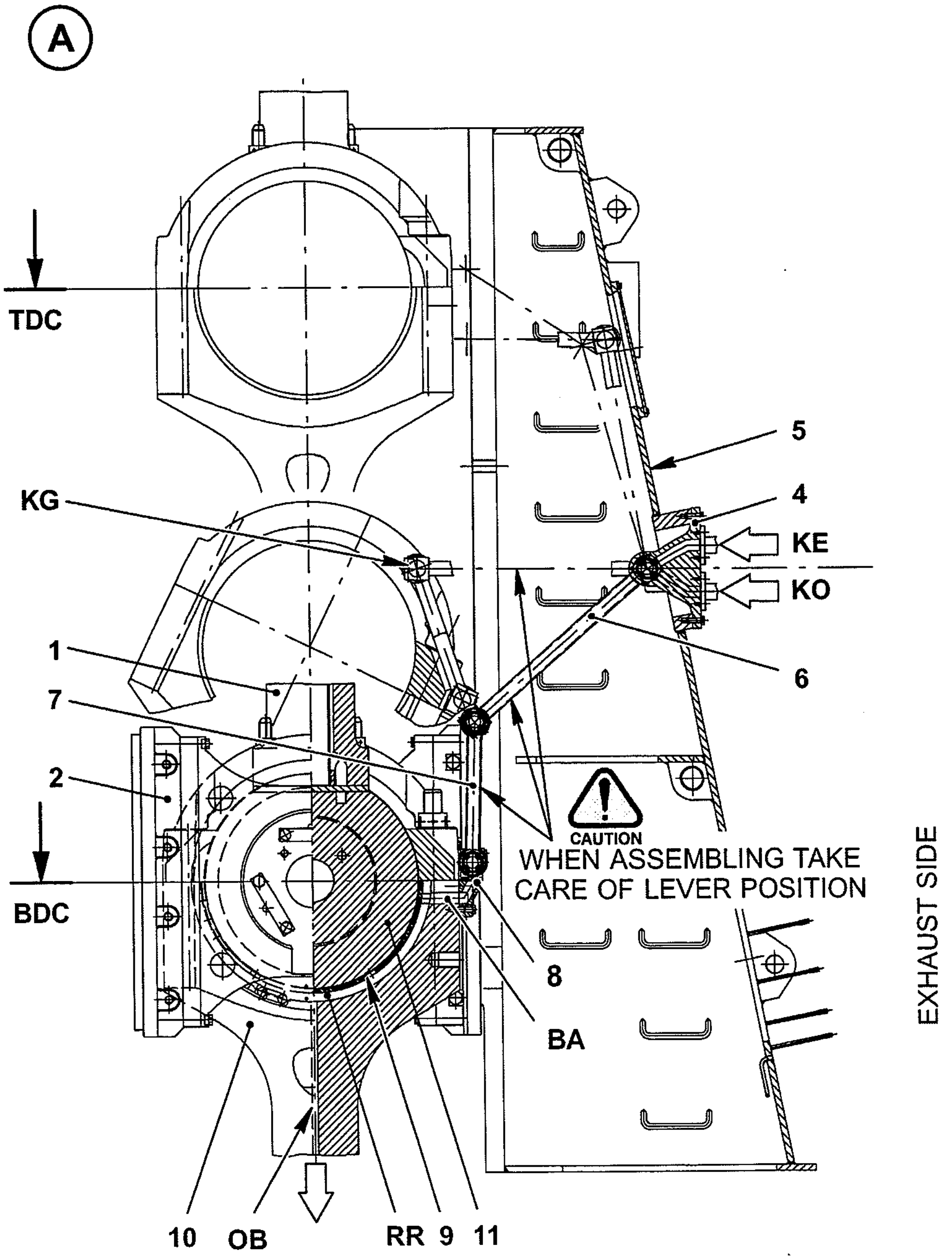
1	Piston crown
2, 2a	Top piston ring
3	Piston skirt
4	Spray plate
5	Piston rod
6	Oil pipe to spray plate
8	Crosshead pin
9	Elastic bolt
10	Round nut
EN	Inlet slot (groove)
KO	Piston cooling oil
OR	Oil return from piston
SO	Spray oil

1. General

The pistons are cooled by bearing lubricating oil. The crosshead is lubricated by bearing oil which has been boosted to a higher pressure. Both oil systems are led to the crosshead via a double articulated lever with separate oil supplies.

2. Crosshead lubrication

The crosshead lubricating oil "KE" reaches the connecting piece (8), which is fitted to the connecting rod (10), by-passing through the support (4), the lower lever (6) and the upper lever 7. The oil enters the ring space "RR" through bore "BA". The crosshead pin is lubricated through bores in the crosshead bearing shell (9) (see Fig. 'A').
Bore "OB" through the connecting rod (10) leads the oil to the crankpin bearing.



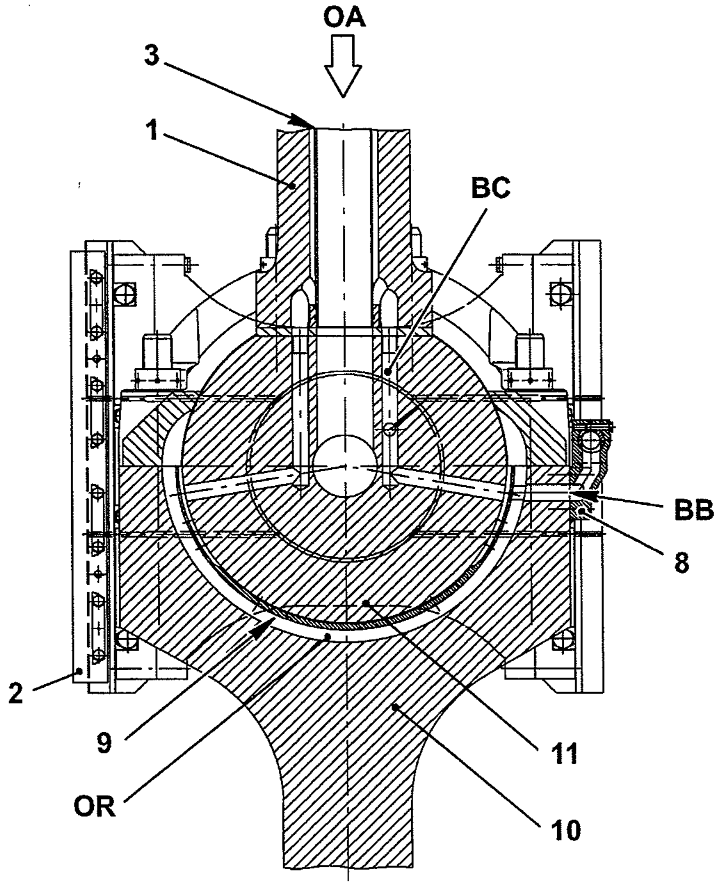
3. Piston cooling

Bearing oil “KO” passes through the support (4), the lower lever (6) and the upper lever (7) to the connecting piece (8), which is fitted to the connecting rod (10). The cooling oil is led to the working piston through the bore “BB”, the ring space “OR”, bores in the crosshead bearing shell (9) and the bores “BC”, then outside the oil pipe (3) through the piston rod (1). The oil then flows through the oil pipe (3) to the central bore in the crosshead pin (11) and returns to the crankcase. Part of the piston cooling oil is used to lubricate the guide shoes (2) and the guide shoe pins as shown in Fig. ’B’ (see also 3326–1).

WARNING

When fitting the upper lever (7) to connecting piece (8) great care must be taken that the toggle lever **(knee) ’KG’ buckles upwards as per Fig. ’A’.** Wrongly fitted, this would certainly lead to very grave damage to the toggle lever, the crosshead and the column. Besides **this it will cause interruption of the lubricating oil supply with further heavy damage resulting.**

B



Key to Illustrations :
‘A’ Articulated lever arrangement
‘B’ Cross section through crosshead

1	Piston rod
2	Guide shoe
3	Oil pipe
4	Support
5	Column
6	Lower lever
7	Upper lever
8	Connecting Piece
9	Crosshead bearing shell
10	Connecting rod
11	Crosshead pin
BA	Bore for crosshead lubricating oil
BB	Bore for piston cooling oil
BC	Bore in crosshead pin
KE	Inlet for crosshead bearing oil
KO	Inlet for piston cooling oil
KG	Toggle lever (knee)
OA	Piston cooling oil return
OB	Bore for crosshead lubricating oil to The crankpin bearing
OR	Ring space for piston cooling oil
RR	Ring space for crosshead Lubricating oil

Group 4

4

Engine Control and Control Elements — Group 4

▽ Engine Control

▽ Control Diagram

▽ Control and Auxiliary System

Overview

1. General

The WECS-9520 (Wärtsilä Engine Control System) has been specially designed for two-stroke engines with Wärtsilä Common Rail technology, covering all enginerelated (section 3) and cylinder-related (section 4) control functions.

Engine-related control functions:

- Fuel rail pressure
- Servo oil pressure for exhaust valve drive
- Control oil pressure supply

Cylinder-related control functions:

- Volumetric injection control (including VIT)
- Exhaust valve control (including VEO and VEC)
- Starting valve control
- Crank angle sensor

The 'Common Function' to the external systems is ensured by data buses to the propulsion control system and to the ship alarm and monitoring system (section 5). They serve as interface between operator and engine control.

2. Components

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

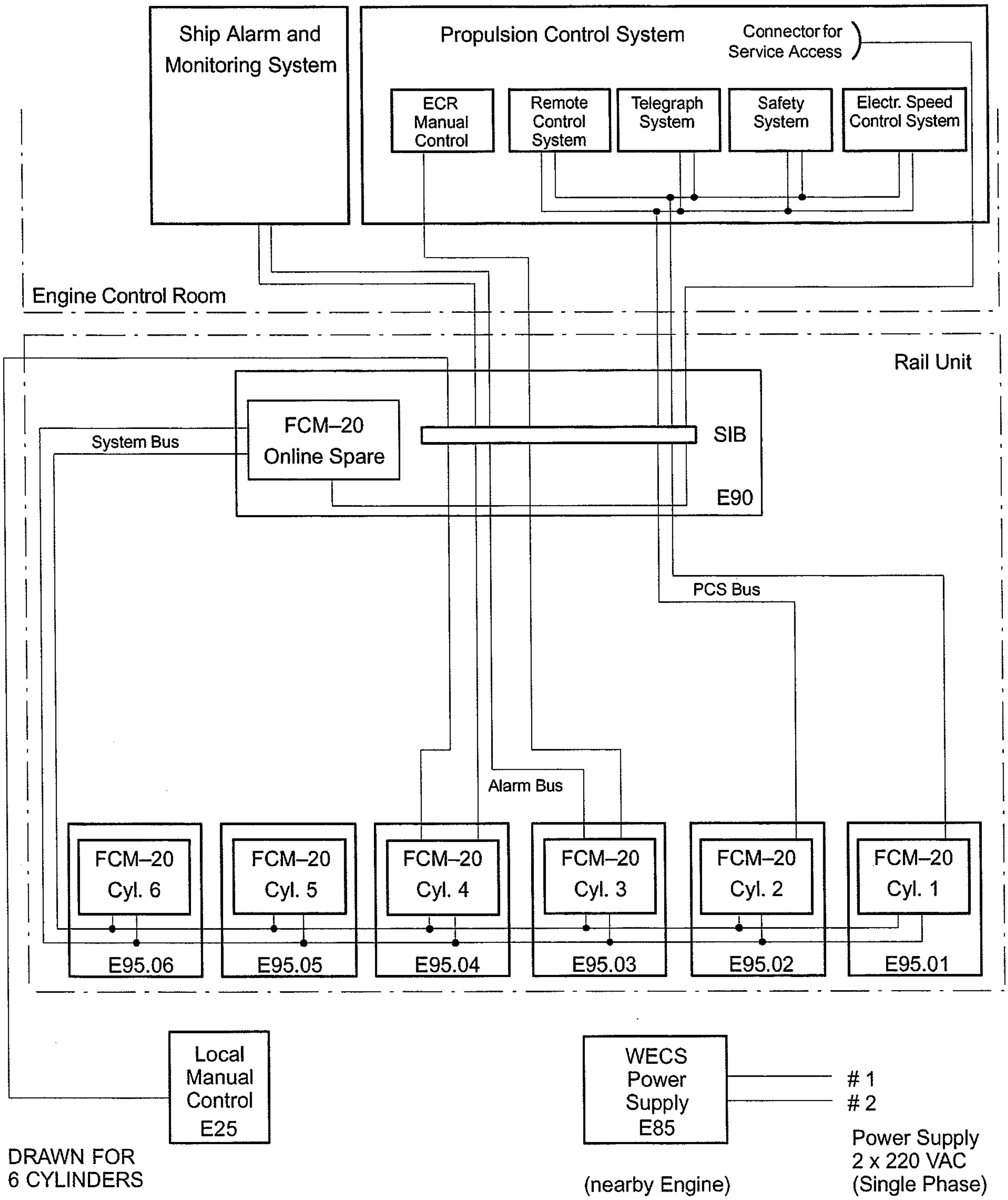
Main components of WECS-9520:

- Control box E90 (SIB) as communication to the external systems, containing a FCM-20 module as 'Online Spare'.
- Per cylinder a control box E95.xx, containing a FCM-20 module each for engine and cylinder-related control functions.

All modules are connected by the system bus.

All control boxes (E90, E95.xx) are arranged on the rail unit, and power supply boxes (E85) are placed nearby the engine.

(A)


Ship Alarm and Monitoring System
Propulsion Control System
Connector for Service Access
ECR Manual Control
Remote Control System
Telegraph System
Safety System
Electr. Speed Control System
Engine Control Room
Rail Unit
FCM–20 Online Spare
SIB
E90
System Bus
PCS Bus
Alarm Bus
FCM–20 Cyl. 6
FCM–20 Cyl. 5
FCM–20 Cyl. 4
FCM–20 Cyl. 3
FCM–20 Cyl. 2
FCM–20 Cyl. 1
E95.06
E95.05
E95.04
E95.03
E95.02
E95.01
Local Manual Control E25
WECS Power Supply E85
1
2
Power Supply 2 x 220 VAC (Single Phase)
(nearby Engine)
DRAWN FOR 6 CYLINDERS

3. Engine-related control functions

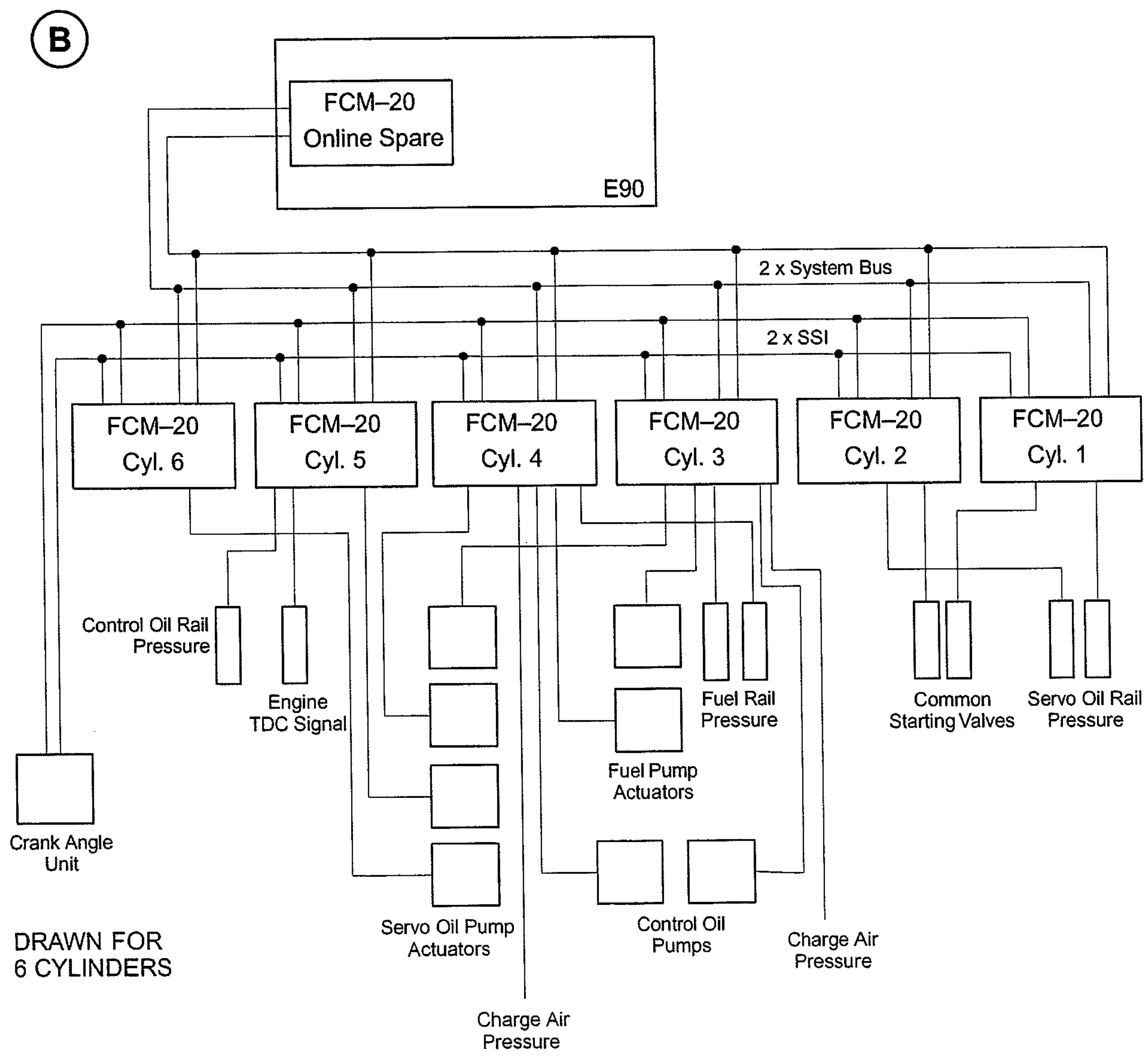
3.1 General

All engine-related control functions are distributed within six FCM-20 modules (cylinders 1 ~ 6) for 6 to 10 cylinder engines, however, there are eight modules for 11 to 14 cylinder engines.

For safety reasons all important functions, input and output signals of the modules are redundant. The engine remains in operation if one module fails. The power supply is also redundant (see Fig. 'B').

A defective module has to be replaced with the 'Online Spare' module.

The control box E90 must subsequently be completed with a new module as 'Online Spare' which will receive a download of all application data.

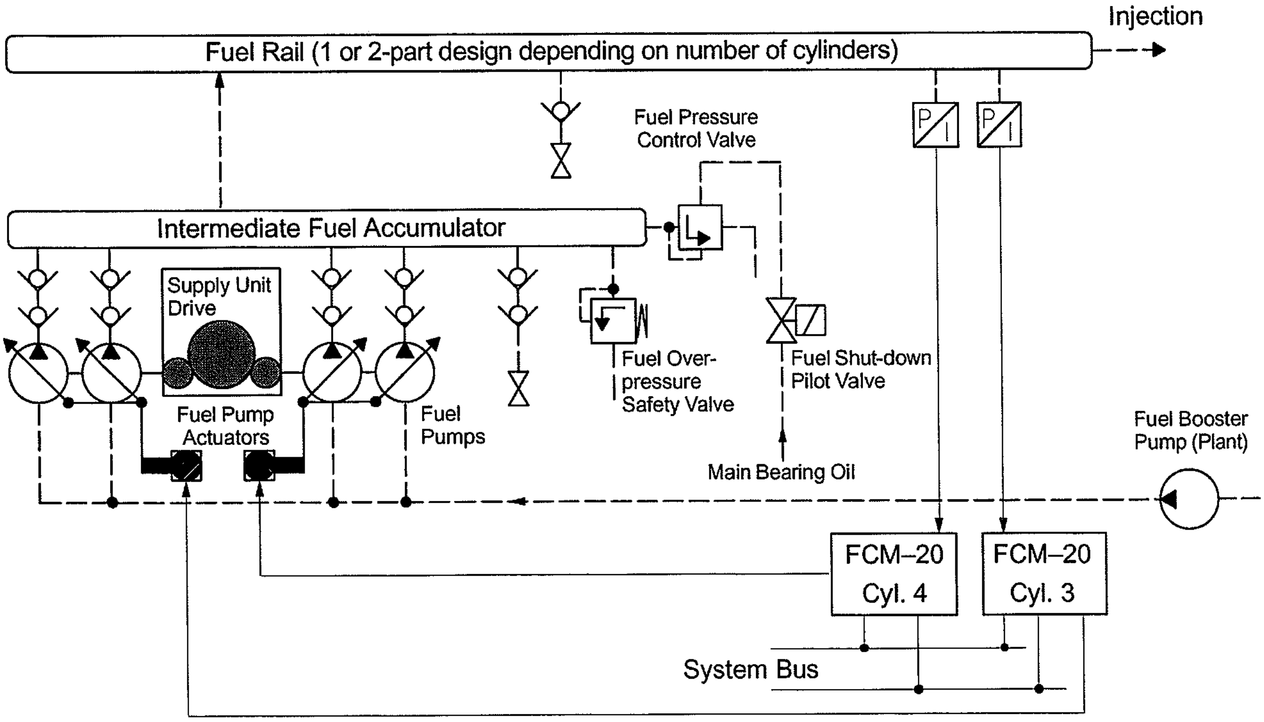


Functions:

- Fuel pressure control
- Servo oil pressure control
- Monitoring and triggering functions
- Servo oil pumps
- Control oil pumps
- Fuel pump actuators

3.2 Fuel pressure control

C



Starting:

At starting, the fuel pump actuators are set to start position due to fuel rail pressure.

Engine running:

The fuel pressure is dependent on the engine load.

The control loop for the fuel rail pressure can basically be described as follows:

- WECS-9520 generates a control signal based on engine speed and 'fuel command'.
- The signals from the FCM-20 modules control the fuel pump actuators. One actuator regulates two fuel pumps.
- The resulting fuel rail pressure is measured by two pressure transmitters as feedback to the FCM-20 modules of cylinders 3 & 4.

Shut-down:

At shut-down the fuel pump actuators are set to position 'zero' and the fuel shutdown pilot valve is activated by the safety system.

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3.2.1 Emergency mode

One actuator brokendown:

If one of the fuel pump actuators is brokendown, its regulating linkage remains in position or moves to maximum position by means of a spring.

The other actuators still control the fuel pressure. Below medium load any surplus fuel is released by the fuel pressure control valve.

3.2.2 Monitoring

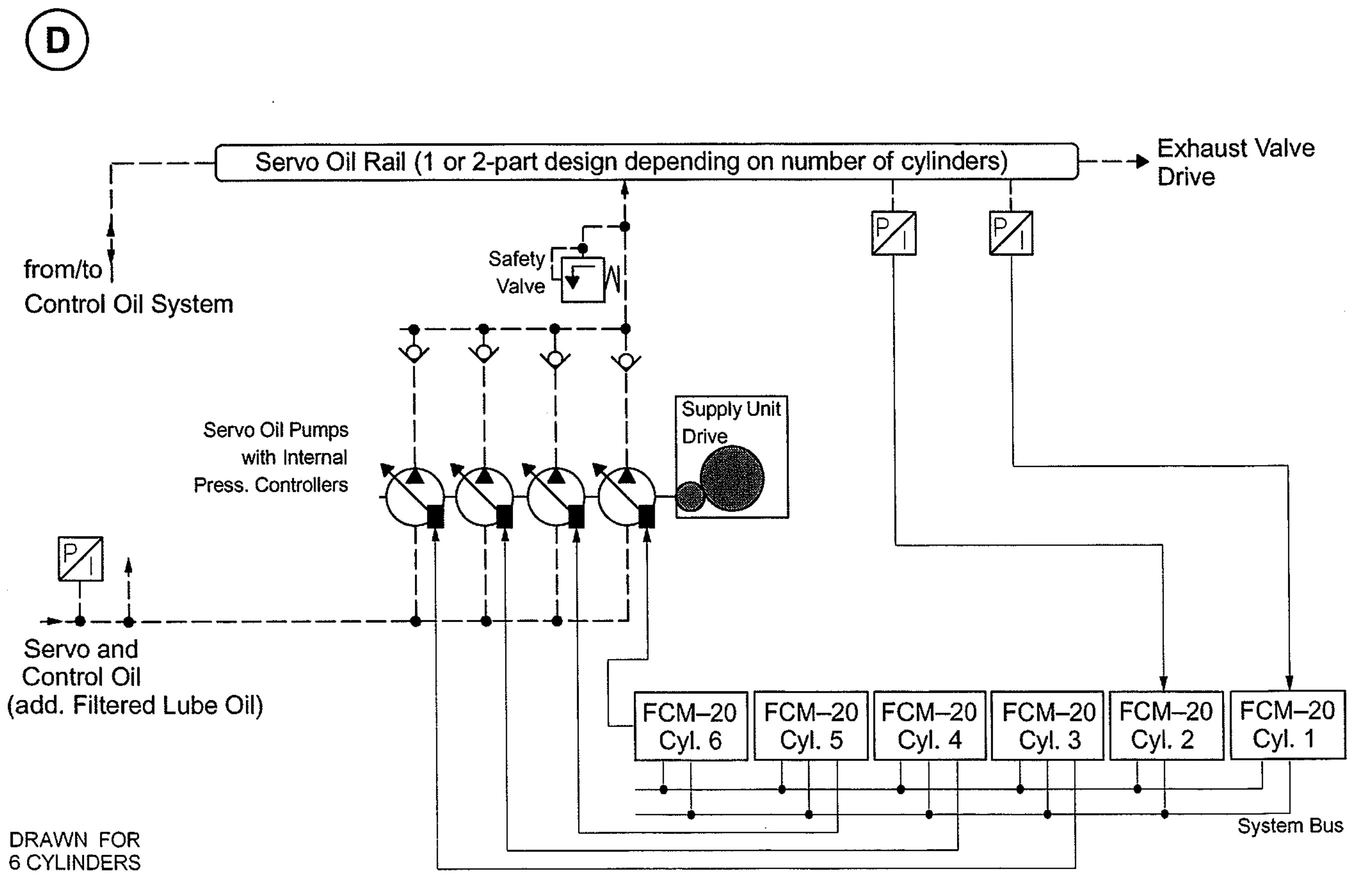
Pressure:

The pressure is monitored. If out of tolerance, a failure is indicated.

Sensors:

The sensors are monitored. If out of range or exceeding difference, a failure is indicated, and it can furthermore be observed with blinking LEDs on FCM-20 modules of cylinders 3 & 4 (see 0850-1 'Failures and Defects of WECS Components').

3.3 Servo oil pressure setpoint



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3.3.1 Pressure setpoint

An internal mechanical pressure controller with an electrical setpoint is provided for each servo oil pump. This setpoint determined by a pulse width modulation (PWM) signal.

The setpoint is mainly dependent on the engine load and generated in the FCM-20 Module.

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

Every pressure controller of the four to six pumps (depending on number of cylinders) is connected to a FCM-20 module (cylinders 3, 4, 5, 6, 7 & 8). This decentralization increases the availability of the servo oil system.

3.3.2 Emergency mode

One servo oil pump may fail, however, the system keeps running. The load is taken over by the other pumps.

3.3.3 Sensor monitoring

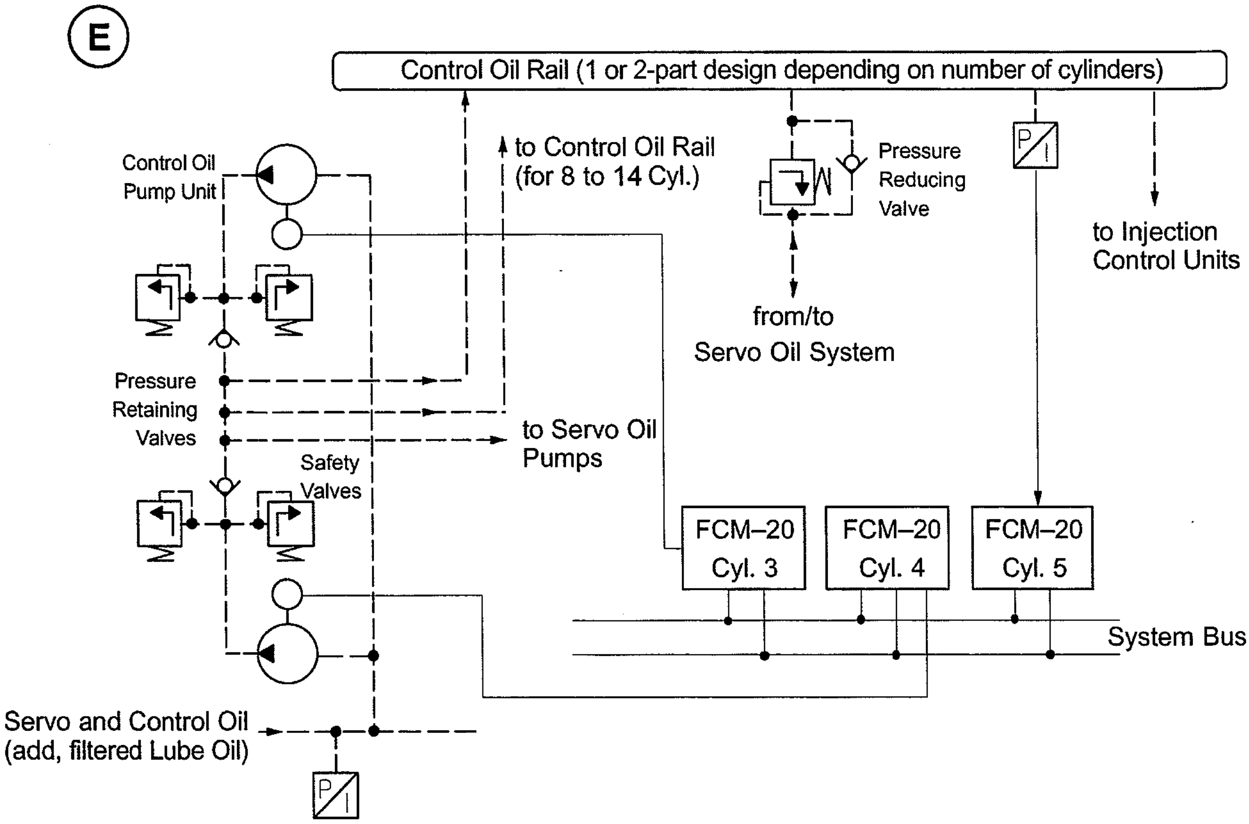
Pressure:

The pressure is monitored. If out of tolerance, a failure is indicated.

Sensors:

The sensors are monitored. If out of range or exceeding difference, a failure is indicated, and it can furthermore be observed with blinking LEDs on FCM-20 modules of cylinders 1 & 2 (see 0850-1 'Failures and Defects of WECS Components').

3.4 Control oil pressure supply



3.4.1 General

The control oil system is used to control the injection.
One of the two electrically-driven control oil pumps provides the control oil pressure, maintaining it over the entire load range.
Prior to engine start a servo oil rail pressure of approx. 7.5 MPa is produced via the pressure reducing valve, until the engine-driven servo oil pumps deliver the required pressure.

3.4.2 Emergency mode

Upon failure of a control oil pump the second pump ensures the correct pressures.

3.4.3 Pressure monitoring

The pressure is monitored. If out of tolerance, a failure is indicated.
It can be observed with the relevant blinking LED on FCM-20 module of cylinder 5 (see 0850-1 'Failures and Defects of WECS Components').

4. Cylinder-related control functions

4.1 General

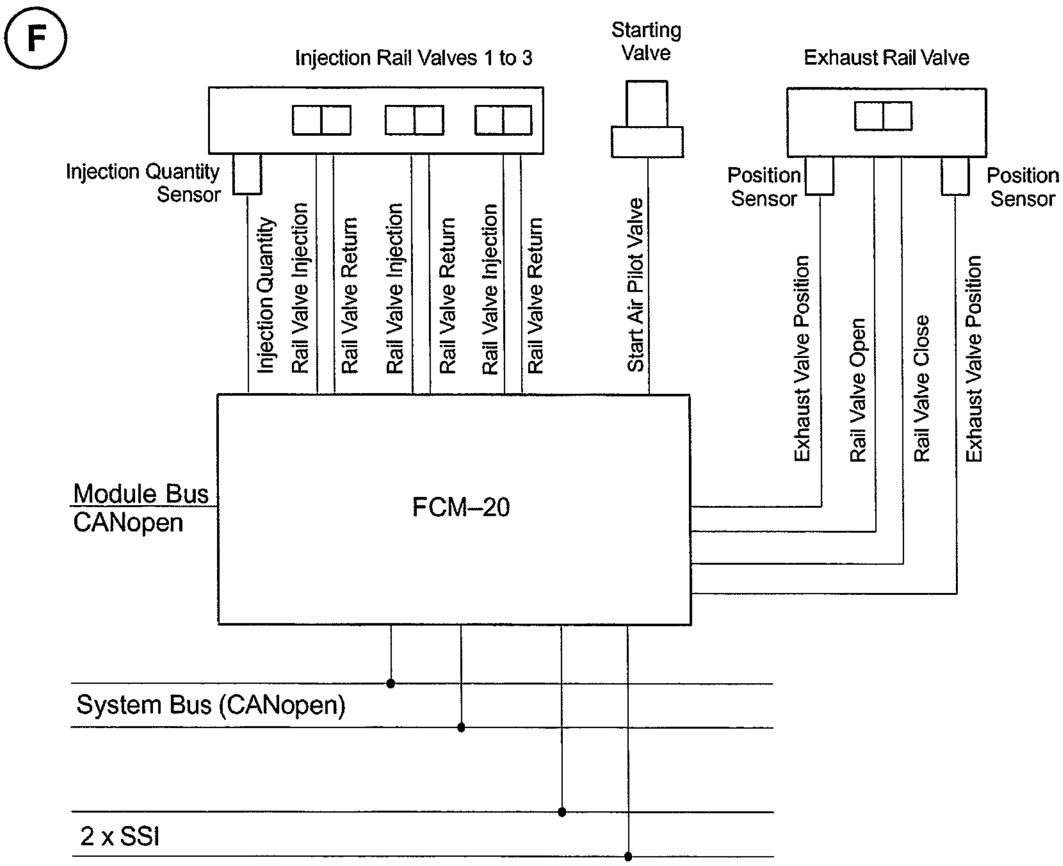
Every cylinder is equipped with an FCM-20 module. A redundant system bus provides communication between the FCM-20 modules.

The FCM-20 modules receive the crank angle signal via a redundant SSI bus.

If a FCM-20 module breaks down, the respective cylinder is cut out. The other FCM-20 modules remain in operation.

Functions:

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



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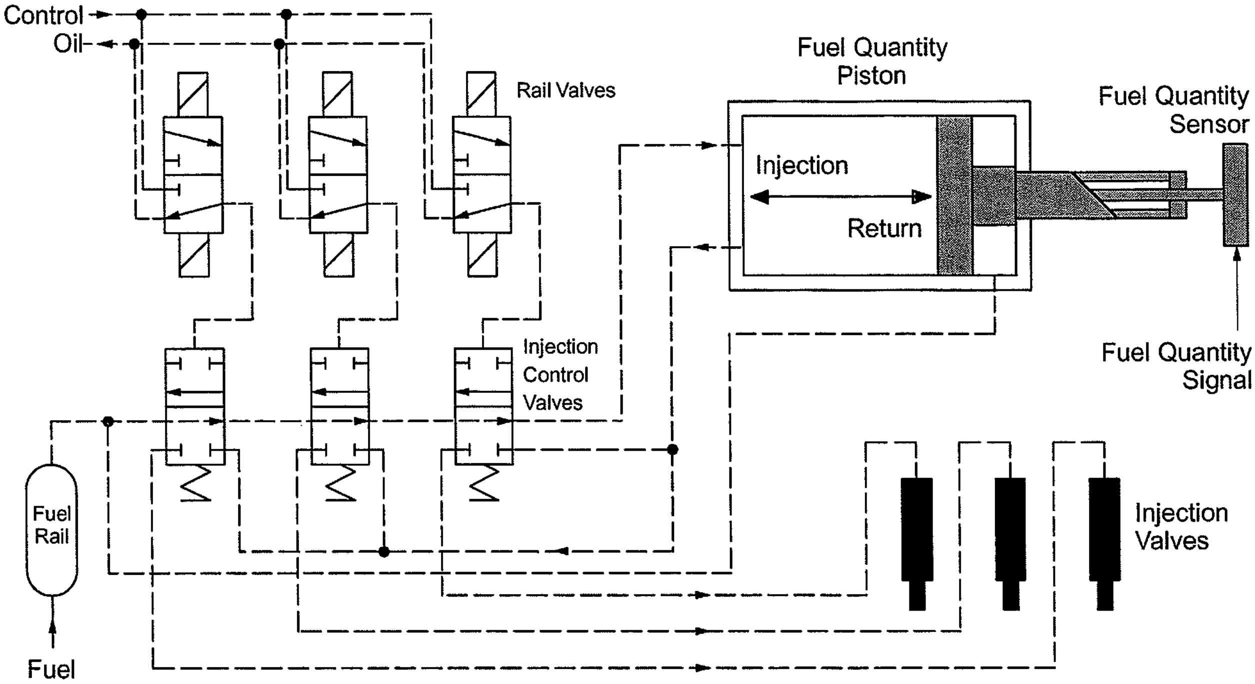
4.2 Injection control

G



All components are shown in position NO INJECTION

Injection valve control function:

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

Normally all injection valves are activated at the same time. Special operation modes enable injection with only one or two injection valve(s) or with spray delay in three injection valve (sequential patterns), (see also 0280-1 'WECS-9520 Injection control').

In order to improve atomizing at low load one or two injection valves are cut out automatically.

The FCM-20 is used to amplify control outputs up to the required signal level for the rail valves.

Rail valve ON-time measurement:

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

It allows a certain interpretation of the rail valve condition.

Initial setpulse:

Since the rail valves are bistable, their initial position is undefined. Therefore, at engine standstill, setpulses are periodically applied to the rail valves to obtain a defined position.

Injection control:

Fuel injection is controlled as follows:

- Calculation of injection begin with reference to crank angle and VIT.
- Releasing the injection by actuating the rail valves.
- The time difference between injection start signal and injection begin is called 'injection deadtime'. The injection begin is detected with the movement of the fuel quantity piston.
- The actual injection quantity is determined by the stroke of the fuel quantity piston. The injection is stopped when the fuel quantity piston reaches the calculated stroke.
- Based on the control signal the injection quantity is calculated by the governor.
- On the following injection cycle, the calculation of the correct injection time includes the measured injection deadtime.
- The functionality of the injection system is monitored at each cycle.

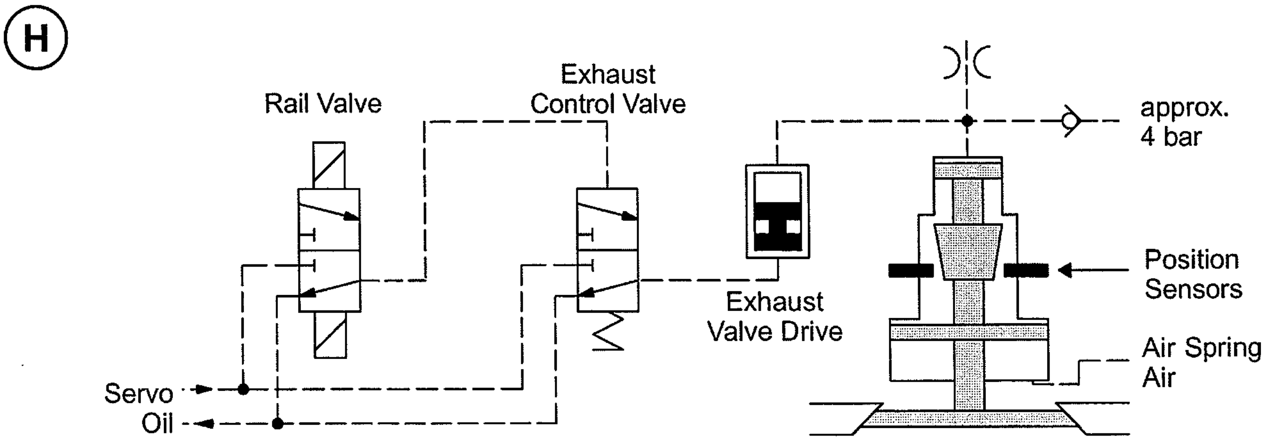
Reversing:

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

Emergency mode:

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

4.3 Exhaust valve control



All components are shown in position CLOSED

Exhaust valve function:

The exhaust valve opens and closes once per crankshaft revolution. Its movement is measured by two position sensors.

The FCM-20 is used to amplify control outputs up to the required signals for the rail valves.

Rail valve ON-time measurement:

The time between start signal and moving the valve piston is measured and indicated in the remote control.

Initial setpulse:

Since the rail valves are bistable, their initial position is undefined. Therefore, at engine standstill, setpulses are periodically applied to the rail valves to obtain a defined position.

Exhaust valve control:

The exhaust valve movement is controlled as follows:

- The opening command of the exhaust valve is calculated with reference to crank angle and VEO.
- Triggering of the opening rail valve.
- Measuring opening deadtime: Displacement time from 0 ~ 15% valve stroke.
- The closing command is calculated with reference to crank angle and VEC.
- Triggering of the closing rail valve.
- Measuring closing deadtime: Displacement time from 100 ~ 15% valve stroke.
- After a completed crankshaft revolution the timing for the next cycle is corrected according to the deadtime of the previous one.

Reversing:

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

Emergency mode:

In case of one broken position sensor the process goes on with the functioning sensor.

In case of both broken position sensors the process continues with time control for the affected cylinder.

4.4 Starting valve control

The starting valve is opened and closed directly by the FCM-20 once per crankshaft revolution at a certain crank angle until the engine is running.

Reversing:

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

4.5 Crank angle sensor

Two crank angle sensors are mounted at the free end; they are driven by the crankshaft via a coupling. They provide an absolute angle signal (not an incremental signal).

Both signals are transmitted to each FCM-20, however, excluded is the 'Online Spare' module.

Following works on the crank angle sensors or their associated drives, the signals must be compared to the reading on the flywheel. If necessary the offset must be readjusted on the remote control.

Crank angle signal monitoring:

Both crank angle signals and the TDC signal are compared with each other.

An alarm, slow-down or shut-down is indicated if the three signals do not correspond within a certain tolerance.

5. Communication between WECS-9520 and external systems

WECS-9520 provides the following data communications to:

- Propulsion control system
- Ship alarm and monitoring system
- Control panel at local manoeuvring stand
- BACKUP control box in control room.

The standard version of WECS-9520 covers the following external communications:

- 2 redundant data cables to remote control
- 2 redundant data cables to ship alarm and monitoring system
- 1 data cable to local control panel
- 1 data cable to BACKUP control box in control room
- 1 data cable to a connector at BACKUP control box of remote control for connecting a notebook of the service personnel.

Schematic diagrams see Fig. 'I' and 'A'.

Remark : The communications between the systems may differ slightly Depending on approved system manufacturer (see therefore the relevant documentation).

5.1 Propulsion control system

The propulsion control system is divided into the following subsystems:

- Remote control system (RCS)
- Electronic speed control system
- Safety system
- Telegraph system

Remark : The safety and telegraph systems work independently and are fully operational also at failure of the remote control functions.

5.2 Remote control system

Main functions:

- Start, stop, reversing
- Automatic slow turning
- Auxiliary blower control
- Transfer control
- Speed setting
- Automatic speed setting program

Information about current WECS-9520 status is available in the remote control.

This includes measured values of sensors, alarm indications, parameter settings and trendlines (see documentation of remote control manufacturer).

User parameters e.g. FQS can be adjusted by the engine operator.

All commands to run the engine, e.g. AHEAD or ASTERN, are generated in the RCS according to operator requirements.

On the other hand, the corresponding FCM-20 generates a load signal to the RCS out of the average from the measured fuel quantity signals.

Two charge (scavenge) air signals are transmitted to RCS via WECS-9520, therefore, the signal is redundant.

If WECS-9520 detects a failure, it sends an alarm signal to the ship alarm system or a slow-down / shut-down signal to the safety system.

Parameter setting:

The parameters are divided into two groups:

- User parameters, access without password
- Expert parameters, access with password only

User parameters e.g. FQS can be adjusted by the engine operator.

Expert parameters are changed only by service personnel, mainly during commissioning. A typical expert parameter is the firing order of the engine, which is set only once. A connector for service access is provided in the engine control room.

5.3 BACKUP control box

It is part of the propulsion control system and arranged in the ECR console.
The same control functions can be carried out as at the local control panel (see also 4618-1).

5.4 Electronic speed control system

- Maintains engine speed at required value from remote control
- Transfers 'fuel command' to WECS-9520
- Fuel quantity limitation depending on charge (scavenge) air pressure and engine Protection

The speed control system for the engine is an independent electronic device and not part of WECS-9520.

WECS-9520 receives a 'fuel command' signal from the speed governor.

This signal is distributed to all FCM-20 modules. This is the setpoint for the fuel quantity to be injected.

In case of a speed control system failure, the engine can be run either in:

- LOCAL mode by manually adjusted fuel quantity at local control panel, or
- ECR BACKUP mode from BACKUP control box in control room.

CAUTION

> In BACKUP mode an engine with controllable pitch propeller (CPP) shall be operated with blocked propeller pitch to avoid overspeed.

5.5 Safety system

Main functions:

- Emergency stop
- Overspeed protection
- Automatic shut-down
- Automatic slow-down

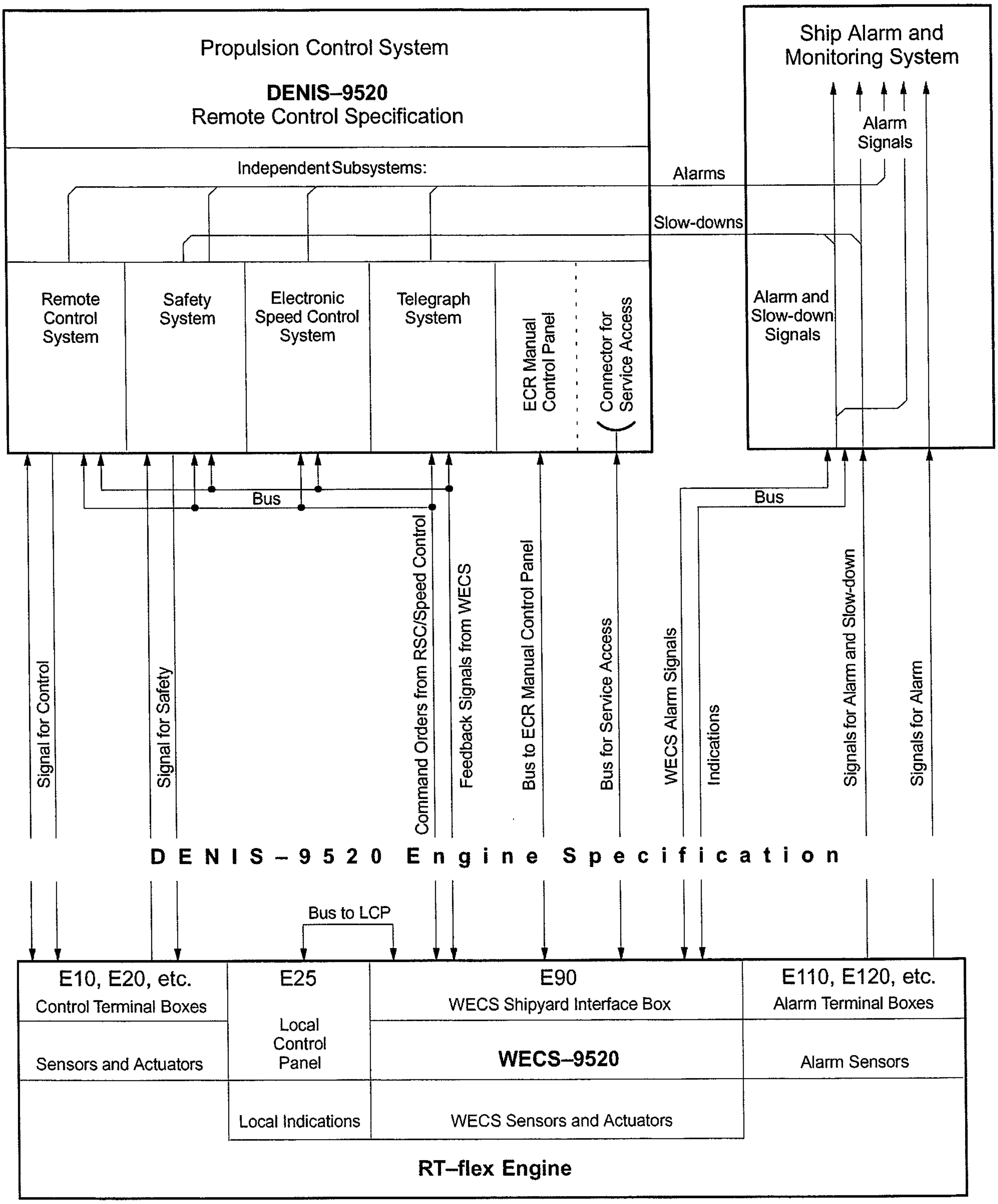
Each irregularity generates within WECS-9520 a request to the safety system.

See detailed failure description in 0850-1 'Failures and Defects of WECS Components'.

5.6 Telegraph system

- Used for transmission of manoeuvring orders from the wheelhouse to the control room and local control panel.

I


Propulsion Control System
DENIS–9520
Remote Control Specification
Independent Subsystems:
Remote Control System
Safety System
Electronic Speed Control System
Telegraph System
ECR Manual Control Panel
Connector for Service Access
Alarms
Slow-downs
Ship Alarm and Monitoring System
Alarm Signals
Alarm and Slow-down Signals
Bus
Bus
Signal for Control
Signal for Safety
Command Orders from RSC/Speed Control
Feedback Signals from WECS
Bus to ECR Manual Control Panel
Bus for Service Access
WECS Alarm Signals
Indications
Signals for Alarm and Slow-down
Signals for Alarm
DENIS–9520 Engine Specification
Bus to LCP
E10, E20, etc.
Control Terminal Boxes
Sensors and Actuators
E25
Local Control Panel
Local Indications
E90
WECS Shipyard Interface Box
WECS–9520
WECS Sensors and Actuators
E110, E120, etc.
Alarm Terminal Boxes
Alarm Sensors
RT–flex Engine

1. General

'User parameter settings' are accessible to the operator without password.

'Maintenance settings' are accessible to the operator with password or key only depending on remote control manufacturer!

Setting or altering the parameters listed in WECS-9520 can be carried out using the 'Operator interface' of the remote control as follows:

– 'User parameters' in USER
– 'Maintenance settings' in ADJUST.

How to reach these areas in order to alter the corresponding values is described in the manual of the remote control manufacturer.

1.1 Overview of user parameters

Parameter	Purpose and effect
FQS (Fuel quality setting)	FQS can be set to adjust maximum firing pressure to nominal value. A negative correction angle will **advance** the injection begin and increase max. pressure. A positive correction angle will **retard** the injection begin and reduce max. pressure.
VIT on/off	VIT is normally switched on (shown as ON). It can be switched off (shown as OFF) for running-in. OFF means injection begins at nominal angle independent of the engine power.
Inj. cut off (Injection cut off)	Can be used to stop fuel injection to individual cylinders if necessary (e.g. in case of liner/piston ring problems or damaged injection system). The exhaust valve remains in normal operation.
Inj. venting (Injection venting)	Injection units of individual cylinders or all of them can be vented. Rail valves of cylinders will be rhythmically activated for some time. It is advisable that a control oil pump is running. This should be done preferably before every engine start after a stop of some hours.
Exv. A/M Cmd (Exhaust valve auto/manual command)	Use it to manually open and close single exhaust valve at **stopped engine**. Useful for testing and venting, e.g. after maintenance works. Preconditions: One control oil pump must be running, building up some pressure in servo oil rail. Air spring pressure must be up.
Switching Control Oil Pumps	Start standby pump and stop the running one.
Start Valves Checking (Common start valves 1/2, enable/disable)	For function checks of control valves on shut-off valve for starting air. Switch off a valve in order to check the other one.
Heavy Sea Mode	Can be switched on in case of heavy sea. This function sets the fuel rail pressure to a constant value, independent of the engine power. Pressure control becomes more stable. Switch off when weather conditions have normalized and before manoeuvring.

1.2 Overview of maintenance settings

Parameter	Purpose and effect
Crank Angle (PARA3) Crank angle offset, engine TDC offset	Crank angle settings and checks after maintenance or replacement of crank angle sensor unit. Input of crank angle deviations (mean values) and checking of measured values.
Exv. closing offset (Exhaust valve closing offset)	Cylinder pressure fine tuning in service: Permits adjusting of compression pressure.
Inj. begin offset (Injection begin offset)	Cylinder pressure fine tuning in service: Permits adjusting of maximum firing pressure.
Inj. correction factor (Injection correction factor)	Injected fuel quantity for each cylinder can be reduced individually to 80 %. Useful to run in single cylinders or in case of running troubles on single cylinders.

Regular Checks and Recommendations for WECS-9520

1. General

For safety reasons redundant control systems and the components in standby mode should be checked periodically for trouble-free functioning.

2. Monthly checks

2.1 LOCAL MANUAL CONTROL (Local Control)

⇒ Carry out an engine start in LOCAL MANUAL CONTROL mode.

3. Quarterly checks

3.1 Level switch

See 8016-1 'Servo oil leakage system' and 8019-1 'Fuel leakage system'.

⇒ Check electric cable junctions.

⇒ Remove the terminals cover from the sensor and change the selector switch from MAX to MIN.

- An alarm should be triggered and the LED display on the sensor shows red.

⇒ Set the selector switch back to the original position and fit the terminals cover.

3.2 Power supply to FCM-20 modules and fuel pump actuators

⇒ Check in power supply box E85 if all of the corresponding circuit breakers are cut in (see also Location of flex Electronic Components 9362-1 and block diagram in box E85).

⇒ Check the main supply switch-over functions by cutting out in the AC #1 at the main switch board (plant side). WECS-9520 must remain in full operation.

☞ *Remark* : Carry out the above check only at engine standstill, e.g. during the start preparations.

3.3 Pressure switch PS5017C on shut-off valve

☞ *Remark* : If the pressure switch PS5017C on the shut-off valve is defective, starting in LOCAL MANUAL CONTROL mode (Local Control) is not possible.

⇒ At engine standstill, push LOCAL MANUAL CONTROL (Local Control) at WECS-9520 manual control panel (see 4618-1).

⇒ Check the indications of the turning gear:

- engaged = switch open
- disengaged = switch closed

3.5 Starting air control valves

⇒ Switch off one of the starting air control valves activated by FCM-20 of cylinder1 or 2 in the remote control (user parameter, function 'Start Valves Checking').

⇒ Carry out an engine start with starting air (AIR RUN) only or slow turning.

⇒ Repeat the test procedure with the second control valve.

Remark : After every start attempt, WECS-9520 reactivates both control valves automatically.

4. Recommendations for replacing FCM-20 modules

- Carry out at engine standstill if possible.
- Cut out the power supply to the modules concerned and control box E90.
- Insert 'Online Spare' module from control box E90.
- The control box E90 must subsequently be completed with a new module as 'Online Spare' which will receive a download of all application data.

Overview

1. General

The DENIS-9520 (**D**iesel **E**ngine Co**N**trol and Opt**I**mizing **S**pecification) and the WECS-9520 (**W**ärtsilä **E**ngine **C**ontrol **S**ystem) have been designed in such a manner, that various remote controls can be used. To this end all nodes are exactly defined. Terminal boxes are mounted on the engine, to which the cable ends from the control room or from the bridge (depending on remote control) can be connected.

The engine control comprises all parts which are necessary for operation, monitoring and safety of the engine.

Synopsis of engine control *(4003-2):*

The **Control Diagram** is a schematic synopsis of all control components and of their functional connections.

All code numbers and designations used in the following description are found in the control diagram and summary 4003-2.

2. Functions of control

The engine control permits carrying out the following functions:

- Starting, operation, manoeuvring and shutting down.
- Regulating the engine speed.
- Partly safeguarding and monitoring the engine.

All functions can be checked (see paragraph 4. 'Checking the engine control system before commissioning the engine').

Interlocks protect against and prevent manoeuvring errors.

Medium of the control	Pressure
Control air from board system	0.7 ~ 0.8 MPa 1)
Control air from starting air bottle	max. 2.45 MPa 2)
Starting air from starting air bottle	max. 2.45 MPa
Main bearing and piston cooling oil	0.48 ~ 0.6 MPa
Crosshead bearing oil	1.0 ~ 1.2 MPa
Servo oil	7.5 ~ 20.0 MPa
Control oil	20.0 MPa

1) Adjusted to 0.65 MPa with pressure reducing valve 23HA

2) Adjusted to 0.60 MPa with pressure reducing valve 19HA

3. Engine local control

The engine can be operated on local control panel (see also 4618-1).

This mode of operation can be chosen e.g. in case of electronic speed control system or remote control failures. The operator may under no circumstances leave the local control panel. He must regularly observe the engine speed enabling him to immediately adjust the fuel supply when the speed varies to some extent.

Additional preparation:

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

Starting:

⇒ Start auxiliary blowers.

⇒ Press button FUEL CONTROL MODE.

⇒ Turn rotary knob for fuel injection quantity to approx. 15% start fuel charge (see display).

⇒ Press requested button START AHEAD or START ASTERN until the engine runs.

⇒ Slowly adjust rotary knob for fuel injection quantity until the engine runs at the required speed. The corresponding value can be read on display and speed indicator.

Reversing:

⇒ Turn rotary knob to 15% fuel injection quantity (see display).

⇒ Press requested button START AHEAD or START ASTERN until the engine runs in the correct direction.

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

Stopping:

⇒ Reduce engine speed / load with rotary knob.

⇒ Press button STOP.

☞ **Remark** : The above mentioned starting procedure may also be carried out on ECR manual control panel.
However, buttons and rotary knob function only in the corresponding mode of operation, i.e. with active control stand (see 4618-1 'WECS-9520 manual control panel').

4. Checking the engine control system

Should elements of the pneumatic control system have been dismantled, removed or replaced during an overhaul, then a general operational check must be made before recommissioning. The following passages describe how to proceed.

The item numbers of the following mentioned valves and designations correspond to those in the schematic engine control diagram 4003-2.

CAUTION: Any detected leakages must be eliminated during checking the control system!

4.1 General preparatory works

⇒ Open indicator valves.
⇒ Close shut-off valves on starting air bottles. Close shut-off valve for starting air (2.03) with handwheel (2.10). Vent starting air supply pipe with venting valve (2.21).
⇒ Vent starting air distributor main using venting valve (2.27).
⇒ Vent control air bottle 287HA.
⇒ Engage turning gear.
⇒ Remove roller lifting tools if fitted.
- Control oil pumps (3.72-1) and (3.72-2) must be cut out (main switch).

4.2 Control air supply unit [A]

⇒ Open 2.45 MPa feed to control air supply unit using shut-off cock 36HC at connection A2.
⇒ Adjust air for air spring and control air to **0.60 MPa** with reducing valve 19HA. For this shut-off cock (4.08) must be open. The pressure can be checked on pressure gauge PI4341M.
⇒ Open 0.8 MPa feed from board supply system to control air supply unit using shut-off cock 36HB at connection A1.
⇒ Adjust air for air spring and control air to **0.65 MPa** with reducing valve 23HA. The pressure can be checked on pressure gauges.
⇒ Make sure air is fed to valve unit [E] via blocking valve (2.13).

4.3 Starting up of WECS-9520 control system

- Switch on all breakers in the power supply boxes E85.
- Check that both green indication LEDs light up on all FCM-20 modules.
- The FCM-20 modules are able to function if no red LEDs light up after the countdown process.

4.4 Safety and alarm system

⇒ WECS-9520, RCS, safety system, alarm and monitoring system must be switched on.

⇒ Actuate EMERGENCY STOP on the control room console as well as on the local control panel. Check each time if fuel shut-down pilot valve (3.08) is electrically activated (i.e. the coil is energized).

- For the safety system the setting of the pressure switches must be carried out with falling pressures by means of the compressed air pump (tool), in accordance with the following table :

Medium	Code No.	Pressure	Action
Main bearing oil	PS2002S	0.46 MPa	Stop
T/C bearing oil	PS2620S	0.07 MPa	Stop
Air spring	PS4341S	0.45 MPa	Stop

Remark : Valid settings see Operating Data Sheet 0250–2.

- For passive failure monitoring a resistor must be inserted in the plug of the following pressure switches between connections 1 and 2:
- PS2002S
- PS2620S
- PS4341S

The value of the resistors depends on the remote control supplier:

Supplier	Resistor [kOhm]	Power [W]
KONGSBERG Maritime	10	0.6
NABTESCO	3.9	0.25
SAM / Lyngsø	8.2	0.6

⇒ Trigger a system alarm in the oil mist detection system by means of:

– removing a plug from the junction box or

– starting the 'Test Menu' in the control unit.

⇒ Connect smoke testing instrument (tool) to test connection on a sensor. Simulate oil mist and with that trigger an alarm in the safety system.

⇒ Check pick-ups for speed measurement:

– Turn crankshaft with turning gear. LEDs on speed pick-ups go on and off in the pattern of passing teeth.

⇒ Check level switches in the condensate drain units. Release a high-level alarm by manual actuating of the floater.

⇒ Check level switch in the leakage oil return. Release a high-level alarm by manual actuating of the floater.

4.5 Automatic filter

⇒ Ensure compressed air at the automatic filter. Check whether stop valve (4.37) is open in oil pipe before automatic filter, and stop valve is closed in pressure compensating pipe near the oil outlet.

⇒ Ensure power supply at control box and turn on main switch.

⇒ For checking the parameter setting, press both the 'C' and 'Q' buttons till the green LED goes out.

⇒ For adjusting the parameters setting, press the 'F' button till the green LED blink.

On the display the parameters can be adjusted as follows:
(See also instructions of filter manufacturer)

Function	Parameter	Adjustment
Flushing interval in h	PA2	1
Flushing interval in min.	PA3	0
Flushing interval in sec.	PA4	20
Flushing interval monitoring (alarm)	PA8	ON

⇒ For saving the adjusted parameter setting, press the 'F' button till the green LED goes out.

⇒ For re-operating, press both the 'C' and the 'Q' button till the green LED comes on.

⇒ Touch 'Flushing' button on the display. A flushing cycle of 20 seconds duration must now be initiated.

⇒ Observe whether the motor of the rotating device turns in the indicated direction (clockwise viewed from top).

4.6 Auxiliary blowers

⇒ Switch on electric power supply for all auxiliary blowers.

⇒ Start all auxiliary blowers.

In case of providing the time delay in the auxiliary blower control box

- Auxiliary blower 1 must start immediately.
- Other auxiliary blowers must start with a delay of setting time.

⇒ This delay period can be set on time relay in the auxiliary blower control box.

⇒ Check rotation direction of all auxiliary blowers.

⇒ Pressure switches PS4051C, PS4052C and PS4053C, which are adjusted to correct pressure setting, must be provided for the each auxiliary blower.

If these pressure switches is adjusted with wrong pressure setting, these pressure switches must be re-adjusted as following,

⇒ For pressure switches connect compressed air pump, simulate scavenge air pressure.

⇒ With rising air pressure the individual auxiliary blowers must be switched off by their differential pressure switches at a pressure of 0.046 MPa.

⇒ With sinking pressure the auxiliary blowers must be switched on at a pressure of 0.034 MPa.

⇒ This pressure of 0.034 MPa has to be set on each differential pressure switch.

⇒ The individual auxiliary blowers are again switched on with time delay.

⇒ Remove compressed air pump.

4.7 Cylinder lubrication

Please refer to the 7218-1

4.8 Control oil and servo oil system

⇒ Start main bearing oil pump and check whether the operating pressure is properly adjusted.

⇒ Start control oil pump (3.72-1) and check control oil pressure of 20.0 MPa.
If necessary adjust pressure by means of pressure retaining valve (3.73-1A).
The pressure can be read off on display of WECS-9520 manual control panel (4618-1).

Remark : At engine standstill and low load, the control oil pressure may be indicated slightly higher, according to oil temperature and adjustment at shop. The control oil pressure is adjusted with 20.0 MPa at high load (e.g. MCMR).

⇒ Stop control oil pump (3.72-1).

⇒ Start control oil pump (3.72-2) and check control oil pressure of 20.0 MPa.
If necessary adjust pressure by means of pressure retaining valve (3.73-2A).
The pressure can be read off on display of WEC-9520 manual control panel.

⇒ Open stop valves (4.30-1 to 4) in the connection between servo oil rail and control oil rail.

⇒ Adjust pressure in servo oil rail (4.11) to 7.5 MPa by means of pressure reducing valve (4.27). The pressure can be read off on display of WECS-9520 manual control panel.

4.9 Exhaust valve drive

⇒ Open exhaust valve (4.01) of cylinder 1 manually in remote control
(user parameter, function 'Exv. A/M Cmd').

⇒ Simultaneously with opening the exhaust valve, note indicated values (mA) in remote control, EXV of fields 'Open position sensor 1/2'.

Remark : These values must be noted immediately after opening the exhaust valve, since the valve will automatically close slowly.

⇒ Shut exhaust valve (4.01) of cylinder 1.

⇒ With exhaust valve closed, note indicated values (mA) in remote control, EXV of fields 'Open position sensor 1/2'.

⇒ Repeat procedure above for each exhaust valve.

- The shown values shall be approximately the same for all cylinders. If not, the valve is not fully open or the sensors are defective.

⇒ Set parameters of each exhaust valve drive to AUTO in remote control
(user parameter, function 'Exv. A/M Cmd').

4.10 Regulating linkage

⇒ Verify if the regulating linkages to the fuel pumps have been fitted according to Maintenance Manual 5801-1 'Adjusting the regulating linkage'.

⇒ Ensure that the regulating linkage moves freely over the entire stroke.

CAUTION

Never switch on actuators which are disconnected from the regulating linkage, nor disconnect the regulating linkage of already powered up actuators!
This leads to actuator damages!

4.11 Fuel oil system

⇒ Start fuel booster pump (3.15).

⇒ Check if the pressure before supply unit has be set to 0.7 ~ 1.0 MPa. If not, the pressure before supply unit should be adjusted to the correct pressure value with the pressure retaining valve (3.53) (at ship side). The pressure before supply unit can be read off pressure gauge PI3421L (setting values see also Operating Data Sheet 0250-1).

⇒ All stop valves after intermediate fuel accumulator (3.04) and before fuel rail (3.05) must be open.

⇒ Check whether knurled screw is adjusted and tightened at its lower stop corresponding to the opening pressure on fuel pressure control valve (3.06).

⇒ Loosen plugs (3.35) by two to three turns of the first and last cylinders on injection control units (3.02). Close and tighten them with a torque of 270 Nm as soon as fuel flows bubble-free.

⇒ Remove plug (3.39) and the nut with conical plug on stop valve (3.40) and connect the pipe (tool 94583) between fuel rail (3.05) and control oil rail (3.75).

⇒ Start main bearing oil pump and control oil pump (3.72-1).

⇒ Open stop valve (3.40) between control oil rail and fuel rail. Fuel rail must now be pressurized with 12.0 ~ 20.0 MPa.

⇒ Start the venting function of the injection system in remote control (user parameter, functions 'Inj. Venting' and 'Venting all').

- The fuel pressure shall not drop too much, then the venting function is completed.

⇒ Press all EMERGENCY STOP buttons, triggering a shut-down.

- Fuel pressure control valve (3.06) must open at once, and the pressure in fuel rail (3.05) must drop to '0' MPa. This pressure drop can be watched on display of WECS-9520 manual control panel (4618-1).

⇒ Close stop valve (3.40).

⇒ Relieve pressure in fuel rail (3.05) and control oil rail (3.75). Remove the pipe (tool 94583) between fuel rail (3.05) and control oil rail (3.75). Refit and tighten plug (3.39) and the nut with conical plug.

⇒ Reset EMERGENCY STOP so that the system is operative again.

4.12 Starting system and start interlock

Start interlock:

- Shut-off valve for starting air (2.03) is closed and starting air supply piping vented.
- Turning gear is engaged.

⇒ Loosen the piping to valve unit $\boxed{E}$ at connection E6. **No** air must come out of the pipe.

⇒ Slowly disengage turning gear. As long as the pinion of the turning gear is engaged, and as long as the clearance between the tooth of the flywheel and the pinion of the turning gear does not exceed 10 mm, no air must issue from the piping. This check has to be made when engaging and disengaging the turning gear.

⇒ Reconnect the piping to connection E6. Disengage the turning gear.

Shut-off valve for starting air:

⇒ Remove shuttle valve 115HA from valve unit E.
(pay attention not to lose the three O-rings!)

⇒ Press button LOCAL MANUAL CONTROL at WECS-9520 manual control panel (see 4618-1) in order to takeover the control.

⇒ Press button AIR RUN.

⇒ Check that both solenoid valves ZV7013C and ZV7014C are energized (using screwdriver or magnet tester), and control air comes out at both outer bores at shuttle valve place in valve unit E.

- Shut-off valve for starting air (2.03) manually closed, no active shut-downs released, the auxiliary blowers start and turning gear disengaged.

⇒ Press button START AHEAD at WECS-9520 manual control panel.

- Indications 'Start Interlock' must be displayed on WECS-9520 manual control panel. No start command is released.

⇒ Carry out same test with START ASTERN button.

- Control air comes out at both outer bores at shuttle valve place in valve unit E.

⇒ Refit shuttle valve 115HA with O-rings in valve unit E.

Turning gear interlocks:

- Turning gear is engaged.

⇒ Check whether pressure switch PS5017C (switching point 0.2 MPa) and switch ZS5016C are not activated (open contact).

- Indication 'Turning Gear Engaged' must be displayed on both WECS-9520 manual control panels, i.e. at the control room console and local control panel.

CAUTION: It must be ensured that the engine is ready for service, shut-off valve for starting air (2.03) is closed and starting air supply piping vented.

⇒ Press button LOCAL MANUAL CONTROL at WECS-9520 manual control panel (see 4618-1) in order to takeover the control.

⇒ Press button START AHEAD.

- Indication 'Start Interlock' must be displayed on both WECS-9520 manual control panels. No start command is released.

⇒ Repeat test also from ECR manual control panel and with remote control.

⇒ Disengage turning gear.

- Indication 'Start Interlock' disappears from both WECS-9520 manual control panels. Start command is cleared in remote control.

4.13 Overspeed system and start preparations

⇒ Close venting valves (2.21) and (2.27). Put handwheel (2.10) of shut-off valve for starting air (2.03) in position AUTOMAT and open shut-off valves at the starting air bottles.

- Turning gear is disengaged.

⇒ Set the overspeed safeguard monitoring to < 30 min^{-1}.

⇒ Make absolutely sure that the safety system checks have been carried out successfully and fuel shut-down pilot valve (3.08) functions properly.

⇒ Switch on main bearing, crosshead and control oil pumps, and if there are oil pumps for turbochargers with external supply.

⇒ Switch on cooling water pumps.

⇒ Press button LOCAL MANUAL CONTROL at WECS-9520 manual control panel (see 4618-1) in order to takeover the control.

⇒ Start the engine with air only by pressing AIR RUN button.

- When the engine reaches a speed of 30 min^{-1}, the overspeed monitoring should respond, activating a shut-down.
- Fuel pressure control valve (3.06) must open, and existing pressure in fuel rail (3.05) must drop at once. This can be watched on display of WECS-9520 manual control panel.
- At the same time the fuel pump actuators move the regulating linkages to position '0'.

⇒ Reset the overspeed monitoring so that the system is operative again.

- If these overspeed tests have been successfully completed, the overspeed monitoring in the safety system can be set to nominal speed +10%.

4.14 Start on fuel oil

- The engine is ready for service (see 0110–1 'Checks and preparations').

⇒ Turn the engine with air by pressing AIR RUN button.

⇒ Press button FUEL CONTROL MODE.

⇒ Set fuel injection quantity to 25% with rotary knob on local control panel.

⇒ The engine can now be started by pressing START AHEAD button on WECS-9520 manual control panel. Regulate the speed by means of rotary knob for fuel injection quantity. Run the engine until all cylinders fire regularly.

⇒ Press button STOP. The engine stops.

⇒ At WECS-9520 manual control panel, press button REMOTE AUTO. CONTROL for mode transfer to remote control.

⇒ After takeover the engine can be started via remote control.

Designations (Description to 4003-1 and 4003-2)

1. Summary of part code number

- A Control air supply unit
- B Fuel supply
- C Fuel injection
- D Servo oil supply
- E Valve unit for start
- F Exhaust valve drive
- G Supply unit
- H Instrument panel
- I Pressure switches, pressure transmitters
- K Local control panel
- L Control oil pump unit

1.	Speed setting system	3.	Fuel system
01	Crank angle sensor unit	38	Plug (only for emergency operation)
04	Pick-ups	39	Plug
2.	**Starting system**	40	Stop valve
03	Shut off valve for starting air	41	Injection control valve
04	Non-return valve	42	Fuel quantity piston
05	Control valve	43	Actuator piston
06	Drain and test valve	45	Control oil return piping
07	Starting valve	46	Fuel leakage pipe
08	Flame arrester	47	Injection pipe
09	Relief valve	48	Fuel leakage pipe pressurized
10	Handwheel for shut-off valve	49	Fuel leakage pipe injector
13	Blocking valve on turning gear	51	Non-return valve
21	Venting valve	52-1	Fuel overpressure safety valve
27	Venting valve	52-2	Fuel overpressure safety valve
3.	**Fuel system**	53	Pressure retaining valve (at ship side)
01	Fuel injection valve	54	Filling connection
02	Injection control unit	55	Camshaft
03	Fuel quantity sensor	56	Non-return valve
04	Intermediate fuel accumulator	62-1	Stop valve
05	Fuel rail	62-2	Stop valve
06	Fuel pressure control valve	67	Non-return valve
08	Fuel shut-down pilot valve	68	Drain valve
10	Level switch	70	Overflow pipe
12	Leakage inspection point	71	Return valve
14	Fuel pumps	72-1	Control oil pump 1
15	Fuel booster pump	72-2	Control oil pump 2
19	Cut-out device (tool)	73-1A	Pressure retaining valve
20	Fuel pump linkage	73-1B	Safety valve
21	Fuel pump actuator	73-2A	Pressure retaining valve
22	Non-return valve	73-2B	Safety valve
24	Fuel inlet pipe	74	HP control oil piping
28	Piping	75	Control oil rail
29	Fuel rising pipe	76	Rail valve
33-1	Stop valve	77-1	Pressure transmitter
33-2	Stop valve	77-2	Pressure transmitter
33-3	Stop valve	78	Pressure transmitter
33-4	Stop valve	79-1	Stop valve
34	Non-return valve with throttle	79-2	Stop valve
35	Plug	80-1	Stop valve
37	Plug (only for emergency operation)	80-2	Stop valve

Designations (Description to 4003-1 and 4003-2)

4.	Exhaust valve dive	4.	Exhaust valve drive
01	Exhaust valve	66	Hydraulic pipe
01	Air spring	68	Disc spring
02	Non-return valve	69	Two-stage piston
06	Non-return valve with throttle	70-1	Stroke sensor
08	Air spring venting	70-2	Stroke sensor
10	Exhaust valve drive	71	Stroke measuring device
11	Servo oil rail	72	Drain valve
14	Leakage inspection point	76	Rail valve
15	Servo oil pump	77-1	Pressure transmitter
16	Pressure control valve	77-2	Pressure transmitter
18	Level switch	**7.**	**Monitoring**
20	Automatic filter	18	Collector for leakage oil from air spring
22	Crankcase		
23	Safety valve	**9.**	**Engine room**
24	Non-return valve	01	Starting air bottles
25-1	Stop valve		
25-2	Stop valve		
26-1	Stop valve		
26-3	Stop valve		
26-4	Stop valve		
27	Pressure reducing valve		
29	Non-return valve		
30-1	Stop valve		
30-2	Stop valve		
30-3	Stop valve		
30-4	Stop valve		
32	Plug		
33	Plug		
34	Plug		
35	Non-return valve		
36	Stop valve		
37	Stop valve		
39	Gear wheel crankshaft		
41	Intermediate wheel supply unit		
42	Gear wheel		
44	Gear wheel		
45	Pinion		
50	Shaft with shearable overload protection		
51	Supply pipe		
52	Collector block		
54	Flow sensor		
55	Servo oil rising pipe		
63	Servo oil return pipe		
64-1	Pressure retaining valve		
64-2	Pressure retaining valve		

Designations (Description to 4003-1 and 4003-2)

	Sensors		Actuators
PT2051A	Servo oil pump inlet pressure	**CV**7231~34C	Fuel pump actuator A1~B2
PT2071C	Servo oil pressure	CV7221~25C	Servo oil pump actuator No. 1~5
PT2072C	Servo oil pressure		
PT2081C	Control oil pressure	**XS**5046~49A	Fuel pump actuator failure
PT2083A	Control oil pressure, leak		
PT3421A	Fuel pressure supply unit	**ZV**7201~11A/B	Exhaust valve drive Cyl. 1~11
PT3461C	Fuel rail pressure	ZV7201~11C~H	Injection control unit Cyl. 1~11
PT3462C	Fuel rail pressure	ZV7241~51C	Starting air pilot valve Cyl. 1~11
		ZV7061S	EM. STOP (Fuel SHD pilot valve)
		ZV7013C	Common start valve 1
LS2055A	Servo oil supply unit, leak	ZV7014C	Common start valve 2
LS2085A	Control oil supply unit, leak		**Local indications**
LS3426A	Fuel supply unit, leak	**PI**2051L	Servo oil pump (inlet pressure)
LS3444A	Rail unit general leakage (DE)	PI2071M	Servo oil pressure
LS3445A	Rail unit general leakage (FE)	PI2081M	Control oil pressure
LS3446A	Injection control unit or pipe for injection valve leak (DE)	PI3421L	Fuel pressure supply unit inlet
LS3447A	Injection control unit or pipe for injection valve leak (FE)	PI3462M	Fuel rail pressure
		LI2056L	Servo oil pipe, leak ind. Upper section
FS2061~65A	Servo oil pump 1~5 (flow)	LI2057L	Servo oil pipe DE, leak ind. lower section
GT5126C	Crank angle sensor 1	LI2058L	Servo oil pipe, leak ind. Upper section
GT5127C	Crank angle sensor 2	LI2059L	Servo oil pipe FE, leak ind. lower section
TE3431~38C	Fuel pump A1~B4 Outlet temperature	LI3427L	Fuel supply unit, pump and HP pipe leak
		LI3428L	Fuel supply unit, HP pipe DE and FE and Intermediate fuel accumulator, leak
ZS5016C	Turning gear disengaged		
ZS5018C	Start air shut-off valve man. closed	LI3429L	Fuel relief valves, leak
		LI3452L	Fuel HP pipe DE leak ind. lower section
ZS5123C	Engine TDC signal	LI3453L	Fuel HP pipe, leak ind. upper section
		LI3455L	Fuel HP pipe FE leak ind. lower section
ZT5421~31C	Exhaust valve 1~14, open and close positions (drive end)	LI3456L	Fuel HP pipe, leak ind. upper section
ZT5441~51C	Exhaust valve 1~14, open and close positions (free end)	**FI**2076L	Exhaust valve hydraulic oil, HPpipe Leakage indication on exhaust valve drive
ZT5461~71C	Fuel injection quantity cylinder 1~14		
		SI5101M	Engine speed

Designations (Description to 4003-1 and 4003-2)

1. Summary of part code number

- [A] Control air supply unit
- [B] Fuel supply
- [C] Fuel injection
- [D] Servo oil supply
- [E] Valve unit for start
- [F] Exhaust valve drive
- [G] Supply unit
- [H] Instrument panel
- [I] Pressure switches, pressure transmitters
- [K] Local control panel
- [L] Control oil pump unit

1.	**Speed setting system**
01	Crank angle sensor unit
04	Pick-ups
2.	**Starting system**
03	Shut off valve for starting air
04	Non-return valve
05	Control valve
06	Drain and test valve
07	Starting valve
08	Flame arrester
09	Relief valve
10	Handwheel for shut-off valve
13	Blocking valve on turning gear
21	Venting valve
27	Venting valve
3.	**Fuel system**
01	Fuel injection valve
02	Injection control unit
03	Fuel quantity sensor
04	Intermediate fuel accumulator
05	Fuel rail
06	Fuel pressure control valve
08	Fuel shut-down pilot valve
10	Level switch
12	Leakage inspection point
14	Fuel pumps
15	Fuel booster pump
19	Cut-out device (tool)
20	Fuel pump linkage
21	Fuel pump actuator
22	Non-return valve
24	Fuel inlet pipe
28	Piping
29	Fuel rising pipe
33-1	Stop valve
33-2	Stop valve
33-3	Stop valve
33-4	Stop valve
34	Non-return valve with throttle
35	Plug
37	Plug (only for emergency operation)

3.	**Fuel system**
38	Plug (only for emergency operation)
39	Plug
40	Stop valve
41	Injection control valve
42	Fuel quantity piston
43	Actuator piston
45	Control oil return piping
46	Fuel leakage pipe
47	Injection pipe
48	Fuel leakage pipe pressurized
49	Fuel leakage pipe injector
51	Non-return valve
52-1	Fuel overpressure safety valve
52-2	Fuel overpressure safety valve
53	Pressure retaining valve (at ship side)
54	Filling connection
55	Camshaft
56	Non-return valve
62-1	Stop valve
62-2	Stop valve
67	Non-return valve
68	Drain valve
70	Overflow pipe
71	Return valve
72-1	Control oil pump 1
72-2	Control oil pump 2
73-1A	Pressure retaining valve
73-1B	Safety valve
73-2A	Pressure retaining valve
73-2B	Safety valve
74	HP control oil piping
75	Control oil rail
76	Rail valve
77-1	Pressure transmitter
77-2	Pressure transmitter
78	Pressure transmitter
79-1	Stop valve
79-2	Stop valve
80-1	Stop valve
80-2	Stop valve

Designations (Description to 4003-1 and 4003-2)

4.	Exhaust valve dive	4.	Exhaust valve drive
01	Exhaust valve	66	Hydraulic pipe
01	Air spring	68	Disc spring
02	Non-return valve	69	Two-stage piston
06	Non-return valve with throttle	70-1	Stroke sensor
08	Air spring venting	70-2	Stroke sensor
10	Exhaust valve drive	71	Stroke measuring device
11	Servo oil rail	72	Drain valve
14	Leakage inspection point	76	Rail valve
15	Servo oil pump	77-1	Pressure transmitter
16	Pressure control valve	77-2	Pressure transmitter
18	Level switch	**7.**	**Monitoring**
20	Automatic filter	18	Collector for leakage oil from air spring
22	Crankcase		
23	Safety valve	**9.**	**Engine room**
24	Non-return valve	01	Starting air bottles
25-1	Stop valve		
25-2	Stop valve		
26-1	Stop valve		
26-3	Stop valve		
26-4	Stop valve		
27	Pressure reducing valve		
29	Non-return valve		
30-1	Stop valve		
30-2	Stop valve		
32	Plug		
33	Plug		
34	Plug		
35	Non-return valve		
36	Stop valve		
37	Stop valve		
39	Gear wheel crankshaft		
41	Intermediate wheel supply unit		
42	Gear wheel		
44	Gear wheel		
45	Pinion		
50	Shaft with shearable overload protection		
51	Supply pipe		
52	Collector block		
54	Flow sensor		
55	Servo oil rising pipe		
63	Servo oil return pipe		
64-1	Pressure retaining valve		
64-2	Pressure retaining valve		

Designations (Description to 4003-1 and 4003-2)

	Sensors		Actuators
PT2051A	Servo oil pump inlet pressure	**CV**7231~34C	Fuel pump actuator A1~B2
PT2071C	Servo oil pressure	CV7221~25C	Servo oil pump actuator No. 1~5
PT2072C	Servo oil pressure		
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PT3421A	Fuel pressure supply unit	**ZV**7201~11A/B	Exhaust valve drive Cyl. 1~11
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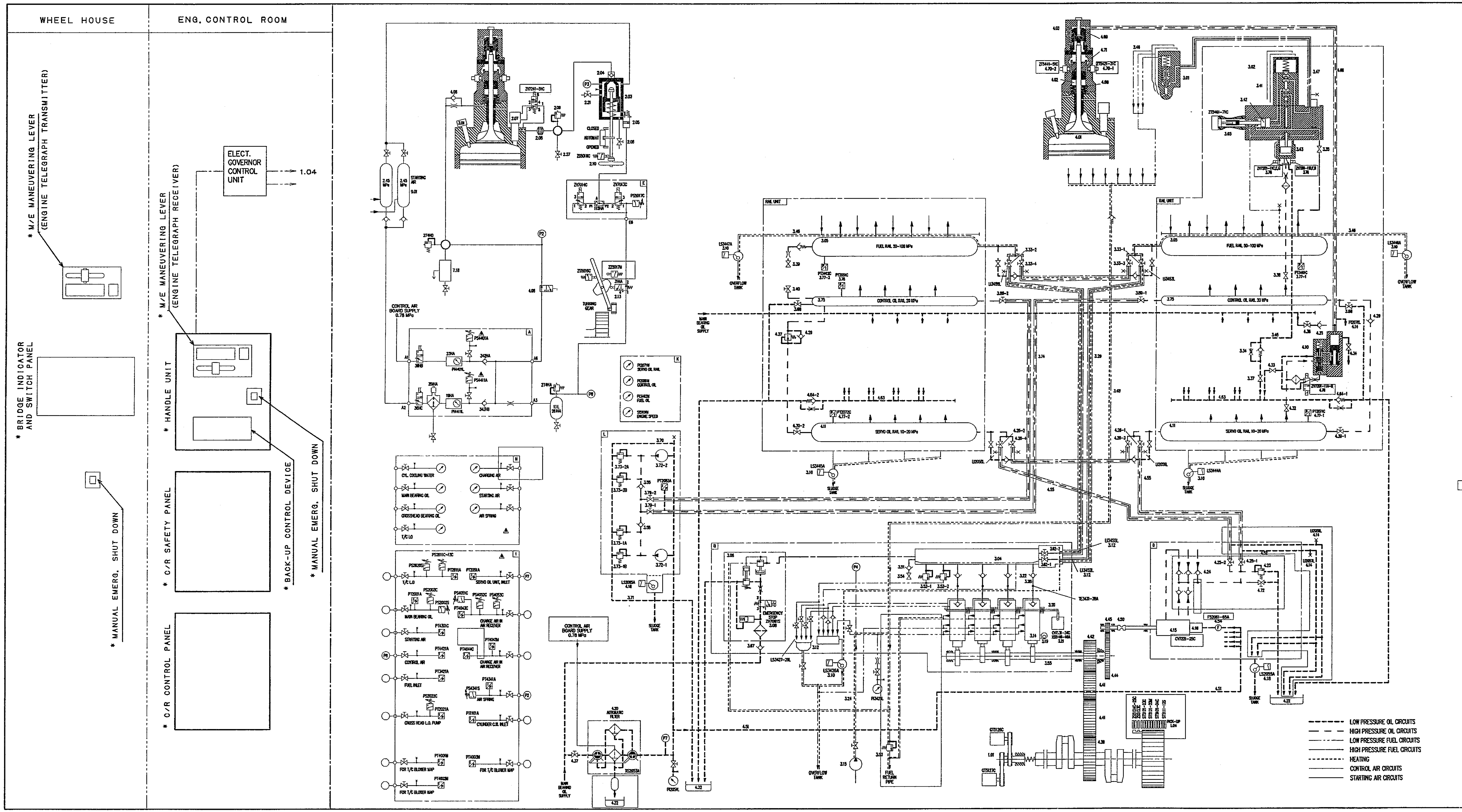
		ZV7013C	Common start valve 1
LS2055A	Servo oil supply unit, leak	ZV7014C	Common start valve 2
LS2085A	Control oil supply unit, leak		**Local indications**
LS3426A	Fuel supply unit, leak	**PI**2051L	Servo oil pump (inlet pressure)
LS3444A	Rail unit general leakage (DE)	PI2071M	Servo oil pressure
LS3445A	Rail unit general leakage (FE)	PI2081M	Control oil pressure
LS3446A	Injection control unit or pipe for injection valve leak (DE)	PI3421L	Fuel pressure supply unit inlet
LS3447A	Injection control unit or pipe for injection valve leak (FE)	PI3462M	Fuel rail pressure
		LI2056L	Servo oil pipe, leak ind. Upper section
FS2061~65A	Servo oil pump 1~5 (flow)	LI2057L	Servo oil pipe DE, leak ind. lower section
GT5126C	Crank angle sensor 1	LI2058L	Servo oil pipe, leak ind. Upper section
GT5127C	Crank angle sensor 2	LI2059L	Servo oil pipe FE, leak ind. lower section
TE3431~38C	Fuel pump A1~B4 Outlet temperature	LI3427L	Fuel supply unit, pump and HP pipe leak
		LI3428L	Fuel supply unit, HP pipe DE and FE and Intermediate fuel accumulator, leak
ZS5016C	Turning gear disengaged		
ZS5018C	Start air shut-off valve man. closed	LI3429L	Fuel relief valves, leak
		LI3452L	Fuel HP pipe DE leak ind. lower section
ZS5123C	Engine TDC signal	LI3453L	Fuel HP pipe, leak ind. upper section
		LI3455L	Fuel HP pipe FE leak ind. lower section
ZT5421~31C	Exhaust valve 1~14, open and close positions (drive end)	LI3456L	Fuel HP pipe, leak ind. upper section
ZT5441~51C	Exhaust valve 1~14, open and close positions (free end)	**FI**2076L	Exhaust valve hydraulic oil, HPpipe Leakage indication on exhaust valve drive
ZT5461~71C	Fuel injection quantity cylinder 1~14		
		SI5101M	Engine speed

4003-2/A1



3rd ANGLE PROJECTION

PLAN RECORD

ISO METRIC SCREW THREADS

A CONTROL AIR SUPPLY UNIT
B FUEL SUPPLY

D SERVO OIL SUPPLY
E VALVE UNIT FOR START

H INSTRUMENT PANEL
I PRESSURE SWITCHES AND PRESSURE TRANSMITTERS
K LOCAL CONTROL PANEL
L CONTROL OIL PUMP UNIT

1. SPEED SETTING SYSTEM
1.01 CRANK ANGLE SENSOR UNIT
1.04 SPEED PICK-UPS

2. STARTING SYSTEM
2.03 SHUT OFF VALVE FOR STARTING AIR
2.04 NON-RETURN VALVE
2.05 CONTROL VALVE
2.06 DRAIN AND TEST VALVE
2.07 STARTING VALVE
2.08 FLAME ARRESTER
2.09 RELIEF VALVE
2.10 HANDWHEEL FOR SHUT OFF VALVE
2.13 BLOCKING VALVE ON TURNING GEAR
2.21 VENTING VALVE
2.27 VENTING VALVE

3. FUEL SYSTEM
3.01 FUEL INJECTION VALVE
3.02 INJECTION CONTROL UNIT
3.03 FUEL QUANTITY SENSOR
3.04 INTERMEDIATE FUEL ACCUMULATOR
3.05 FUEL RAIL
3.06 FUEL PRESSURE CONTROL VALVE
3.08 FUEL SHUTDOWN PILOT VALVE
3.10 LEVEL SWITCH
3.12 LEAKAGE INSPECTION DEVICE
3.14 FUEL PUMPS
3.15 FUEL BOOSTER PUMP (PLANT)
3.19 CUT-OUT DEVICE (TOOL)
3.20 FUEL PUMP LINKAGE
3.21 FUEL PUMP ACTUATOR
3.22 NON-RETURN VALVE
3.24 FUEL INLET PIPE
3.28 PIPING
3.29 FUEL RISING PIPE
3.33-1 STOP VALVE
3.33-2 STOP VALVE
3.33-3 STOP VALVE
3.33-4 STOP VALVE
3.34 NON-RETURN VALVE WITH THROTTLE
3.35 PLUG
3.37 PLUG
3.38 PLUG
3.39 PLUG
3.40 STOP VALVE
3.41 INJECTION CONTROL VALVE
3.42 FUEL QUANTITY PISTON
3.43 ACTUATOR PISTON
3.45 CONTROL OIL RETURN PIPING
3.46 FUEL LEAKAGE PIPE
3.47 INJECTION PIPE
3.48 FUEL LEAKAGE PIPE PRESSURIZED
3.49 FUEL LEAKAGE PIPE INJECTOR
3.51 NON-RETURN VALVE (FILLING)
3.52-1 FUEL OVERPRESSURE SAFETY VALVE
3.52-2 FUEL OVERPRESSURE SAFETY VALVE
3.53 PRESSURE RETAINING VALVE (at SHIP SIDE)
~~3.54 FILLING PLUG~~
3.55 CAMSHAFT
3.56 NON-RETURN VALVE
3.62-1 STOP VALVE
3.62-2 STOP VALVE
3.67 NON-RETURN VALVE
3.68 DRAIN VALVE
3.70 OVERFLOW PIPE
3.71 RETURN PIPING
3.72-1 CONTROL OIL PUMP 1
3.72-2 CONTROL OIL PUMP 2
3.73-1A PRESSURE RETAINING VALVE
3.73-1B SAFETY VALVE
3.73-2A PRESSURE RETAINING VALVE
3.73-2B SAFETY VALVE
3.74 HP CONTROL OIL PIPING
3.75 CONTROL OIL RAIL
3.76 RAIL VALVE
3.77-1 PRESSURE TRANSMITTER
3.77-2 PRESSURE TRANSMITTER
3.78 PRESSURE TRANSMITTER
3.79-1 STOP VALVE
3.79-2 STOP VALVE
3.80-1 STOP VALVE
3.80-2 STOP VALVE

4. EXHAUST VALVE DRIVE
4.01 EXHAUST VALVE
4.02 AIR SPRING
4.03 VALVE DRIVE
4.06 NON-RETURN VALVE WITH THROTTLE
4.08 AIR SPRING VENTING
4.10 EXHAUST VALVE ACTUATOR
4.11 SERVO OIL RAIL
4.14 LEAKAGE INSPECTION DEVICE
4.15 SERVO OIL PUMP
4.16 PRESSURE CONTROL VALVE
4.18 LEVEL SWITCH
4.20 AUTOMATIC FILTER
4.22 CRANKCASE
4.23 SAFETY VALVE
4.24 NON-RETURN VALVE
4.25-1 STOP VALVE
4.25-2 STOP VALVE
4.26-1 STOP VALVE
4.26-2 STOP VALVE
4.26-3 STOP VALVE
4.26-4 STOP VALVE
4.27 PRESSURE REDUCING VALVE
4.29 NON-RETURN VALVE
4.30-1 STOP VALVE
4.30-2 STOP VALVE
4.32 PLUG
4.33 PLUG
4.34 PLUG
4.35 NON-RETURN VALVE
4.36 STOP VALVE
4.37 STOP VALVE
4.39 GEAR WHEEL CRANKSHAFT
4.41 INTERMEDIATE WHEEL SUPPLY UNIT
4.42 GEAR WHEEL
4.44 GEAR WHEEL
4.45 PINION
4.50 SHAFT WITH SHEARABLE OVERLOAD PROTECTION
4.51 SUPPLY PIPE
4.52 COLLECTOR BLOCK
4.54 FLOW SENSOR
4.55 SERVO OIL RISING PIPE
4.63 SERVO OIL RETURN PIPING
4.64-1 PRESSURE RETAINING VALVE
4.64-2 PRESSURE RETAINING VALVE
4.66 ACTUATOR PIPE
4.68 DISC SPRING
4.69 TWO-STAGE PISTON
4.70-1 STROKE SENSOR
4.70-2 STROKE SENSOR
4.71 STROKE MEASURING DEVICE
4.72 DRAIN VALVE
4.76 RAIL VALVE
4.77-1 PRESSURE TRANSMITTER
4.77-2 PRESSURE TRANSMITTER

7. MONITORING
7.18 COLLECTOR FOR LEAKAGE OIL FROM AIR SPRING

9. ENGINE ROOM
9.01 STARTING AIR BOTTLES

DRAWING NO.

1 SET	1 SET	MARK	DESCRIPTION	MATERIAL	TEST PIECE	WORKING / QUANTITY PER SET	SPARE	PER PIECE / WEIGHT (kg)	TOTAL	REMARKS
Jul.14.'05 M.I	Jul.14.'05 M.I	DATE / APPROVED	DIESEL ENGINE DEPARTMENT DIESEL ENGINE DESIGNING SECTION	MITSUBISHI SULZER 11RT-flex96c DIESEL ENGINE						
7-891158 7-891258 7-891358 0100	7-891458 7-891558 7-891658 0100	ORDER NO. / ITEM NO.	APPROVED / CHECKED / DRAWN / SCALE ~	ENGINE CONTROL DIAGRAM						
NAGASAKI S.2225 S.2226 S.2227	NAGASAKI S.2228 S.2233 S.2234	OWNER		DRAWING NO.						

納入用 工事用 組工作 (0) 組工作 手配係 組工作 組織係 アサミ 西 図 トレペ 係 合 計 A1 A3 COPY FOR

MHI KOBE SHIPYARD & MACHINERY WORKS DRAWN Jul.14.2005 DRAWN

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1. General

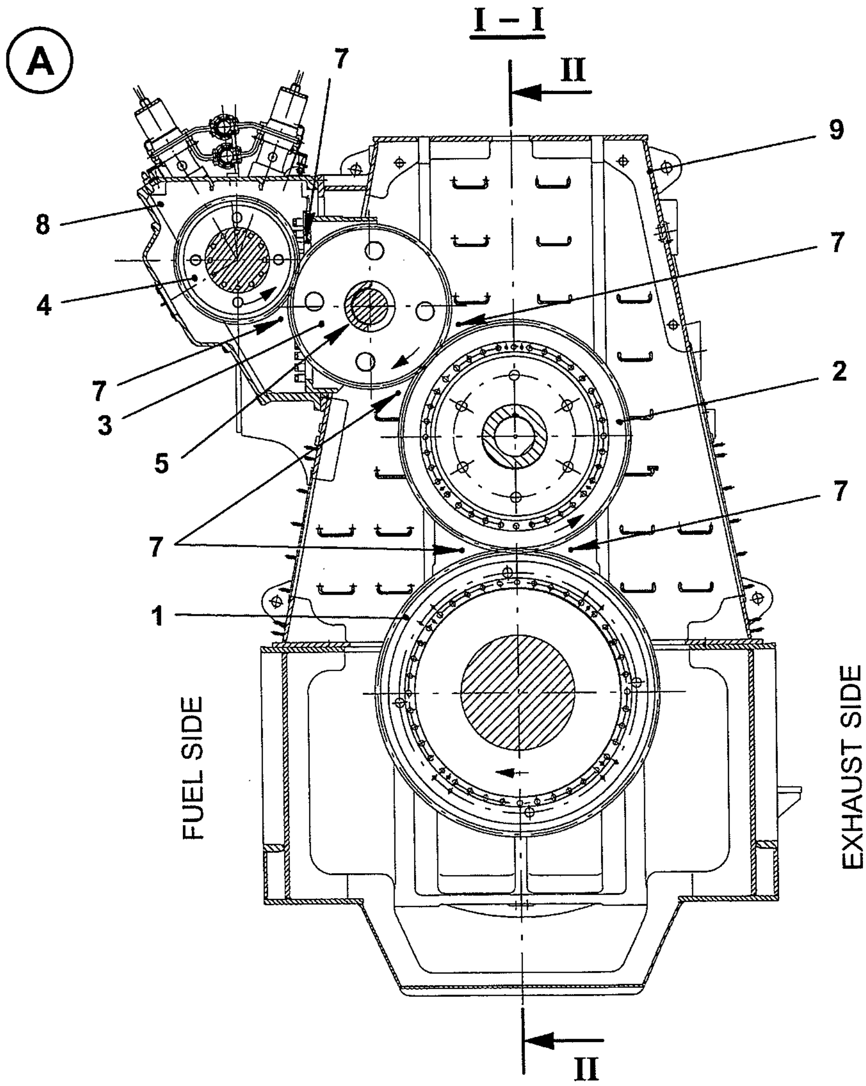
The camshaft connection of supply unit (8) is driven by gear wheel (1) on crankshaft (6) via intermediate wheels (2) and (3). The camshaft connection turns in the opposite sense to the direction of rotation of the crankshaft (see also Supply Unit 5552-1).

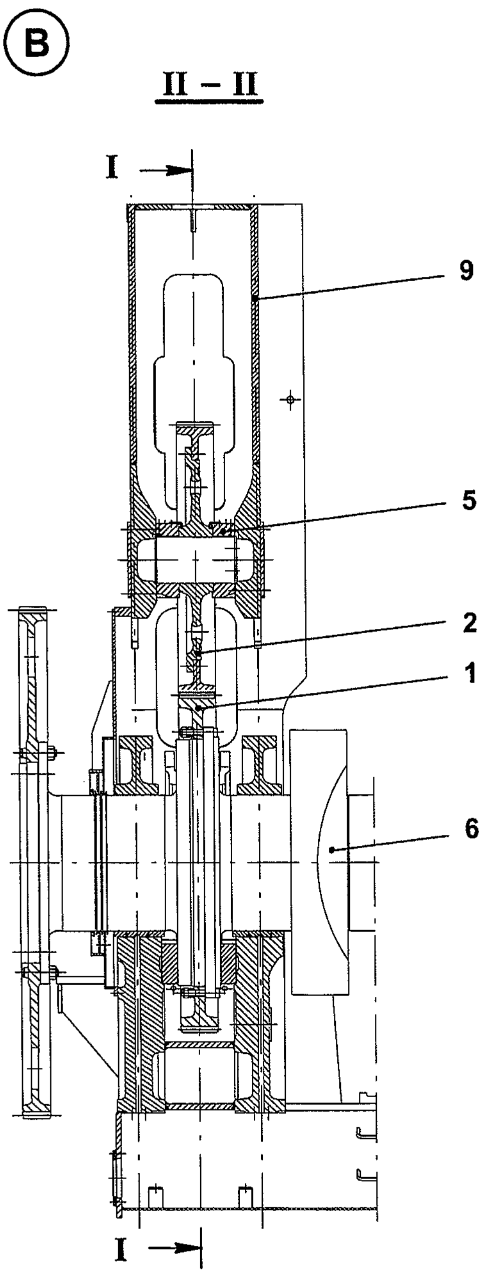
On 6 and 7 cylinder engines the drive is placed at the driving end (see Fig. 'B').
On 8 ~ 12 cylinder engines the drive is arranged at mid-engine (see Fig. 'C').

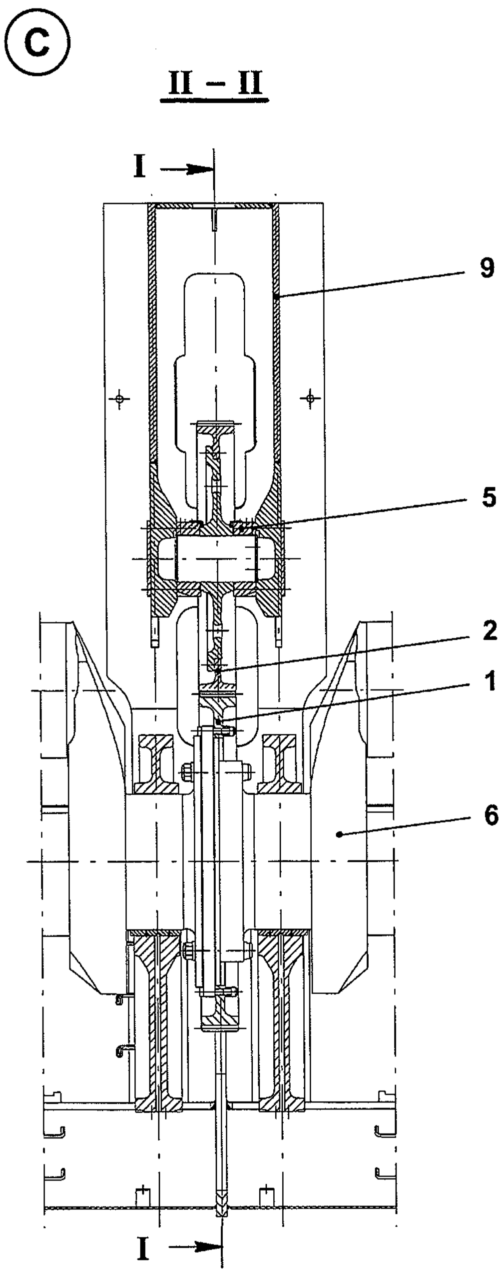
The condition of the tooth profile must be checked periodically. In particular new gear wheels must be checked frequently after a short running-in period (see Maintenance Manual 4103-1).
Should abnormal noises be heard from the area of the gear train, their cause must be established immediately.

2. Lubrication

The bearings (5) of intermediate wheels (2), (3) and the bearing for the camshaft connection are lubricated with bearing oil. The gear teeth are supplied with bearing lubricant through oil spray nozzles (7) (see Lubricating Oil Diagram 8016-1).







Key to Illustrations: **'A'** **Cross section (8 ~ 12 cylinders)**
'B' **Drive at driving end (longitudinal section, 6 and 7 cylinders)**
'C' **Drive at mid-engine (longitudinal section, 8 ~ 12 cylinders)**

1 Gear wheel on the crankshaft
2 Lower intermediate wheel
3 Upper intermediate wheel
4 Gear wheel for supply unit
5 Bearing for intermediate wheels
6 Crankcase
7 Oil spray nozzle
8 Supply unit
9 Column

1. General

(see figure and Control Diagram 4003–2).

The shut-off valve for starting air blocks off or releases the starting air into the engine. It can be put in the following positions by means of the handwheel:

– CLOSED (closed by hand)
– AUTOMAT
– OPENED (opened by hand)

When the engine is on stand-by or in operation the shut-off valve is positioned at "AUTOMAT" where it is held by the locking lever (6).

CHECK The test valve (2.06) can be actuated to check whether the valve opens. When the shut-off valve is ready for operation then valve (1) opens which is clearly audible, however, the engine will not be started.

Remark : When the engine is not in service, the following measures must be taken:

⇒ Close the shut-off valves of the starting air bottles (9.01).

⇒ Close the shut-off valve by means of the handwheel (5) (locking lever (6) in position "CLOSED").

⇒ Open the venting valve (2.21) (by that the shut-off valve and the air feed pipes are vented).

⇒ Open venting valve (2.27) (by that the starting air distribution piping is vented.)

⇒ Engage turning gear.

After each manoeuvring period the starting air distributor piping must be drained of condensate water. To this end venting valve (2.27) has been provided in the distributor piping (see also Starting Air Diagram 8018-1).

2. Function

Ready for starting:

Space "ER" is filled with starting air from inlet pipe "LE". Space "VR" is filled through balancing bore "EB". Valve (1) is held shut by spring (3) and by the pressure in space "VR".

Starting:

Control start valve (8) or (11) is activated by the corresponding FCM-20 module (see also 4002-1 'Engine-related control functions')

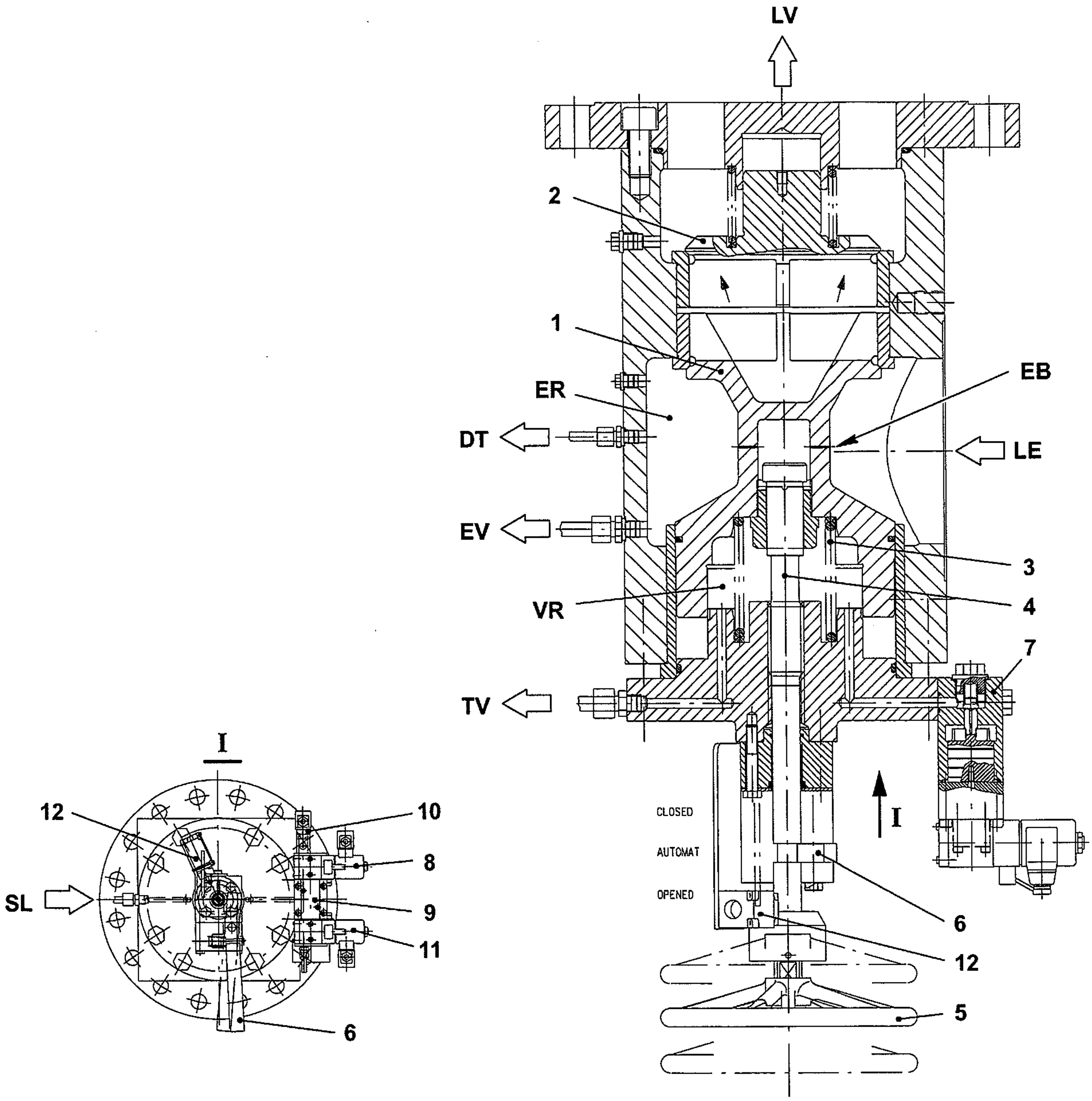
Control valve (7) is actuated by control air "SL" via common start valve (11) and vents space "VR". Valve (1) opens and starting air from space "ER" enters to the starting air distribution piping "LV" via no-return valve (2)

End of start:

Control valve (7) closes space "VR" which again fills with starting air via the balancing bores "EB". Valve (1) shuts.

Function check:

When valve (2.06) is actuated on the ready-to-start engine, space "VR" is vented and valves (1) opens audibly.



Key to Illustration :

1	Valve	DT	To instrument panel and pressure transmitter PT4301C
2	Non-return valve	EB	Balancing bore
3	Spring	ER	Air inlet space
4	Spindle	EV	To venting valve (2.21)
5	Handwheel	LE	Air inlet piping
6	Locking lever	LV	To starting air distributor piping and starting valve (2.07)
7	Control valve (2.05)	SL	Control air
8	Common start valve ZV7014C	TV	To test valve (2.06)
9	Duplex non-return valve 115HA	VR	Valve space
10	Pressure switch PS5017C		
11	Common start valve ZV7013C		
12	Limit switch ZS5018C		

1. General

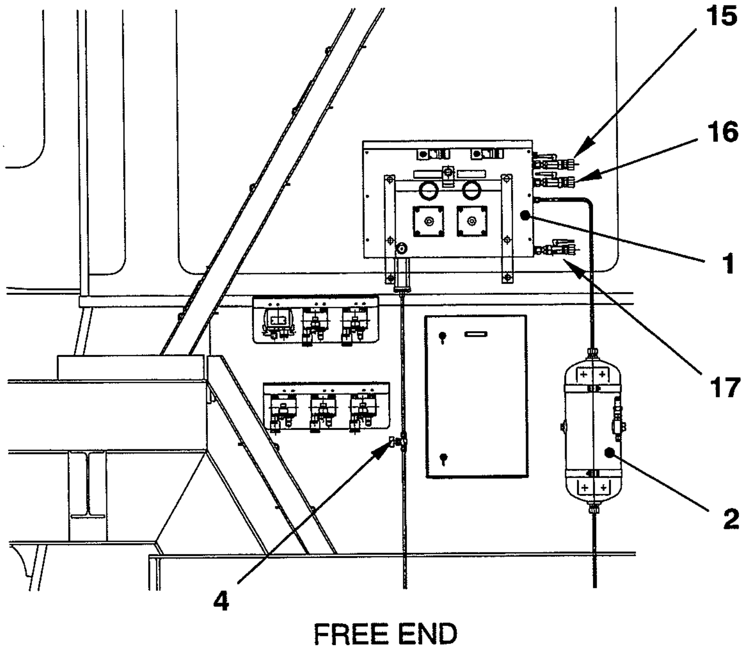
The compressed air required for the air spring of the exhaust valves and the turning gear interlock is primarily taken from the shipboard system. The air must be clean and dry in order to prevent blockages occurring in the control units.

The air piping system is arranged in such a way that, upon failure of the shipboard system supply, reduced compressed air will be taken from the starting air system.

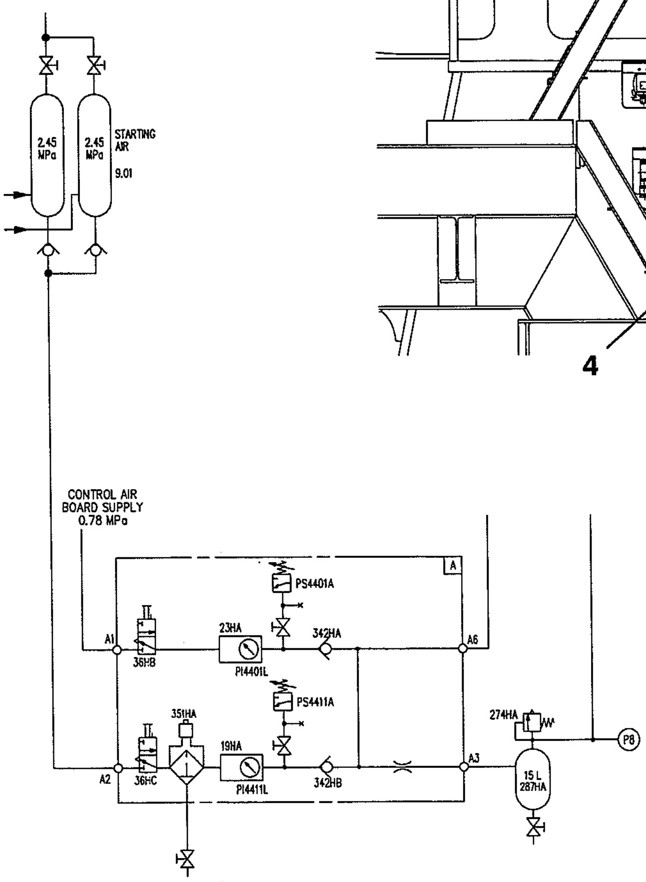
The shut-offs, pressure reducing valve, filters etc. necessary for feeding air to the various units are summarized in the control air supply unit $\boxed{A}$ (Fig. 'C').

The designations used to identify the individual pieces of equipment on the illustrations are identical to the ones used on the Control Diagram 4003-2.

A



B



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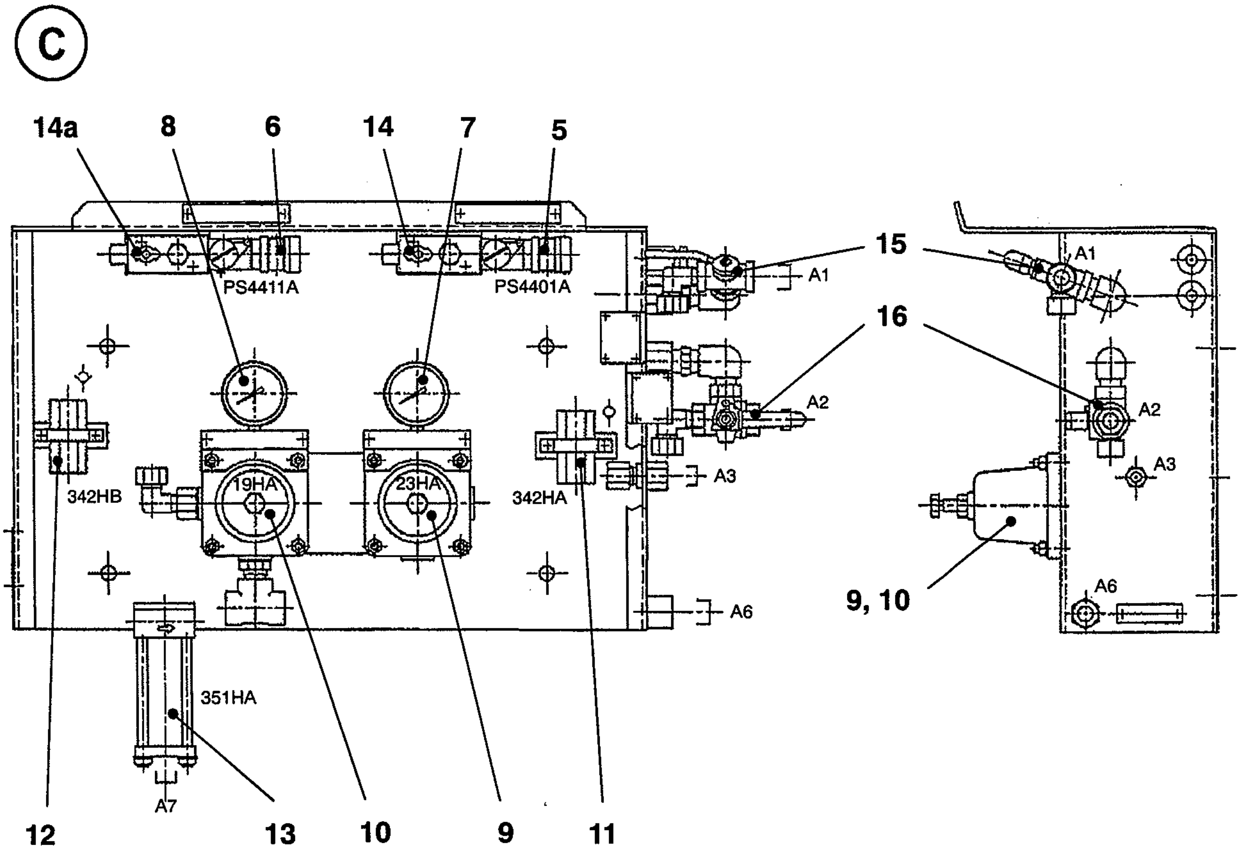


Key to Illustrations: 'A' **Arrangement of control air supply**
'B' **Diagram of control air supply unit**
'C' **Control air supply unit**

1	Control air supply unit [A]	14,14a	Test valve
2	Air bottle 287HA	15	Shut-off and venting cock 36HB for control air
4	Condensate water drain valve	16	Shut-off and venting cock 36HC for starting air
5	Pressure switch PS4401A		
6	Pressure switch PS4411A		
7	Pressure gauge PI4401L		
8	Pressure gauge PI4411L		
9	Pressure reducing valve 23HA	A1	Control air from board system
10	Pressure reducing valve 19HA	A2	Starting air from starting air bottles 9.01
11	Non-return valve 342HA		
12	Non-return valve 342HB	A3	Connection to air bottle 287HA
13	Filter 351HA	A6	Air spring air supply

1. General

Control components are provided in the local control panel required for operating the engine. As this panel is supplied by the remote control manufacturer, the relevant components may differ from the example in Fig. 'B'.

Brief instructions for manoeuvring from the local control panel are given on nameplate for LOCAL MANUAL CONTROL (Local Control) by operating elements (for detailed description see 4003-1 'Engine local control' and Manoeuvring 0260-1).

2. Fitted components

2.1 WECS-9520 MANUAL CONTROL panel

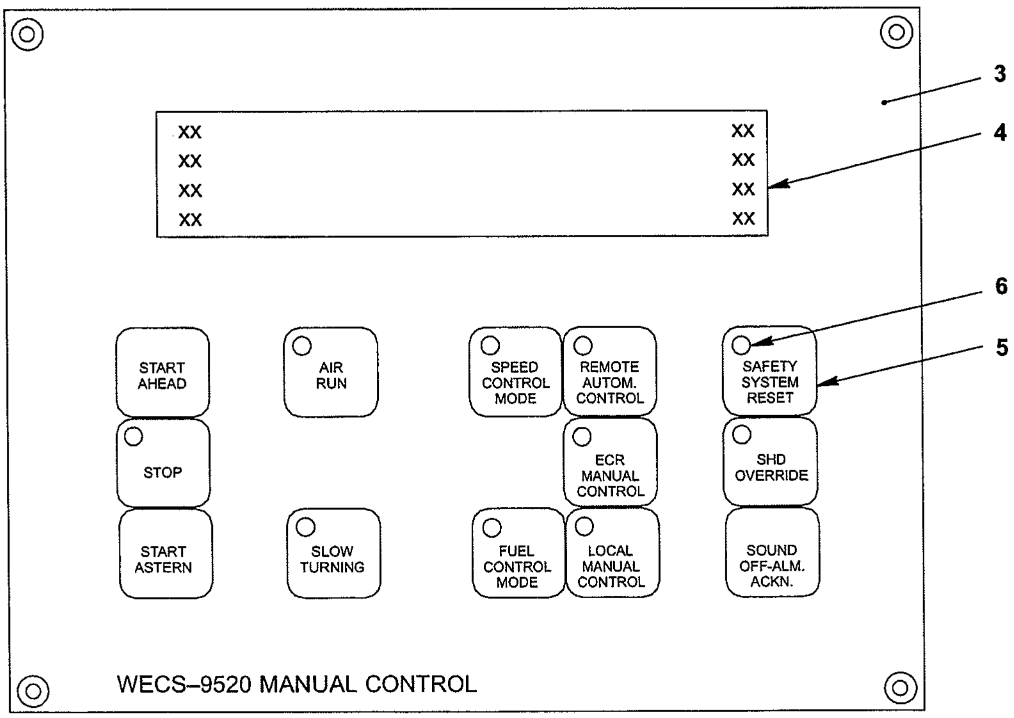
The WECS-9520 manual control panel, supplied by Wärtsilä Switzerland Ltd. to the remote control manufacturers, contains buttons and indications necessary for running the engine from the local manoeuvring stand (in backup mode).

Remark : The buttons function only in the corresponding mode of operation, i.e. with an active control stand. The functions described below may also be carried out on ECR manual control panel which is arranged in the control room console.

The two manual control panels are connected to WECS-9520 which will power them, and therefore these function independently of the remote control. However, they are always identically, and for any problems regarding the manual control panels, please contact Wärtsilä Switzerland Ltd.

Operating buttons and their functions:

A



Button			Function	Purpose, action and remark
Designation	Colour	LED		
START AHEAD	GREEN	none	· Engine START AHEAD · Interrruption running ASTERN (reversing from ASTERN - AHEAD)	· Before pressing button START AHEAD, start auxiliary blowers
STOP	GREY	RED	· Engine STOP interrupts fuel injection	· LED lights up as long as STOP order is on
START ASTERN	RED	none	· Engine START ASTERN · Interruption running AHEAD (reversing from AHEAD – ASTERN)	· Before pressing button START ASTERN, start auxiliary blowers
AIR RUN	GREY	GREEN	· Engine start with starting air only (fuel command adjusted to 'zero') · After a longer shut-down or maintenance works with opened indicator valves	· LED lights up as long as button is pressed · Operation functions at engine standstill
SPEED CONTROL MODE	GREY	GREEN	· Setting of speed nominal value to electronic speed control system, adjustable by rotary knob (speed / fuel)	· LED light up, if SPEED CONTROL MODE is selected LED FUEL CONTROL MODE extinguishes
REMOTE AUTOM. CONTROL	GREY	GREEN	· Transfer LOCAL MANUAL CONTROL (Local Control) to REMOTE AUTOM. CONTROL (Remote control)	· During transfer of control both green LEDs blink and then light up constantly after takeover
ECR MANUAL CONTROL	GREY	GREEN	· Transfer LOCAL MANUAL CONTROL (Local Control) to ECR MANUAL CONTROL	· During transfer of control both green LEDs blink and then light up constantly after takeover
SLOW TURNING	GREY	GREEN	· Releasing an automatic SLOW TURNING (AHEAD) · Slow turning sequence can be stopped at any time by pressing button once again	· LED blinks during SLOW TURNING · Program is stopped automatically, if engine finished a complete revolution or by malfunction

Button			Function	Purpose, action and remark
Designation	Colour	LED		
FUEL CONTROL MODE	GREY	RED	· Setting of fuel injection quantity to WECS-9520, adjustable by rotary knob (speed / fuel)	· LED light up, if FUEL CONTROL MODE is selected upon failure of electr. Speed control or if fuel injection regulation is required
LOCAL MANUAL CONTROL	GREY	GREEN	· Transfer from ECR MANUAL CONTROL to LOCAL MANUAL CONTROL (Local Control) · Transfer from REMOTE AUTOM. CONTROL to LOCAL MANUAL CONTROL (Local Control)	· After takeover of control both green LEDs light up constantly · Takeover to LOCAL MANUAL CONTROL must be acknowledged at control room console
SAFETY SYSTEM RESET	GREY	GREEN	· Resetting of still blocked shut-down condition in safety system	· LED light up, if all shut-down condition are established again and that all shut-downs can be reset
SHD OVERRIDE	GREY	RED	· Overriding of shutdown · Resetting override (by constantly light up LED)	· If a shut-down with possibility of overriding is present, LED blinks or light up constantly if it is overridden · Reestablish previous condition (i.e. of a shut-down still indicated or not reset)
SOUND OFF-ALM ACKN.	GREY	none	· Switch off acoustical alarms (bell / buzzer) · Information about version and check of software on display	· (Shut-down) alarm indications change from blinking to constantly light up · Pressing button for approx. 5 seconds

Display:

- Speed setting
- Fuel injection quntity (fuel command)
- Fuel rail pressure
- Servo oil rail pressure
- Control oil rail pressure

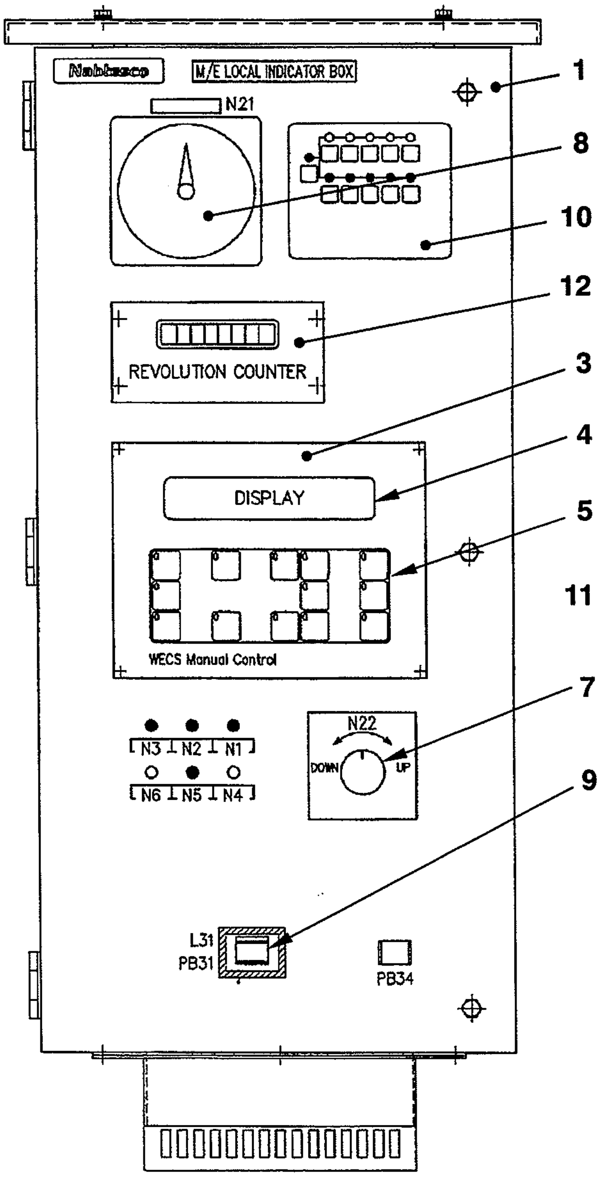
Furthermore, important conditions (statuses) are displayed in 3rd and 4th scaling line on the left as:

- Turning gear Engaged and Aux. Blower Runing
- Emergency stop
- Overspeed
- Shut-down active
- Shut-down expected
- Slow-down request
- Start interlock (together with indication 3rd scanning line)

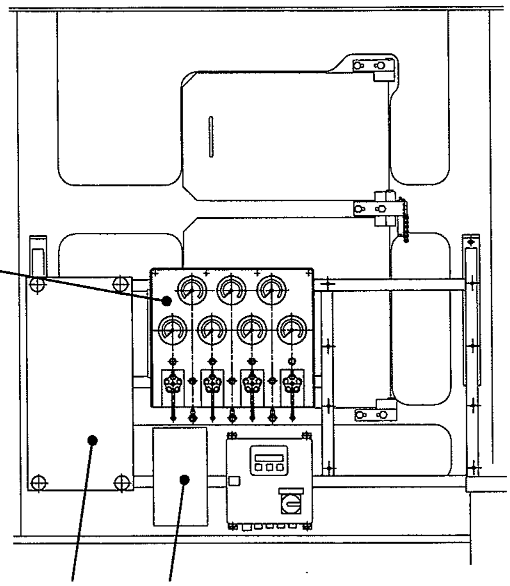
2.2 Local control panel

- Rotary knob for speed setting or fuel injection quantity adjustment
- Emergency stop
- Telegraph

B



C



Key to Illustrations : 'A' WECS-9520 Manual control panel
'B' Front view of local control panel
'C' Arrangement of local control panel

1	Control panel	7	Rotary knob (speed / fuel)
2	Name plate with brief instruction	8	ME tachometer
3	WECS-9520 manual control panel	9	Emergency stop button
4	Display	10	Telegraph
5	Attendance button	11	Instrument panel
6	LEDs	12	Revolution counter

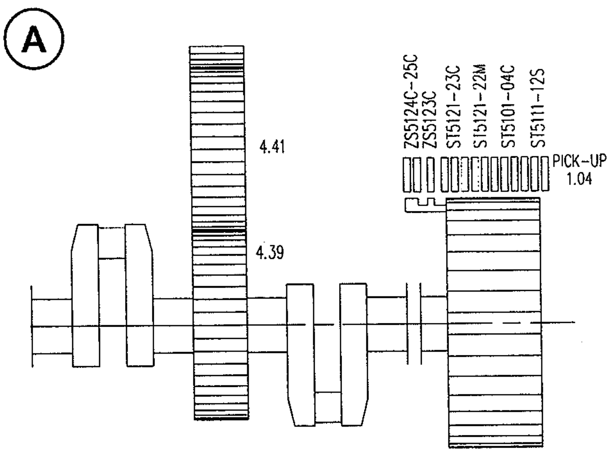
1. General

To measure the engine speed (rpm / min^{-1}) several proximity sensors have been combined to a speed pick-up unit, arranged on the front side of the column.
For safety reasons four electrically separated proximity sensor groups are provided for:

- Speed detection in RCS
- Overspeed safety system
- Speed control system
- ECL system

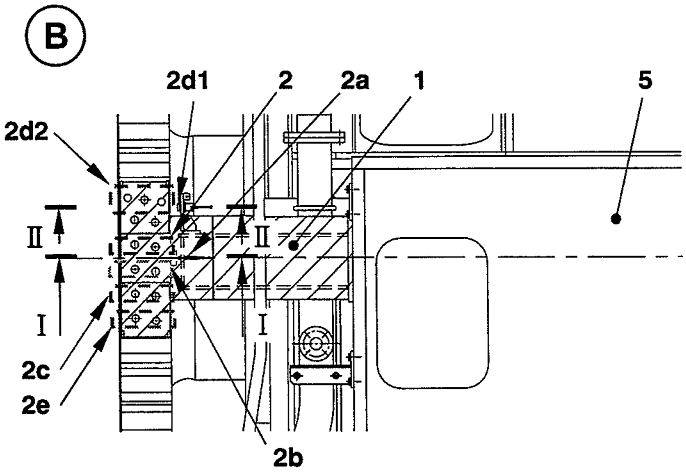
2. Function

The speed impulse measurement takes place with proximity sensors (2) contactless (inductive) at the toothing of flywheel (4). The electric speed signals are transferred via DENIS-9520 to the remote control system for monitoring the load and speed-dependent functions, as well as to the speed indicating instruments.
Proximity sensor (2a) is provided to indicate the comparison measurement of the TDC position for the crank angle transmitters.



Key to Illustrations :

'A'	**Schematic diagram**
'B'	**Arrangement of measuring points**
1	Pick-up holder
2	Proximity sensor for RCS
2a	Proximity sensor for WECS-9520
2b	Proximity sensor for overspeed safety system
2c	Proximity sensor for PCS
2d1	Proximity sensor for ECL (for TDC)
2d2	Proximity sensor for ECL (for engine speed and rotation direction)
2e	Proximity sensor for indication
3	Target for TDC pick- up sensor
4	Flywheel
5	Bedplate



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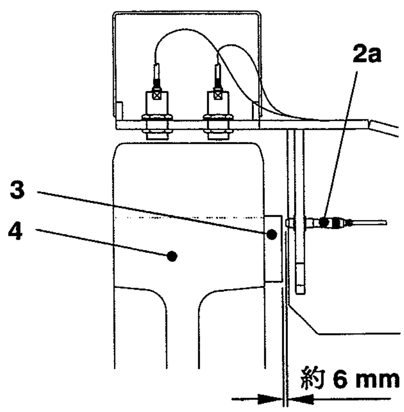
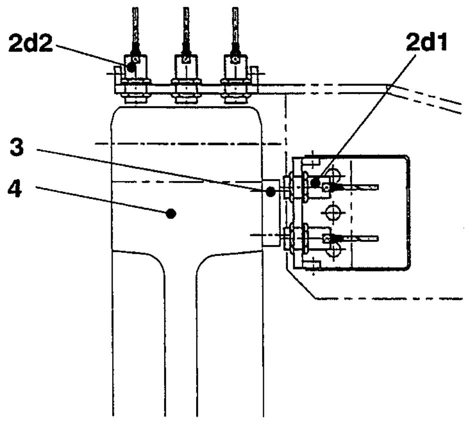


II - II



Group 5

5

Supply Unit, Servo Oil Pump and Fuel Pump — Group 5

1. General

The servo oil pumps (2) are integrated in the supply unit (1) (see Supply Unit 5552-1). These pumps ('wobble-plate pumps') ensure the supply of servo oil for the movements of the exhaust valves and the supply of control oil for the injection system upon failure of the control pumps. They are operated with additionally filtered bearing oil.
The servo oil is fed to the pumps via the automatic filter (6) (see Fig. 'A').

2. Function

In normal operation the pumps are controlled in such a manner that the load of the total load range is equally distributed to them.
The electrically controlled pressure regulating system (normal pressure value depending on engine load) adjusts the servo oil system pressure over the entire load range, i.e. high pressure (about 20.0 MPa) at high engine load, and reduced pressures at low engine load.

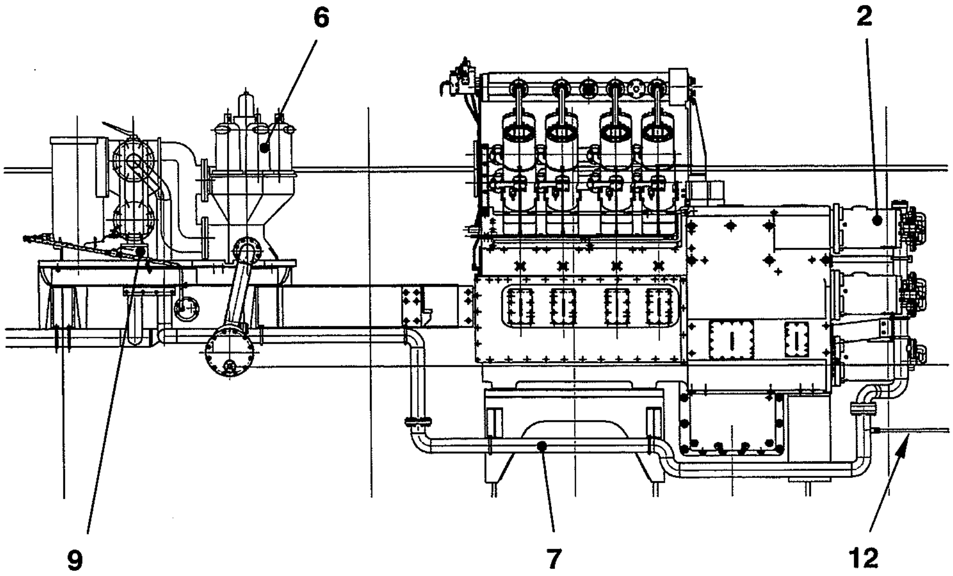
Shearable overload protection 'SB' on each shaft (5) prevent total loss of the gear wheel (3) if a pump is seized completely (see Fig. 'C').

In case of a sigle pump failure, engine operation can be maintained over the entire load range.
In every inlet pipe (10) there are flow sensor (8) monitoring the oil supply through the servo oil pumps. A possible failure of a pump is indicated in the alarm and monitoring system.

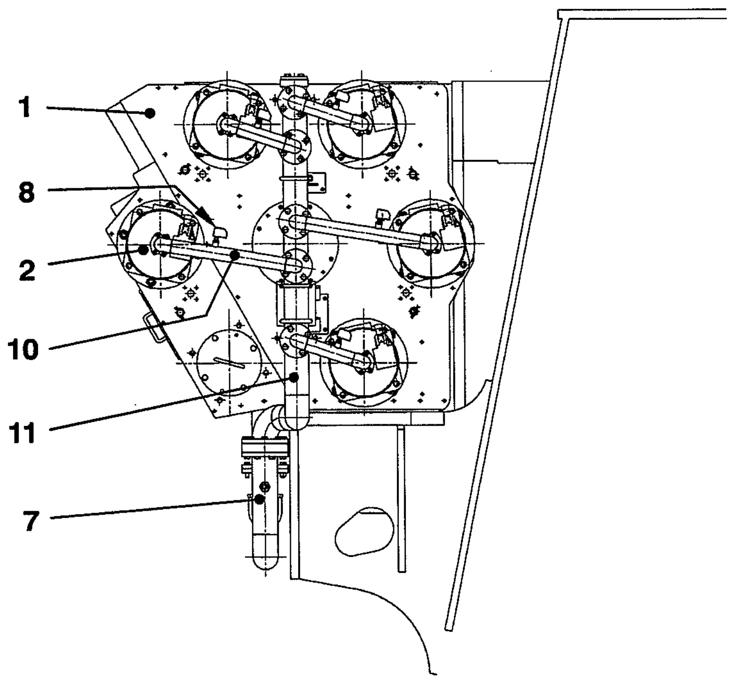
CAUTION

> The operating mode with a defective pump must not be considered as permanent. If another pump fails the engine will no longer be operative! The defective pump has to be exchanged as quickly as possible (see Maintenance Manual 5521-1).

A



B



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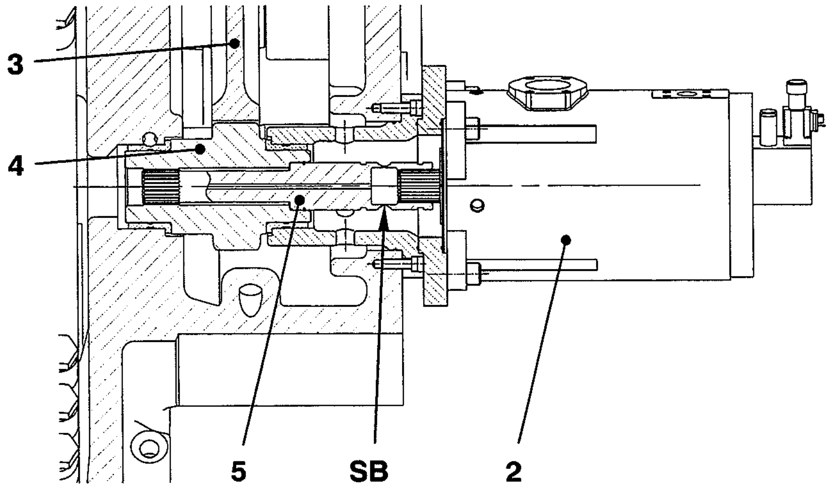


Key to Illustration : 'A' **Arrangement of automatic filter**
'B' **Arrangement of servo oil pump**
'C' **Longitudinal section of servo oil pump drive**

1	Supply unit G	9	Stop valve (4.37)
2	Servo oil pump (4.15)	10	Inlet pipe
3	Gear wheel (4.44)	11	Distributing pipe
4	Pinion (4.45)	12	Oil pipe to control pump unit L
5	Shaft (4.50)		
6	Automatic filter (4.20)		
7	Supply pipe (4.51)	SB	Shearable overload protection (predetermined breaking point)
8	Flow sensor FS2061 ~ 65A		

1. General

The supply unit is mounted on the drive column on fuel side (see Drive Supply Unit 4104-1).
It comprises the servo and fuel oil supply as well as their driving and regulating systems.
Depending on number of cylinders, one or two relief valve(s) is (are) provided on the rear side of the supply unit.
Moreover siphon (19) prevents oil mist from escaping into the crankcase.

Further components are integrated in or mounted on the housing of the supply unit:

Camshaft connection:

It consists of camshaft (2), fuel cam (3), gear wheel shaft (4), gear wheels (5) and (6) for camshaft and pinion (7). It is hydraulically pre-tensioned with bolts (9) and round nuts (10). The bedding is ensured by bearing halves (11) and thrust bearing ring halves (12).

Servo oil pumps:

Depending on the number of cylinders of the engine, four to six servo oil pumps (13) are mounted on the front of the supply unit. The drive is effected via gear wheel (6), pinion (7) and shaft (14).

Description see Servo Oil Pump 5551-1.

Fuel pumps:

Depending on the number of cylinders of the engine, four, six or eight fuel pumps (15) in V-version are mounted on the supply unit.

Description see Fuel Pump, Intermediate Fuel Accumulator and Fuel Pressure Control Valve (3.06) 5556-1.

Regulating linkage:

The regulating linkage (16) is arranged on both fuel pump rows. Depending on number of cylinders two, three or four actuators (17) (electrical control elements) control all fuel pumps (15) simultaneously. Every actuator is connected to two fuel pumps.

Description see Regulating Linkage 5801-1.

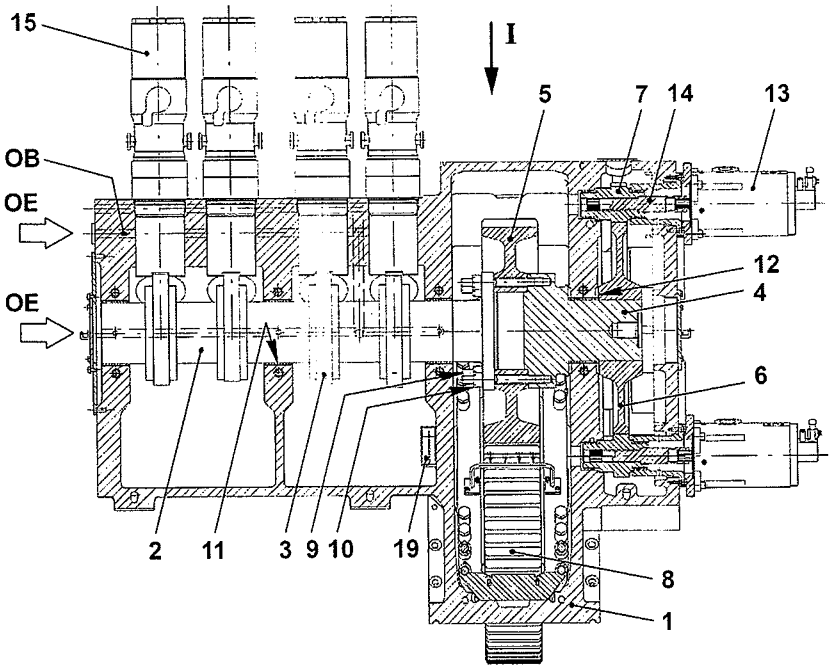
Intermediate fuel accumulator:

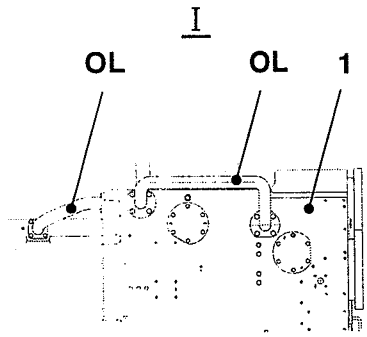
The intermediate fuel accumulator (18) is arranged between the fuel pumps (15).

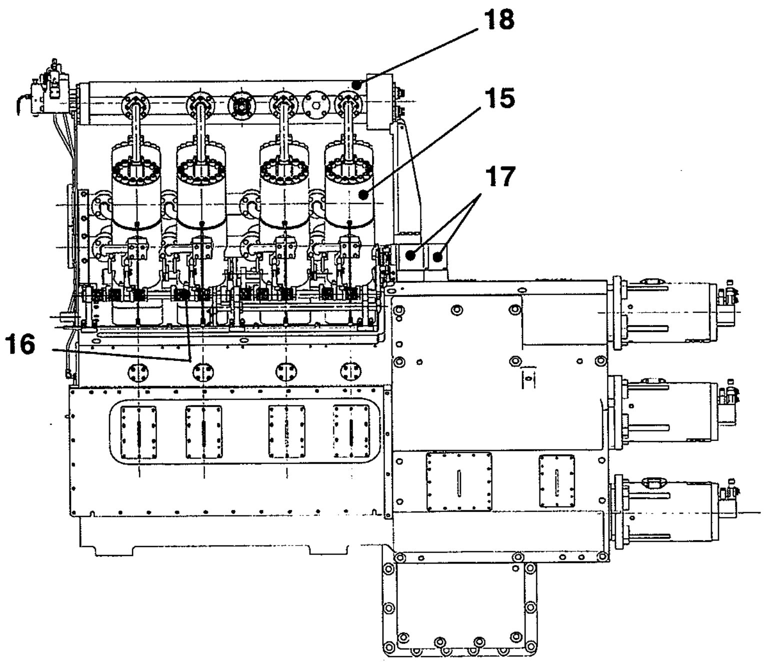
Description see Fuel Pump, Intermediate Fuel Accumulator and Fuel Pressure Control Valve 3.06 5556-1.

2. Lubrication

Lubrication of the bearings, fuel pumps, and spray nozzles is ensured by the oil inlets “OE” via oil bores “OB” and oil pipings “OL”.







Key to Illustration :

1 Housing
2 Camshaft (3.55)
3 Fuel cam
4 Gear wheel shaft
5 Gear wheel (4.42)
6 Gear wheel (4.44)
7 Pinion (4.45)
8 Upper intermediate wheel (4.41)
9 Bolt
10 Round nut
11 Bearing half
12 Thrust bearing ring half
13 Servo oil pump (4.15)
14 Shaft (4.50)
(with shearable overload protection)
15 Fuel pump (3.14)
16 Regulating linkage (3.20)
17 Fuel pump actuator (3.21)
18 Intermediate fuel accumulator (3.04)
19 Shiphon

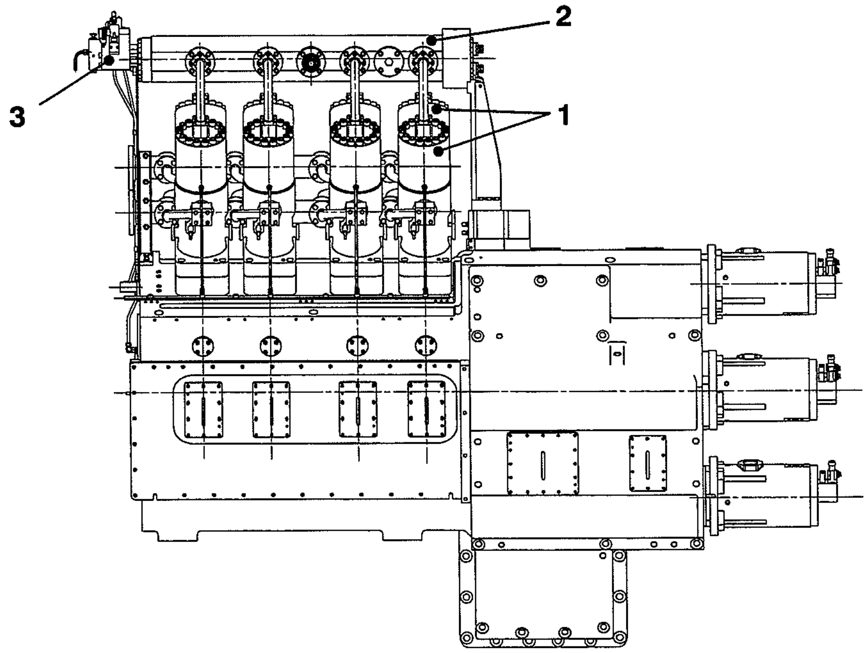
OB Oil bore
OE Oil inlet
OL Oil piping

1. General

Depending on the number of cylinders four, six or eight fuel pumps (1) are fitted in the supply unit (see Fig. 'A').
They deliver fuel under high pressure into the fuel rail via HP pipes, intermediate fuel accumulator (2) and fuel rising pipes.

The fuel pumps are controlled to supply as much fuel as necessary to maintain the required pressure (load-dependent) in the fuel rail.

A



2. Function

The compression spring (12) presses guide piston (13) and roller (15) onto cam (17) via lower spring carrier (14). The pump plunger (19) is brought into a stroke motion by the cam on the rotating camshaft. The required fuel quantity is controlled by control grooves "ST" of the pump plunger.

The regulation of the fuel quantity is carried out by the movement of toothed rack (10) whose teeth mesh on toothed regulating sleeve (9) causing it to turn. The latter is connected to the pump plunger by driver "KM" turning the pump plunger when the toothed rack moves. When the pump plunger passes the BDC plunger space "PR" is filled through two inlet bores "ZB" in the pump cylinder and two control grooves "ST" in the pump plunger (see Fig. 'C') depending on the regulating position ('0' for zero delivery till '10' for maximum delivery).

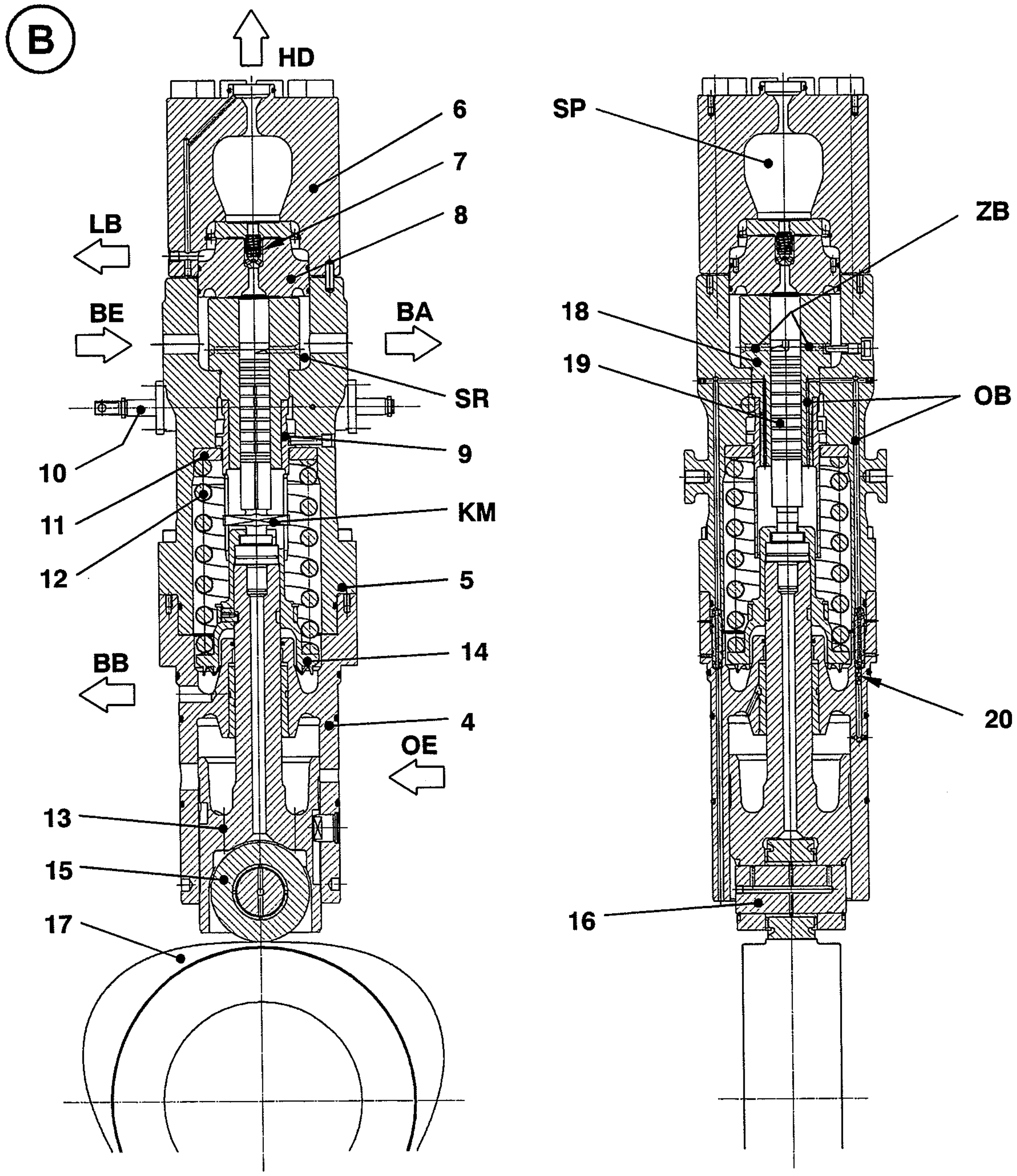
Remark : No fuel is supplied when inlet bores "ZB" overlap control grooves "ST" in position '0'.

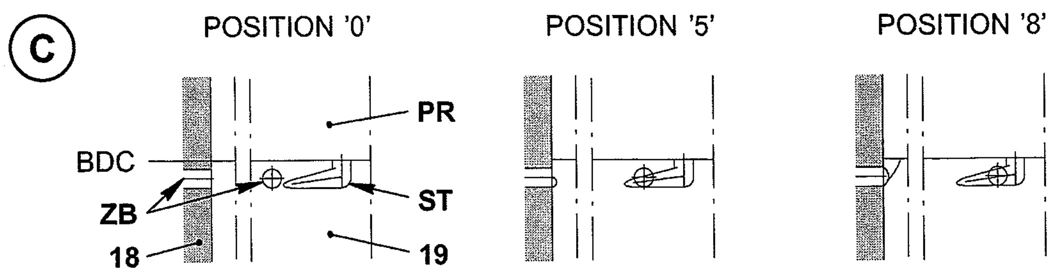
The toothed racks are connected to the fuel regulating shafts through pretensioned spring links. The regulating shafts are turned simultaneously by the actuators via the regulating linkages (see Regulating Linkage 5801-1).

3. Lubrication

The fuel pump is lubricated with engine lube oil which enters the lower housing (4) through inlet bore "OE" in the housing of the supply unit.
Part of lube oil ensures lubrication of the guide piston, floating pin (16) and roller (15) via spot faces, annular groove and bores in the guide piston. The flowing down lube oil lubricates the cam running surface.
An other part of lube oil ensures lubrication of regulating sleeve (9) via lubricating oil bores "OB" in upper housing (5) and pump cylinder (18).

The pump plunger (19) is lubricated with leakage fuel. It is derived via drain bore "BB", together with leakage oil from the regulating sleeve, through an internal bore in the housing of the supply unit.





Key to Illustrations: **'A' Arrangement of fuel pump**
'B' Fuel pump
'C' Control groove of pump plunger

1	Fuel pump (3.14)	18	Pump cylinder
2	Intermediate fuel accumulator (3.04)	19	Pump plunger
3	Fuel pressure control valve (3.06)	20	Throttle
4	Lower housing		
5	Upper housing	BA	Fuel outlet
6	Pump cover	BB	Leakage fuel drain bore
7	Valve body } non-return valve	BE	Fuel inlet
8	Valve block } non-return valve	HD	HP to intermediate fuel accumulator
9	Regulating sleeve	KM	Driver of pump plunger
10	Regulating (toothed) rack	LB	Leakage fuel outlet
11	Upper spring carrier	OB	Lubricating oil bore
12	Compression spring	OE	Lubricating oil inlet
13	Guide piston	PR	Plunger space
14	Lower spring carrier (with umbrella)	SP	Accumulation space
15	Roller	SR	Suction space
16	Pin	ST	Control groove
17	Cam	ZB	Inlet bore

4. Intermediate fuel accumulator

The fuel pumps deliver fuel under high pressure into the intermediate fuel accumulator. Pressure pulsations generated through the conveyance of the fuel pump in the system are reduced by means of the intermediate fuel accumulator.
The non-return valves (2) in the inlet flanges (3) prevent a pressure drop in the high pressure circuit during engine operation when a pump plunger or non-return valve in the pump cover seize as well as when a HP pipe breaks between fuel pump and intermediate fuel accumulator.

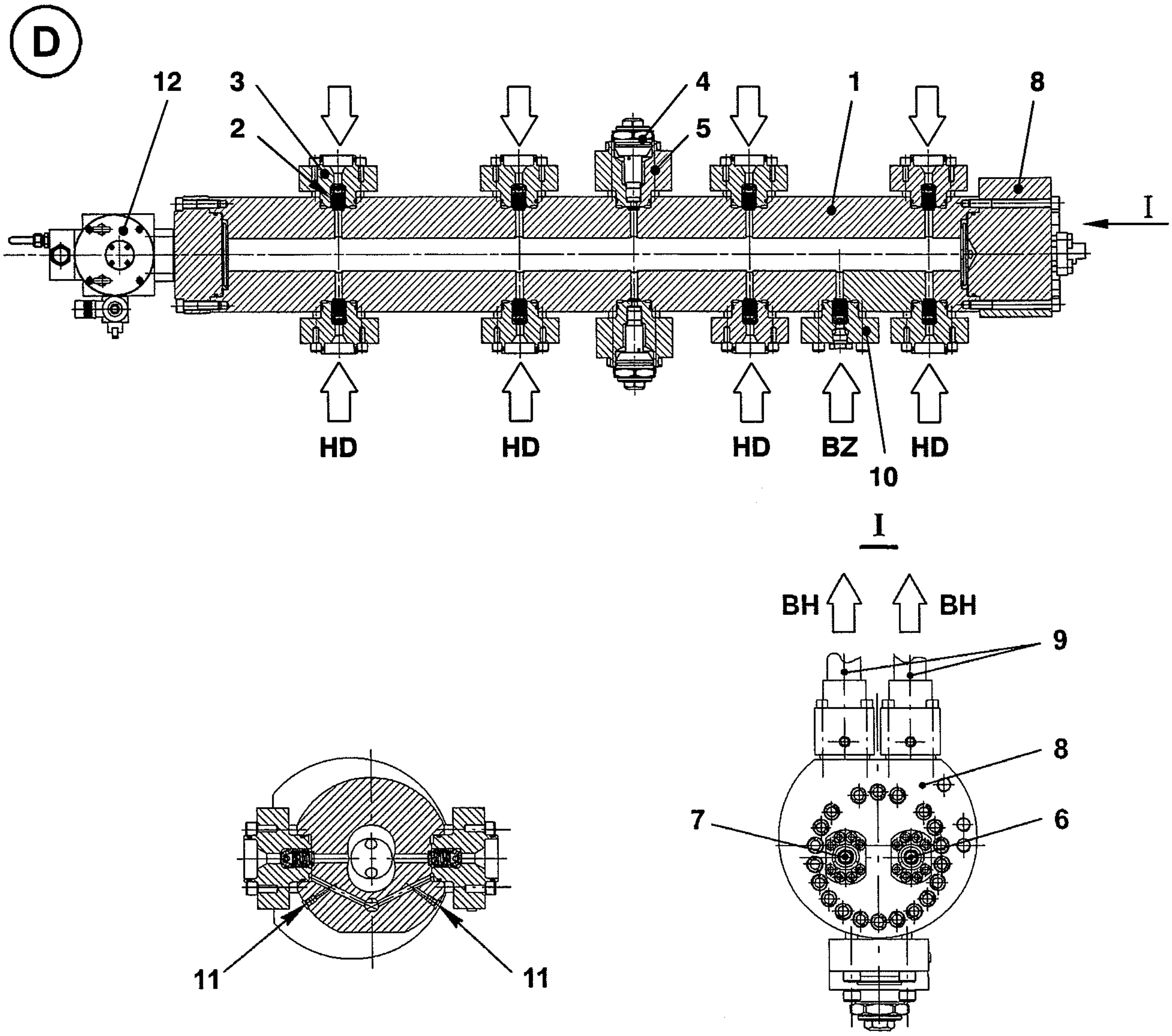
Remark : A defective HP pipe or fuel pump may only be replaced at engine standstill (see Maintenance Manual 5556-1).

Screw plugs (11) are provided for proper leakage localization at the intermediate fuel accumulator.

The overpressure safety valves (4) in the flange (5) open if the maximum pressure has been exceeded e.g. at too high fuel viscosity.
The fuel drain is indicated with an alarm by level switch LS3426A and can also be recognized by the leakage monitoring (see 8019-1 'Fuel leakage System').

In case of a breakdown the corresponding fuel rising pipe can be cut out by means of stop valves (6) and (7) in the end flange (8) (see Fuel Oil System 8019-1).

There is a connection "BZ" at flange (10) in order to fill up (if necessary) the high pressure circuit before taking the engine into service (see 0120-1, 'Priming the fuel system on the engine' and Fuel Oil System 8019-1).



Key to Illustration: 'D' Intermediate fuel accumulator

1	Housing	9	Fuel rising pipe (3.29)
2	Non-return valve (3.22)	10	Flange
3	Inlet flange	11	Screw plug
4	Fuel overpressure safety valves (3.52–1 & 2)	12	Fuel pressure control valve (3.06)
5	Flange		
6	Stop valve (3.62-1)	BH	High pressure to fuel rail
7	Stop valve (3.62-2)	BZ	Fuel supply
8	End flange	HD	High pressure from fuel pumps

5. Fuel pressure control valve 3.06

5.1 General

Normal operation:

CAUTION **In normal operation the knurled (adjusting) screw must be fully turned down!**

WECS-9520 regulates the fuel pressure which remains below the opening pressure of the fuel pressure control valve (1). The latter is normally closed (see also 4002-1 'Fuel pressure control').

The valve acts as a pressure relief valve and opens if the fuel pressure exceeds approx. 105.0 MPa. The opening pressure is properly adjusted by means of adapted adjusting disc (7) and tightened knurled screw (8).

Emergency stop:

The safety system activates fuel shut-down pilot valve (6) reducing the fuel pressure to less than 20.0 MPa (in most cases to '0' MPa). Therefore an injection is no longer possible.

Remark: The fuel shut-down pilot valve is only one out of three actuating devices to shut down the engine; the others are:

- immediate injection stop (WECS-9520)
- fuel pump delivery to '0'.

Emergency operation:

CAUTION **For emergency operation the knurled (adjusting) screw must be fully turned out!**

The fuel pressure control valve takes over the fuel pressure regulating function in case of failures in the fuel pressure regulating system, as by:

- missing or wrong control signals
- fuel pump actuator(s) out of service
- blocked regulating linkage.

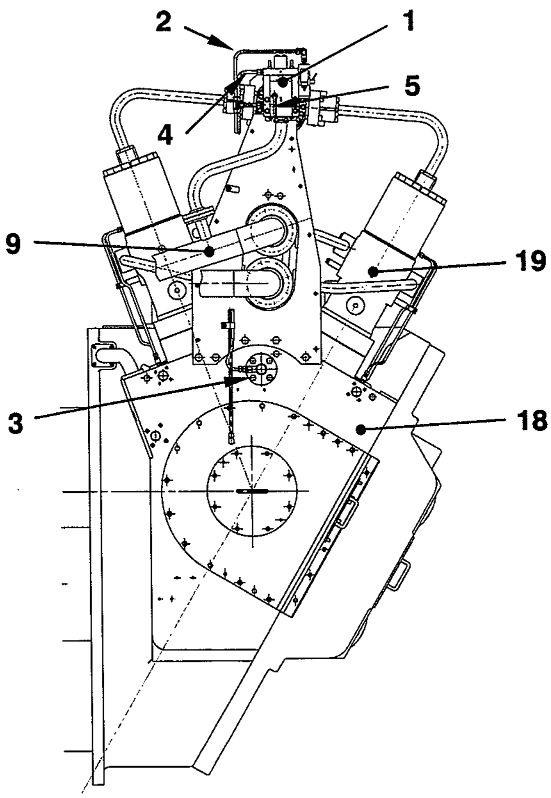
The fuel pumps (19) are fixed in maximum delivery position. This can be applied to all fuel pumps or only to a single one, depending on the failure (see 0515-1 'Defective actuator').

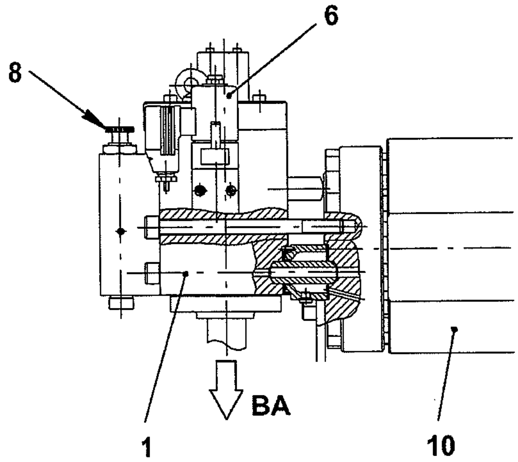
If the fuel pressure exceeds the opening pressure, the fuel pressure control valve will open, gradually draining enough fuel to maintain the adjusted maximum pressure.
In this case a longer operating time should be avoided!

The knurled screw must therefore be fully turned out counter-clockwise till the stop. This reduces the opening pressure to approx. 60.0 MPa, ensuring safe operation over the whole load range.

Remark: The opening of the fuel pressure control valve can be confirmed acoustically: a strong 'whistling' noise indicates that fuel is being drained.

E





5.2 Function

Regulating function:

Due to the oil pressure on top of piston (11) valve tip (12) is pressed onto valve seat (13). The fuel pressure also works against the internal oil pressure regulating valve (17). An increasing fuel pressure reduces the oil pressure. The valve tip is lifted off from the valve seat and fuel is drained if the oil pressure drops below a certain threshold value.

Compression springs (14) & (15) and knurled screw (8) define the regulating characteristic of the oil pressure regulating valve.

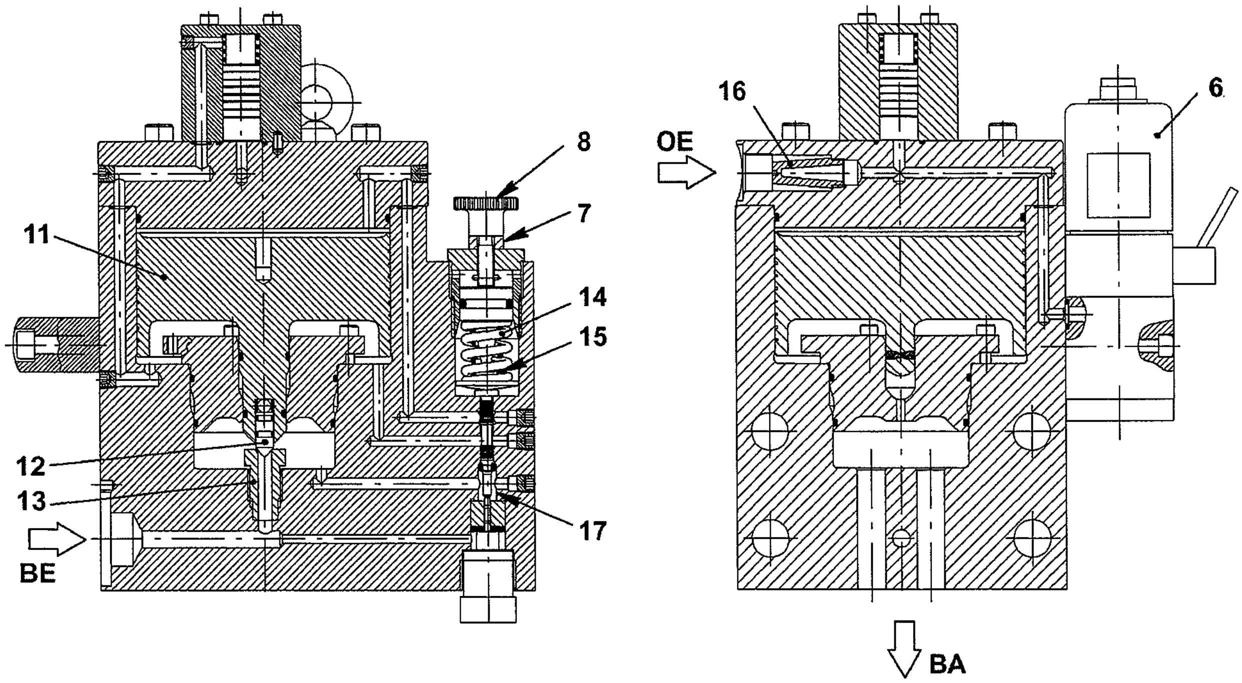
Function check:

During normal operation the function can be confirmed by carefully turning the knurled screw counter-clockwise till the valve starts to open, relieving the fuel pressure.

Emergency stop function:

If the fuel shut-down pilot valve (6) is energized the oil pressure on top of piston (11) is relieved, the valve tip is lifted off from the valve seat and fuel is drained.

F



Key to Illustrations: 'E' **Arrangement of fuel pressure control valve 3.06**
'F' **Fuel pressure control valve 3.06**

1	Fuel pressure control valve (3.06)	13	Valve seat
2	Bearing oil supply pipe	14	Compression spring
3	Non-return valve (3.67)	15	Compression spring
4	Bearing oil drain	16	Filter
5	Leakage control pipe	17	Oil pressure regulating valve
6	Fuel shut-down pilot valve (3.08)	18	Supply unit G
7	Adjusting disc	19	Fuel pump (3.14)
8	Knurled screw		
9	Fuel outlet pipe		
10	Intermediate fuel accumulator (3.04)	BA	Fuel outlet (drain)
11	Piston	BE	Fuel inlet
12	Valve tip	OE	Oil inlet

1. General

As a rule, in the event of a defect in a fuel pump (e.g. seizing of pump plunger) or a HP pipe break between fuel pump and intermediate fuel accumulator, the fault must be remedied immediately.
Should this not be possible because the engine has to be put back in service, the corresponding fuel pump can be cut out.

WARNING

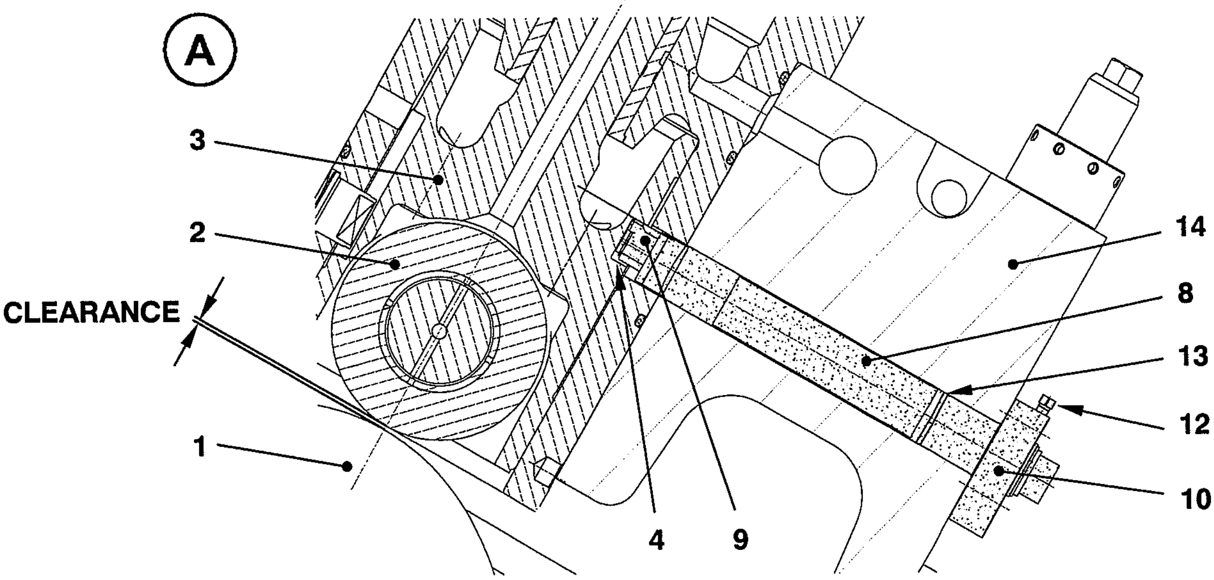
Cutting out and cutting in of defective fuel pumps may only be carried out at engine standstill!

In case of a cam breakdown, both fuel pumps running on the relevant cam must be cut out.

Remark : **With one fuel pump cut out** the engine may be maintained approximately in unrestricted operation.
With two fuel pumps cut out the engine can only be operated at reduced load.

2. Cutting Out and Cutting In of the Fuel Pump

2.1 Device for cutting out and cutting in



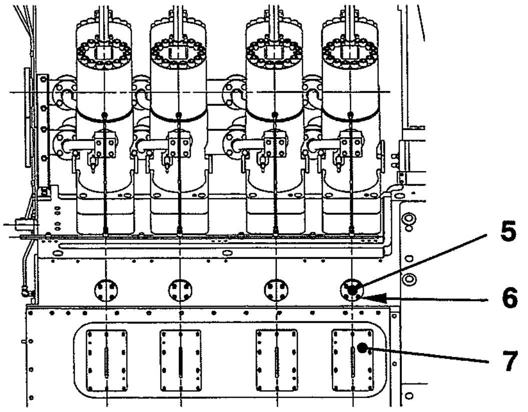
Key to Illustrations:

'A'	**Cut-out device**
'B' to 'F'	**Cutting out sequence**
'G' to 'H'	**Cutting in sequence**

1	Cam	8	Eccentric shaft
2	Roller	9	Fixing block
3	Guide piston	10	Flange
4	Square hole	11	Dowel pin
5	Blank flange	12	Setscrew
6	Screw	13	O-ring
7	Inspection cover	14	Supply unit

Items 8–13: tool 94430

B



2.2 Cutting out procedure

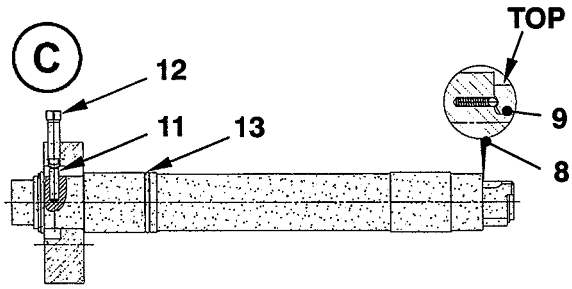
Starting position:

- Engine at standstill.

⇒ Remove inspection cover (7) and ascertain position of the corresponding cam. Turn the engine with turning gear till roller (2) of guide piston (3) reaches the cam peak (see also Fig. 'D').

⇒ Loosen screws (6) and remove them together with blank flange (5) and its gasket.

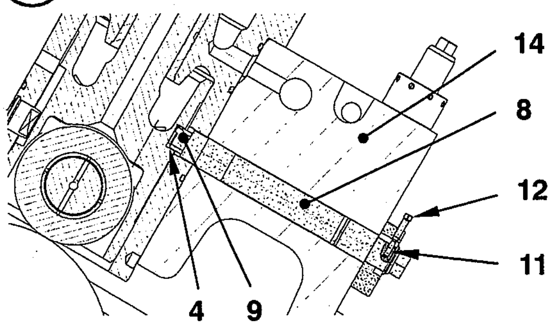
C



⇒ Turn fixing block (9) at eccentric shaft (8) till it engages and mark TOP pointing upwards as dowel pin (11).

- Set screw (12) must be turned back.

D

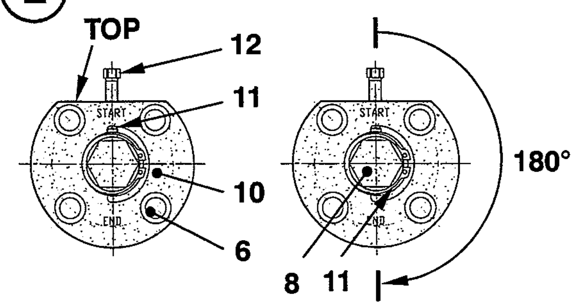


⇒ Push tool (94430) till the stop with dowel pin (11) and mark TOP pointing upwards.

- The fixing block (9) has engaged in square hole (4) of guide piston (3).
  Edge of eccentric shaft is approximately in line (flush) with supply unit (14).

Remark: Make sure that O-ring (13) is not damaged.

E



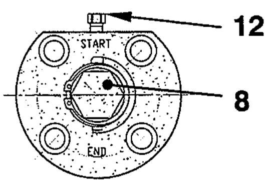
⇒ Fasten flange (10) to the housing of the supply unit with setscrew (12) pointing upwards.

CAUTION: Pay attention to mark TOP.

⇒ Turn eccentric shaft through 180° in a clockwise direction using open end spanner AF30, and dowel pin (11) from position START to END.

- Roller (2) is lifted by the cam (Fig. 'A').

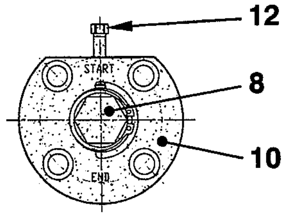
F



⇒ Lock eccentric shaft (8) with setscrew (12) so that it can not turn back.

2.3 Cutting in procedure

G



Starting position:

- Engine at standstill.

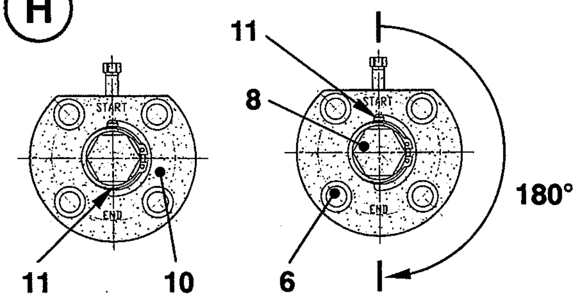
⇒ Remove inspection over (7) and ascertain position of the corresponding cam. Turn the engine with turning gear till roller (2) of guide position (3) reaches the cam peak (see also Fig. 'B' and 'D').

⇒ Loosen and turn setscrew (12) back so that eccentric shaft (8) can be turned.

CAUTION

Setscrew may not project any more in the groove of flange (10) (see Fig. 'G').

H



⇒ Turn eccentric shaft (8) through 180° in an anticlockwise direction using open end spanner AF30, and dowel pin (11) from position END to START.

⇒ Loosen and remove screws (6).

⇒ Withdraw tool (94430).

⇒ Fit blank flange (5) (with gasket) and tighten it with screw (6) (see Fig. 'B').

⇒ Finally store tool (94430).

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1. General

The control oil pump unit (1) is arranged on fuel side (Fig. 'A').

The required oil is branched off after the automatic filter and supplied to control oil pump (4) via oil piping (5).

1.1 Function

One of the two electrically-driven control oil pumps (4) provides the control oil pressure of 20.0 MPa, maintaining it over the entire load range, also during engine start and at low load.

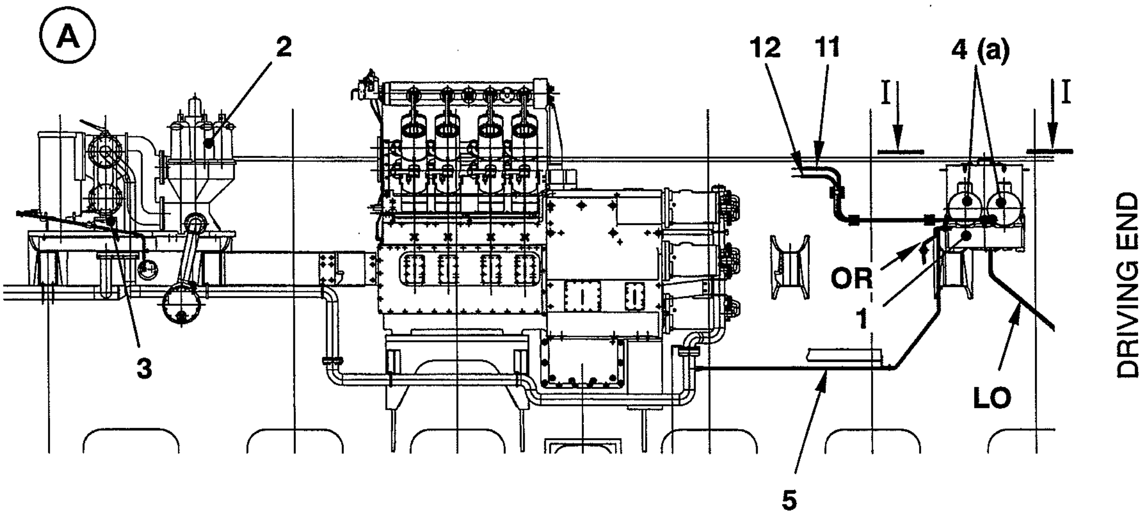
The control oil pumps are started and stopped automatically by the WECS-9520.

CAUTION

Stop valve (3) before the automatic filter and stop valve (19) must be open.

After every pump outlet there is a pressure retaining valve (7) and (8) each used for pressure adjustment in the control oil system, as well as a safety valve (9) and (10) each fitted in distribution block (6).

Double-walled HP control oil pipings (11) and (12) lead to the control oil trail in the rail unit. The mentioned oil is used for actuating the injection control units (see also 8016-1 'Servo and control oil system').



2. Leakage monitoring

Leakage of a HP piping (e.g. failure of the inner pipe) are monitored by pressure transmitter (13) indicating an alarm in the alarm and monitoring system.
However, the engine can be operated normally.

The non-return valves (14) prevent the intermediate space of the intact HP piping from filling up with oil.

CAUTION

The operating mode with a defective HP piping must not be considered as permanent. A defective HP piping has to be exchanged as quickly as possible!

A possible pressure can be relieved by means of drain screw (17) and the accumulated leakage oil be drained.

General leakage in the control oil pump are monitored by level switch (18) (see 8016-1 'Servo and control oil leakage system').

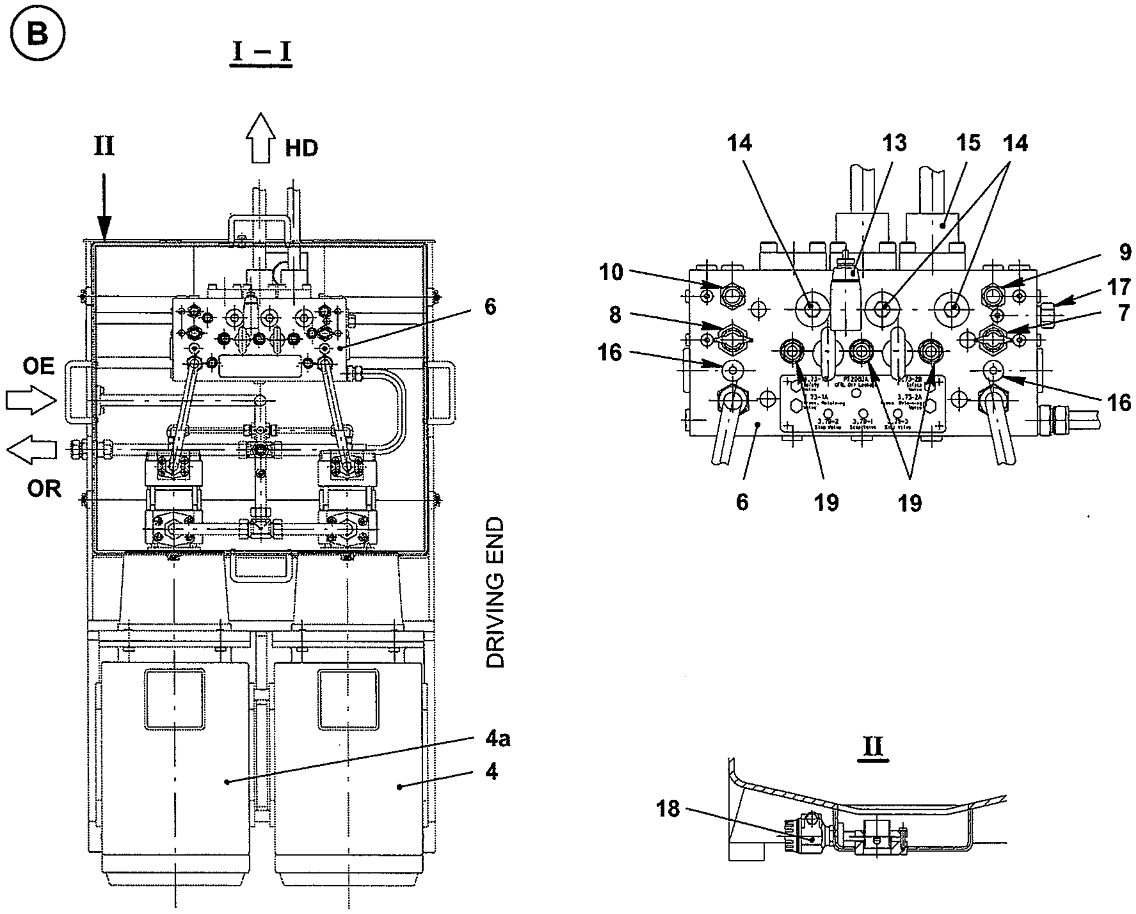
2.1 Localization of a defective HO piping

⇒ Keep control oil pumps running during engine standstill

⇒ Close all stop valves (19) and open drain screw (17).

- 'Control Oil Pressure Leakage' alarm from pressure transmitter (13) disappears (if not, there is a defect in pressure transmitter).

⇒ Close drain screw and reopen stop valves one by one till the leakage alarm is indicated again.



Key to Illustrations: 'A' Arrangement of control oil pump unit
'B' Control oil pump unit [L]

1	Control oil pump unit [L]	13	Eccentric shaft
2	Automatic filter (4.20)	14	Non-return valve
3	Stop valve (4.37)	15	Flange
4, 4a	Control oil pumps (3.72-1 & 2)	16	Non-return valve (3.56)
5	Oil piping	17	Drain screw
6	Distributor block	18	Level switch LS2085A
7	Pressure retaining valves (3.73-1A)	19	Stop valves (3.79-1 & 2)
8	Pressure retaining valves (3.73-2A)		
9	Safety valve (3.73-1B)	HD	HP oil
10	Safety valve (3.73-2B)	LO	Leakage oil drain (pump trough)
11	HP control oil piping (3.74)	OE	Oil inlet
12	HP control oil piping (3.74)	OR	Oil return

1. General

The mechanical regulating linkage is arranged for both fuel pump rows (see Fig. 'A'). It permits the regulating racks (17) to be positioned in fuel pumps (16) by the movement of actuator levers (6).

There are two, three or four electrically-operated (fuel pump) actuators provided, depending on number of cylinders. Every actuator controls two fuel pumps.

Therefore the regulating shafts are designed in two parts as for engines with eight or more cylinders.

The positions of the actuators (1) and regulating shafts (2) are indicated at supports (3) (see Fig. 'B').

2. Function

Controlled by the WECS-9520 system the actuators regulate the required fuel quantity, maintaining the necessary operating pressure in the fuel rail.
During normal operation the actuators work simultaneously, i.e. the regulating position and the fuel quantity of all fuel pumps are identical.

If a pump plunger seizes and therefore blocks the regulating rack, the spring links (items (13) and (14)) ensure proper regulation of the other pump by the actuator.
Appropriate measures to be taken see Cutting Out and Cutting In of the Fuel Pump 5556-2.

6 and 7 cylinder engines:

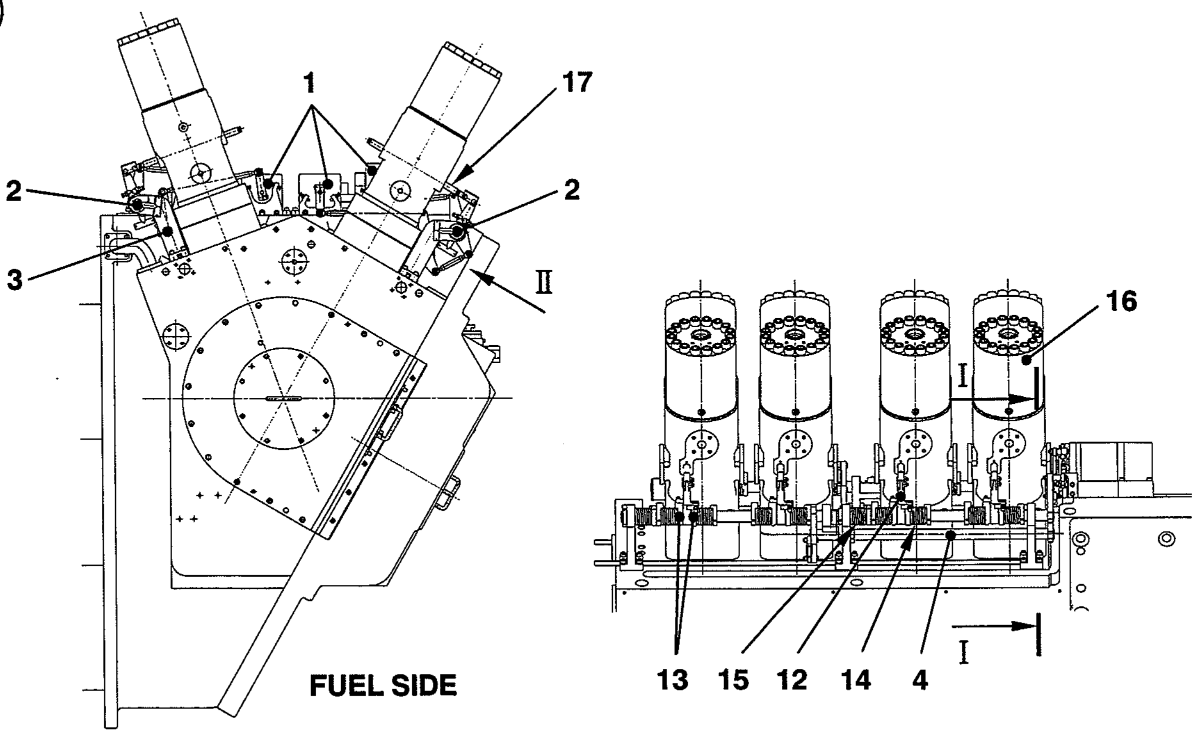
If an actuator fails, its regulating output turns to full quantity (torsion spring) or remains in position. The other actuator takes over the control of the fuel quantity regulation (see also 0515-1 'Defective actuator').

8 to 14 cylinder engines:

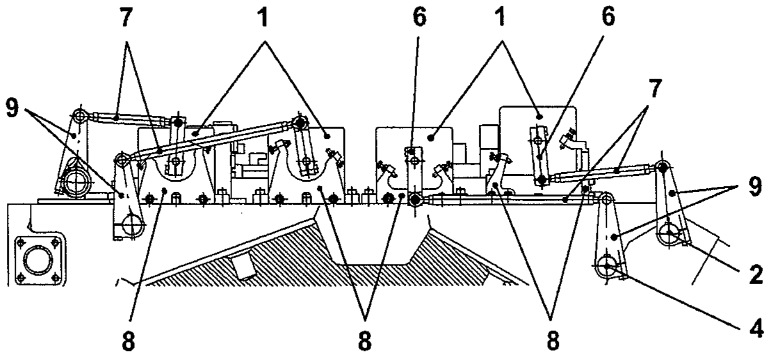
If an actuator fails, its regulating output turns to full quantity (torsion spring) or remains in position. The other actuators take over the control of the fuel quantity regulation (see also 0515–1 'Defective actuator').

☞ *Remark* : In the lower load range (at lower fuel consumption) fuel pressure control valve (3.06) takes over the fuel pressure regulating function as the fuel quantity supply can not further be reduced by the actuator(s) (see also 5556-1'Fuel pressure control valve 3.06').

A

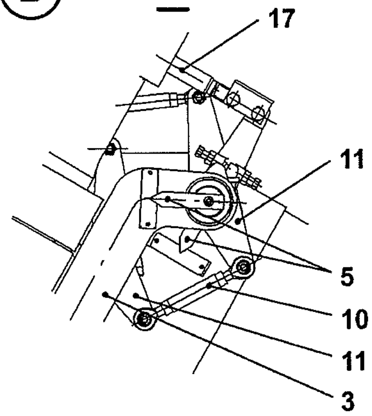


I–I



B

II



Key to Illustrations: 'A' Arrangement of regulating linkage
'B' Actuator position indicator

1	Actuator (3.21)	10	Connecting rod for intermediate and regulating shafts
2	Regulating shaft (3.20)	11	Lever for connecting rod (10)
3	Support	12	Forked lever
4	Intermediate shaft	13	Limit lever
5	Pointer	14	Torsion spring
6	Actuator lever	15	Torsion spring
7	Connecting rod	16	Fuel pump (3.14)
8	Limit lever for actuator lever	17	Regulating (toothed) rack
9	Lever		

Group 6

6

1. General

The scavenge air receiver (1) is fitted to the cylinder jacket (9) on the exhaust side. It is divided into two spaces "VR" and "RC" by a longitudinal wall (12). Air flaps (2) are provided on the separating wall in the region of scavenge air cooler inlet.

2. Function

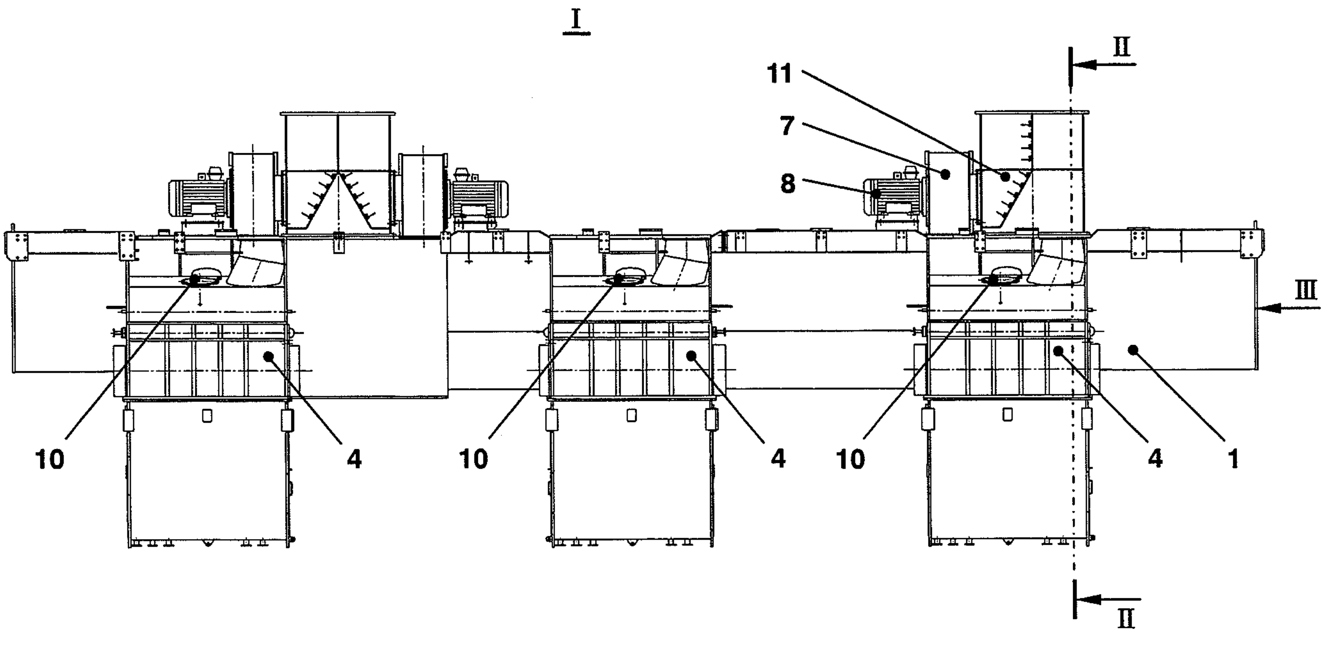
When operating the turbocharger blows scavenge air via the charging module (4) through the scavenge air cooler (14) and the water separator (13) into pre-space "VR" of the receiver. The scavenge air flows into the receiver space "RC" through air flaps (2) via openings in the cylinder jacket (9), then to piston underside "KU" and through scavenge ports into the cylinder, when the respective piston is near BDC.
Air flaps prevent back-flow into the pre-space "VR" of the receiver.

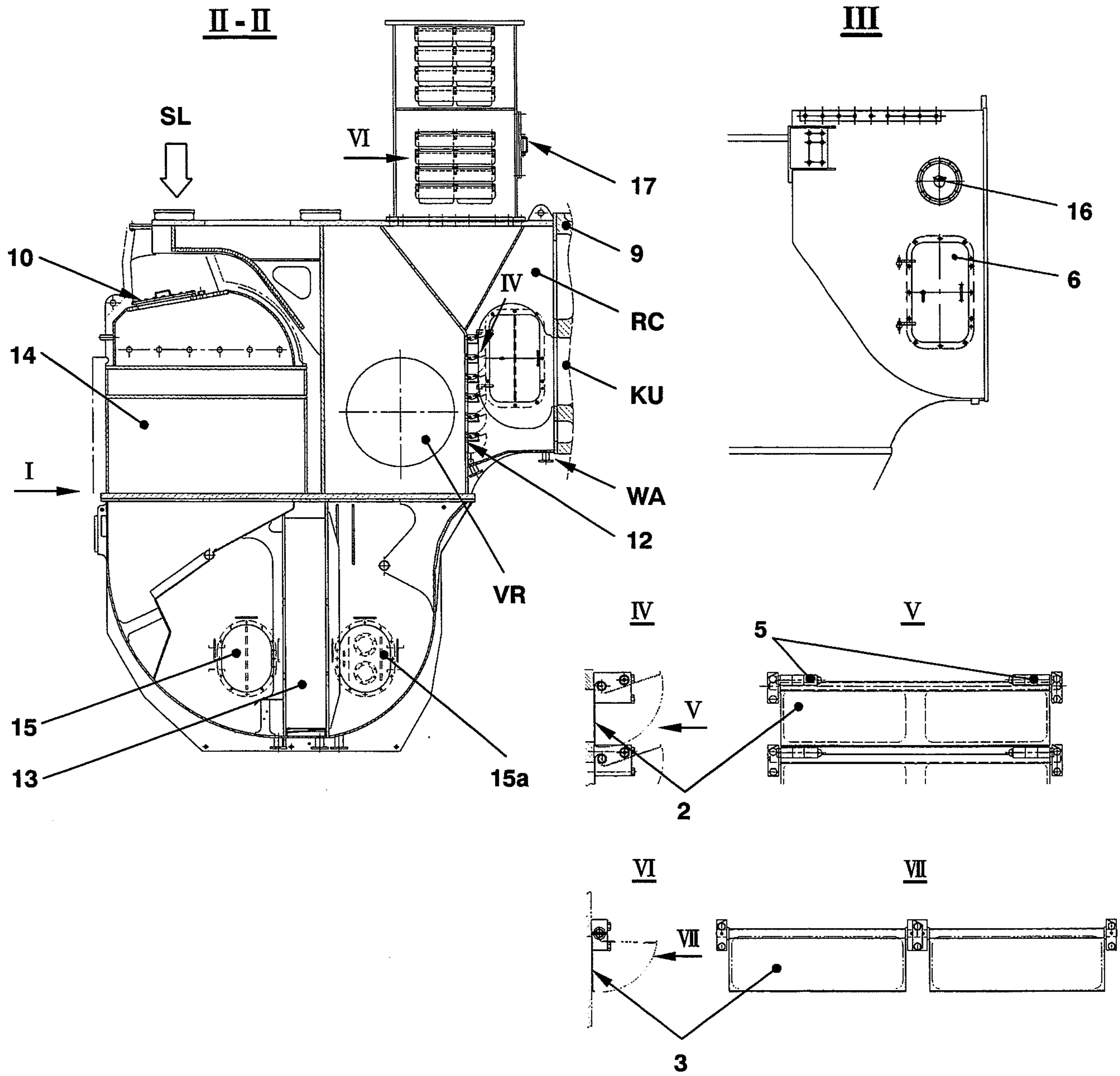
Depending the engine three auxiliary blowers (7) are mounted on the upper receiver side. At the start of the engine or at low engine load the auxiliary blowers are switched on. They suck scavenge air from pre-space "VR" via suction box (11) and deliver it into receiver space "RC". The air flaps (3) fitted in the suction box (11) prevent back-flow of the air when the auxiliary blowers are switched off.

Depending on number of cylinders a relief valve (16) is mounted at one or both end(s) of the scavenge air receiver. These open when the air pressure rises above the admissible value in the receiver space "RC".

Access to the receiver is possible through hinged covers (6) **at engine stop.**
Part of the cylinder liner running surface, of the piston and piston rings as well as of the piston rod grand can be inspected from the receiver space "RC". The covers (17) can be opened to examine the air flaps (3).

Remark : Should the exhaust gas turbochargers be defective, the covers (15a) at the charging module must be opened for emergency operation (see Turbocharger Out of Service 0590-1).





Key to Illustrations:

1	Scavenge air receiver	15, 15a	Cover
2	Air flaps	16	Relief valve
3	Air flaps to auxiliary blower	17	Cover
4	Charging module		
5	Stop bar		
6	Hinged cover		
7	Auxiliary blower		
8	Electric motor	KU	Piston underside
9	Cylinder jacket	RC	Receiver space
10	Cover	SL	Scavenge air from the exhaust gas turbocharger
11	Suction box (support for exhaust gas manifold)	VR	Pre-space
		WA	Water drain from receiver
12	Longitudinal wall	WS	Condensate after scavenge air cooler and dirty water from scavenge air cooler cleaning
13	Water separator		
14	Scavenge air cooler	WW	Water drain from water separator

1. General

Turbochargers are exactly tuned to the engine depending on the number of cylinders, service output, mode of operation etc..

Indications on operation, maintenance and servicing are described in the respective documentation of the manufacturer (which is part of the Operating Instruction).
The cleaning of turbochargers in operation is described in 6510-1.

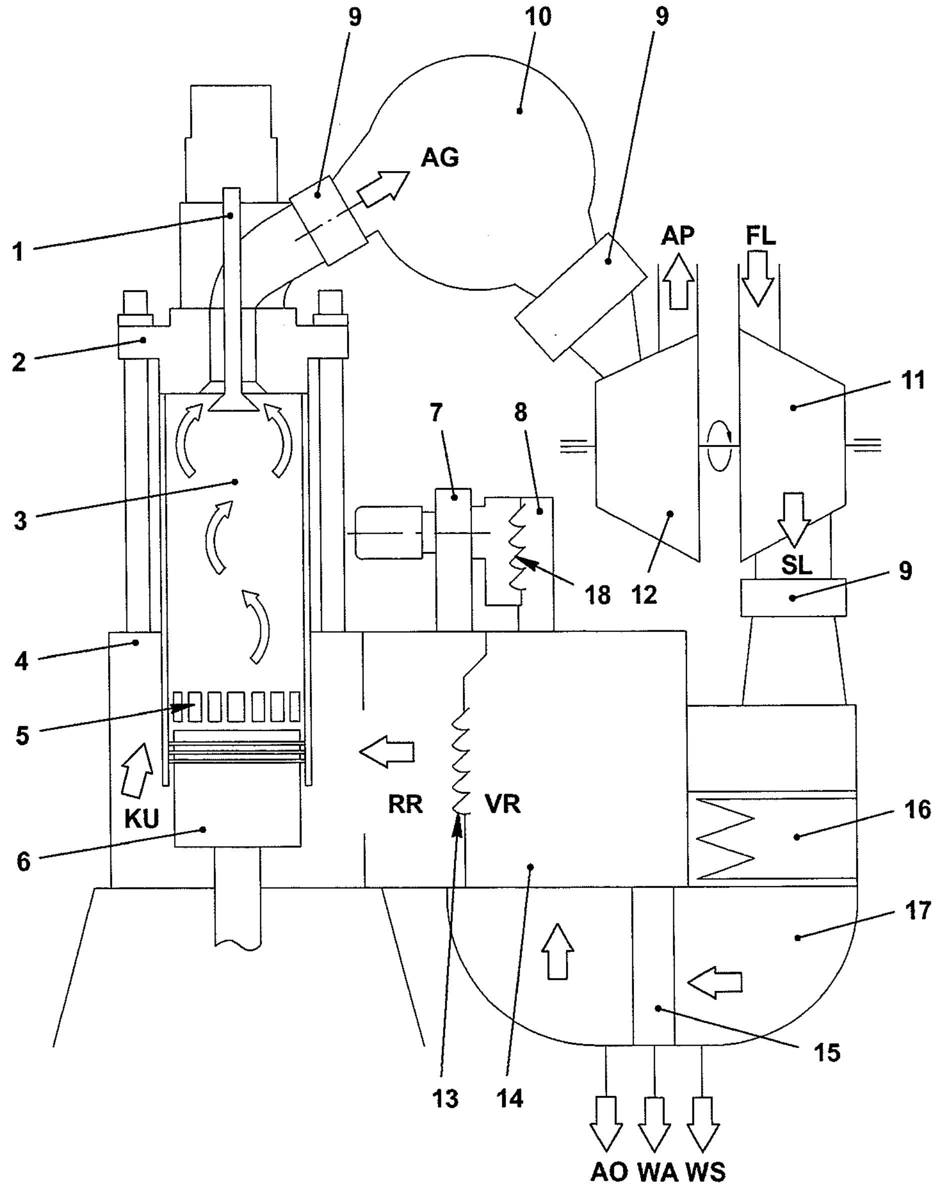
2. Function

Exhaust gas "AG" from the cylinders is accumulated in the exhaust gas manifold (10), led to the turbine (12) of TC and thereafter comes out to the environment "AP" through the ship-side exhaust system. The exhaust gas rotates the turbine which drives the compressor (11) mounted on the same shaft.

The compressor draws fresh air "FL" from the engine room via a filter/silencer and compresses it to the so-called scavenge air pressure "SL". The scavenge air heated by the compression process is led in the charging module (17) to the scavenge air cooler (16) which cools the air to a lower temperature range. Depending on the humidity in the air, the cooling action produces a considerable amount of condensate water which is separated in water separator (15) and drained off via several drains "WA".

The scavenge air passes from the receiver pre-space "VR" to receiver space "RR" through the air flaps (13) and then into the space 'KU' of the piston underside.
When the piston (6) is near to B.D.C. (inlet ports open) scavenge air flows into cylinder (3) through inlet ports (5).
After the compression, combustion, and expansion process, the exhaust valve (1) opens and exhaust gas "AG" flows into the exhaust gas manifold (10), completing the cycle.

When starting the engine or in the case of low load operation, the auxiliary blower (7) supplies air into the receiver space "RR". Air flaps (13) and (18) prevent a back-flow of air (see also Scavenge Air Receiver 6420-1).



Key to Illustrations:

1	Exhaust valve	16	Scavenge air cooler
2	Cylinder cover	17	Charging module
3	Cylinder liner	18	Air flaps before auxiliary blower
4	Cylinder jacket		
5	Inlet ports		
6	Piston	AG	Exhaust gas after cylinder
7	Auxiliary blower	AO	Oily-water drain
8	Air inlet casing	AP	Exhaust gas, out let
9	Expansion piece	FL	Fresh water
10	Exhaust gas manifold	KU	Piston underside piece
11	Compressor	RR	Receiver space
12	Turbine	SL	Scavenge air after blower (compressor)
13	Air flaps	VR	Receiver pre-space
14	Receiver	WA	Water drain
15	Water separator	WS	Condensate after scavenge air cooler

1. General

The exhaust gas turbochargers are equipped with a washing arrangement. From the very beginning of operation blower and turbine have to be cleaned with this arrangement periodically in order to prevent the build-up of increasing contamination. If the dirt accumulation becomes excessive (scavenge pressure drops and higher exhaust gas temperature), the turbocharger must be dismantled for cleaning, whereby the instructions in the turbocharger manual must be followed.

2. Cleaning procedure

a) Wash-Cleaning the Blower (See sheet 6510-1, 4/4)

When it is difficult to keep the engine performance as desired until the next overhaul of the turbocharger because of the turbocharger compressor being extremely fouled owing to various ambient conditions in the engine room, clean the compressor by water-washing.

1) Clean the compressor in accordance with Table 1.

2) The water is to be injected by gravity feed method. (See sheet 6510-1, 4/4)

3) See that there are no foreign matters inside the tank and hose by flushing with water.

4) Do not supply water to the gravity tank directly from water faucet or from large container. Supply water gradually with the use of a small container.

Table 1. Cleaning of compressor side

MET types		90SE	83SD 83SE 83SE II
Turbocharger speed range	[min^{-1}]	4000 ~ 5500	4600 ~ 6000
Water quantity	[liter]	3.0	3.0
Time	[sec]	60 ~ 120	60 ~ 120

b) Cleaning the turbine (See sheet 6510-1, 4/4)

With the new cleaning method, cereal grains or activated coconut charcoal particles are fed into the turbocharger, in front of the turbine, so that these grains or particles, accelerated by gas stream, will hit the turbine nozzles and blades to remove deposits from these components.
There is no need to reduce the engine load, and the cleaning can be performed with the engine kept running at normal load and in very short time. It goes without saying that the exhaust-gas passage and casings are not subjected to thermal shock.
It is advisable that the turbine side be periodically cleaned to prevent turbine from becoming fouled with deposits.

1) Kinds of cleaning media

- Walnuts shell particles
  Particle size : about 2.0 ~ 2.8 mm (MARINE GRIT #8)
  Note : Walnuts shell is made available by HIKAWA MARINE CO., Ltd.

- Grain (rice, wheat, etc.)
  Particle size : about 3.0 or less than

2) Quantity of cleaning medium

Select from Table 2 the quantity of cleaning medium to be used for one cleaning, according to the turbocharger type in use.
Use of too much cleaning medium can result in the turbocharger surging.
Therefore, use the optimum quantity of cleaning medium according to the engine operating conditions.

Table 2 Applicable cleaning medium and device

MET type / Cleaning medium & device		90SE	83SD 83SE 83SEII
Qt'y of cleaning medium	[liter/once]	4.0	3.5
Applicable cleaning device	[reference]	OMT-TC-40	

3) Cleaning Procedure

(1) Cleaning intervals

As a matter of guide, make it a principle to perform the cleaning once every **200 to 250** hours of operation. Adjust the cleaning intervals thereafter in accordance with the decline in turbocharger performance, i.e., changes in exhaust temperature, scavenging pressure, turbocharger revolutions, etc.

(2) Engine operating conditions for performance of cleaning

Perform the cleaning, as a general rule, with the engine operated at normal load (75 to 85% load). Although the cleaning can be performed while the engine is operated at about 50% load, a caution is advised since the cleaning medium can collect in the gas-outlet casing when the engine load goes further down.
Since the maximum permissible turbocharger speed and turbine inlet temperature for the cleaning are as indicated in Table 3, reduce the engine load below the normal level if the turbocharger speed and turbine inlet temperatures at the normal engine load are higher than indicated in the table.

Table 3 Maximum permissible turbocharger speed and tempature before turbine for cleaning

MET type		90SE	83SD 83SE 83SEII
Max. turbochargeer speed for cleaning	[min^{-1}]	8500	9400
Max. temperature before turbine	[° C]	500	

4) How to perform cleaning

Perform the cleaning in the following manner.

(1) When cleaning only once (See sheet 6510/1.6.)

a) Open the valves in the following sequence to pass air for one to two minutes for cooling of the cleaning device.
Valve ① → Valve ④

b) Close the valves in the following sequence.
Valve ④ → Valve ①

c) Fill the tank ② with the specified quantity of cleaning medium. Be sure to close the cap of the tank ② without fail.

d) Open the valves in the following sequence to pass air and inject the cleaning mediumm.
Valve ① → Valve ④

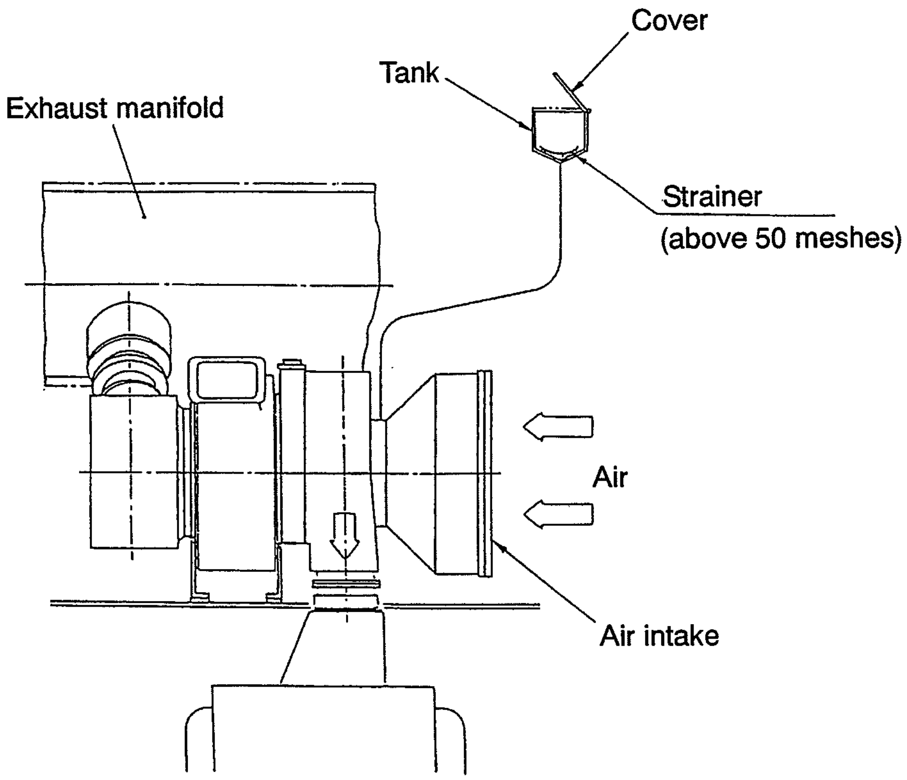
e) Close the valves in the following sequence.
Valve ④ → Valve ①

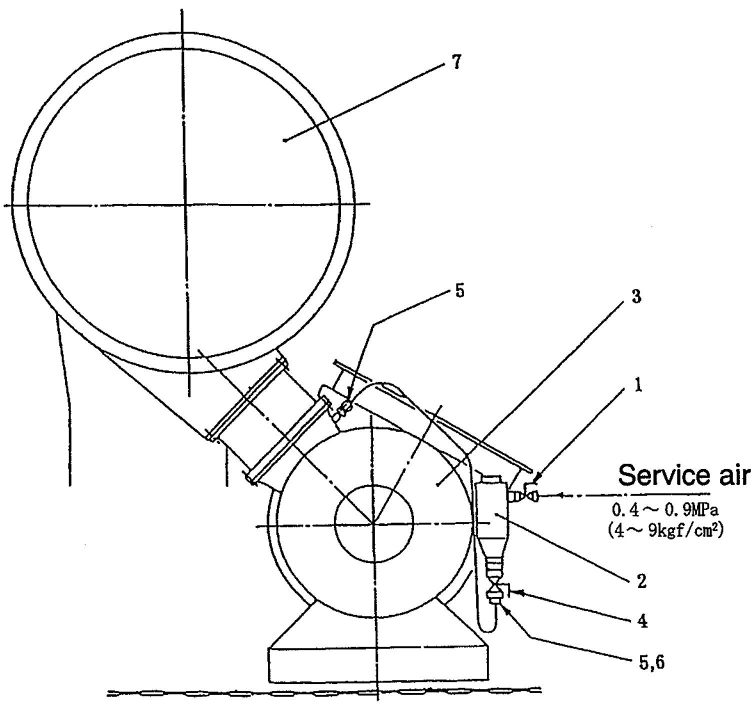
Remark : Do not open the turbocharger gas outlet casing drain discharge during the cleaning.

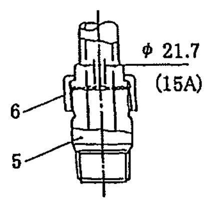
(2) When cleaning repeatedly

a) Should some such sudden change take place in engine operation during injection of the cleaning medium as, for example,very severe surging, etc., use about 1/2 of the quantity indicated in Table 2 per cleaning for trial. Make sure that the engine undergoes stabilized operation, and then repeat the cleaning the same way. Employ this cleaning method thereafter as a standard practice.

b) In case the exhaust temperature, scavenging pressure, turbocharger speed, etc., show no improvement following the cleaning as in (1) above, repeat the process prescribed in (1). If the repeated cleaning also fails to improve the situation, then open up the turbocharger for cleaning.







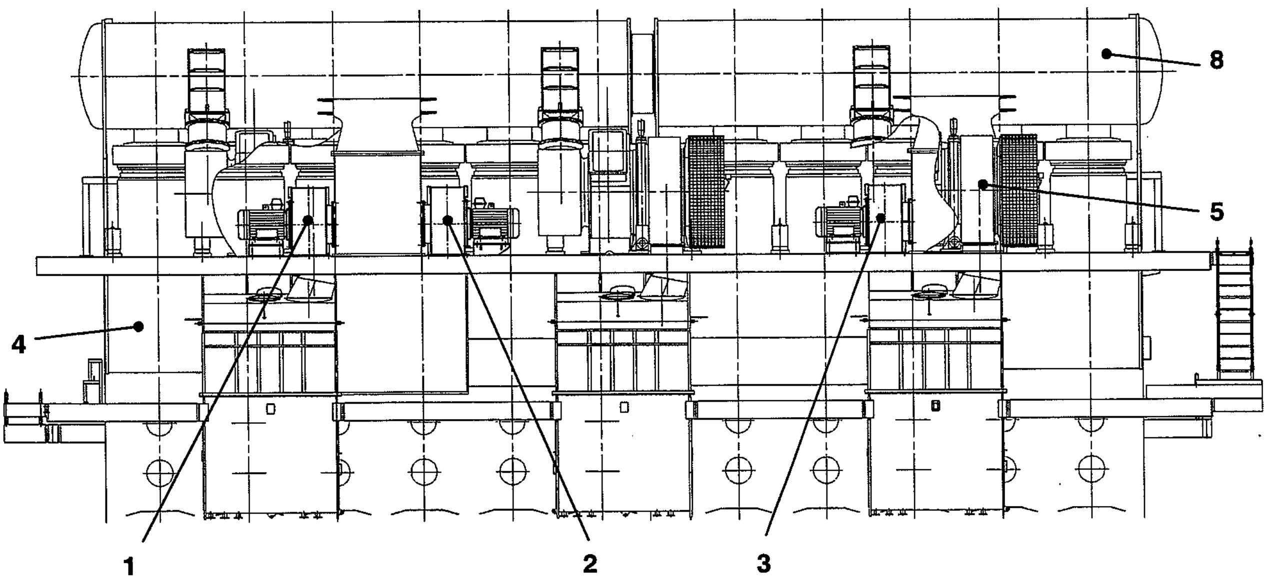
Key to Illustrations:

1 Exhaust valve
2 Cylinder cover
3 MET turbocharger
4 Ball valve
5 Joint
6 Control ring
7 Exhaust gas manifold

1. Auxiliary blower

The auxiliary blowers (6) driven by electric motors (7) are mounted to the upper receiver side (4). They supply air from the receiver pre-space via suction casing into the receiver space during the start and operation at low load. Back-flow to the receiver, of the air blown in by the auxiliary blowers, is prevented by air flaps (see Scavenge Air Cooler 6420-1).

A



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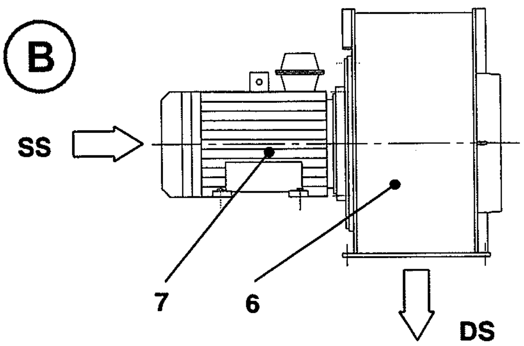


Key to Illustrations : 'A' Arrangement of auxiliary blower
'B' Auxiliary blower

1 No.1 Auxiliary blower
2 No.2 Auxiliary blower
3 No.3 Auxiliary blower
4 Receiver
5 Exhaust gas turbocharger
6 Blower
7 Electric motor
8 Exhaust manifold

DS Pressure side
SS Suction side

Charging Module
Scavenge Air Cooler, Operating Instruction and Cleaning

1. General

Each exhaust gas turbocharger is arranged with a scavenge air cooler mounted on the engine. This serves to cool the compressed, and therefore heated, scavenge air before it reaches the cylinders via the water separator and the scavenge air receiver.

2. Operating Instructions

WARNING

Put on cloth gloves so as not to get burnt in the hand at the inspection during engine operation and right after stopping.

As accumulated air in the cooling water system of the scavenge air cooler can lead to operating troubles on the engine and to damage of the SAC, proper functioning of the SAC venting must be ensured. The scavenge air cooler temperature must be checked periodically in accordance with Operating Data Sheet 0250-1.

In the event of water flowing through the sight glass when the engine is running, it must be investigated whether the water is condensate water or scavenge air cooling water.
Should the latter be the case, then the cooler must be dismantled and repaired (see Maintenance Manual 6606-2).

To prevent damage to the SAC, the correct cooling water flow must be maintained in operation. The flow of cooling water must not be throttled at partial load nor during manoeuvring.

Concerning operation with a defective scavenge air cooler, recommendations can be found in 0550-1.

As a guide to proper functioning of the SAC, the temperature difference between scavenge air outlet and cooling water inlet at the SAC can be taken as a basis. The two temperature values have to be checked periodically.
If the difference increases while engine load and cooling water flow remain unchanged, it is a sign of increasing fouling of the SAC.
At the same time, check the pressure difference (as the initial pressure difference, refer to the shop test record).

If the **fouling is on the water side** of the SAC, the scavenge air temperature increases.

If the **fouling is on the air side**, the pressure difference (Δ p) of the scavenge air through the SAC increases. This does not show the full effect of the fouling because an increased resistance also causes a reduced air throughput from the turbocharger (pay attention to limiting values).

Higher scavenge air temperature and reduced air flows both lead to increased thermal loading of the engine and to higher exhaust gas temperatures.
The air side and the water side of cleaning of the SAC can be carried out at standstill. The procedure on engine at standstill is described in 6606-1 of the Maintenance Manual.

3. Air side cleaning of the SAC in service

The equipment necessary for air side cleaning of the SAC is installed on the engine.

Cleaning intervals

In order to achieve the optimum cleaning effect, carry out the cooler cleaning immediately after cleaning the compressor of the turbocharger. Experience will show whether the time intervals can be extended.
The degree of SAC contamination depends to a major extent on the condition of the intake air and the maintenance of the air suction filter on the turbocharger.

Cleaning procedure

The cleaning should be carried out at standstill. The cleaning is ordered from cleaning maker generally or, when installing the cleaning line, the SAC is cleaned air side with circulating cleaning water on cleaning line.

- Check the three way valve (7) opened to the throttle disc (6) before cleaning.
  In case that the throttling disc is choked, check the ball valve (8) opened to the throttle disc (6a) before cleaning. If not, open the ball valve (8) opened to the throttling disc (6a) and repair the choked throttle disc as soon as possible.
- Pour the cleaning agent compounded in cleaning tank fully and circulate it with pump.
- After cleaning the scavenge air coolers with cleaning agent, clean them used by hot water or fresh water.
- Return three way valve (7) to normal position.

CAUTION

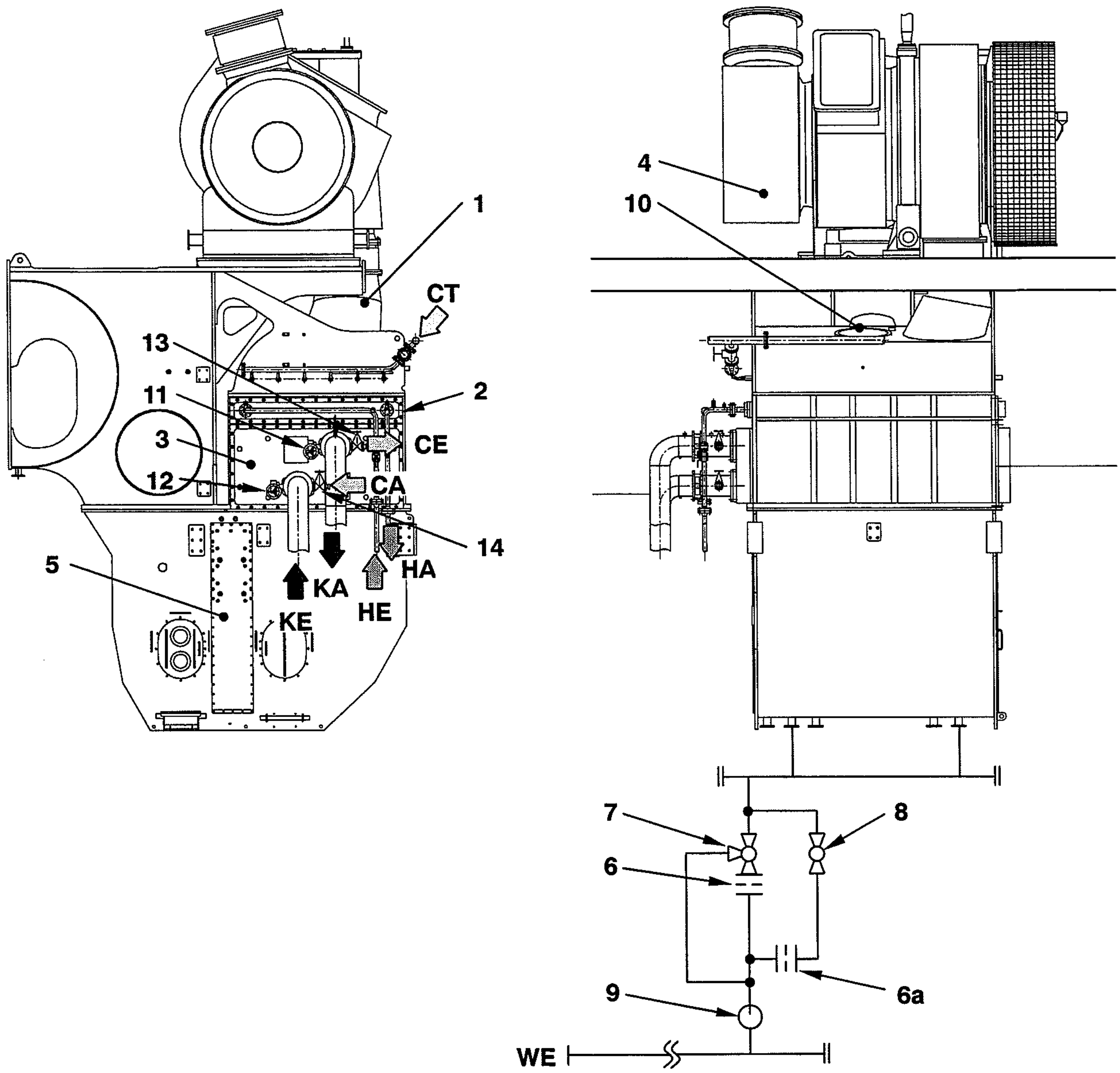
After cleaning the scavenge air cooler, close the stop valve of cleaning inlet line securely.

Cleaning agent

As a rule, only products from reputable firms should be used and their instructions with regard to mixing ratio, etc. must be followed precisely.

Charging Module

Scavenge Air Cooler, Operating Instruction and Cleaning



Key to Illustration :

1	Air duct	13	Hose valve for cleaning water outlet
2	Heater	14	Hose valve for cleaning water inlet
3	Scavenge air cooler		
4	Turbocharger	CA	Cleaning water outlet (cooling water side)
5	Water separator	CE	Cleaning water inlet (cooling water side)
6, 6a	Throttle disc	CT	Cleaning water inlet (air side)
7	Three way valve	HA	Boiler feed water outlet
8	Ball valve	HE	Boiler feed water inlet
9	Sight glass	KA	Scavenge air cooler cooling water outlet
10	Cover	KE	Scavenge air cooler cooling water inlet
11	Battefly valve for cooling water outlet	WE	Condensate water drain or cleaning water outlet (air side)
12	Battefly valve for cooling water inlet		

Group 7

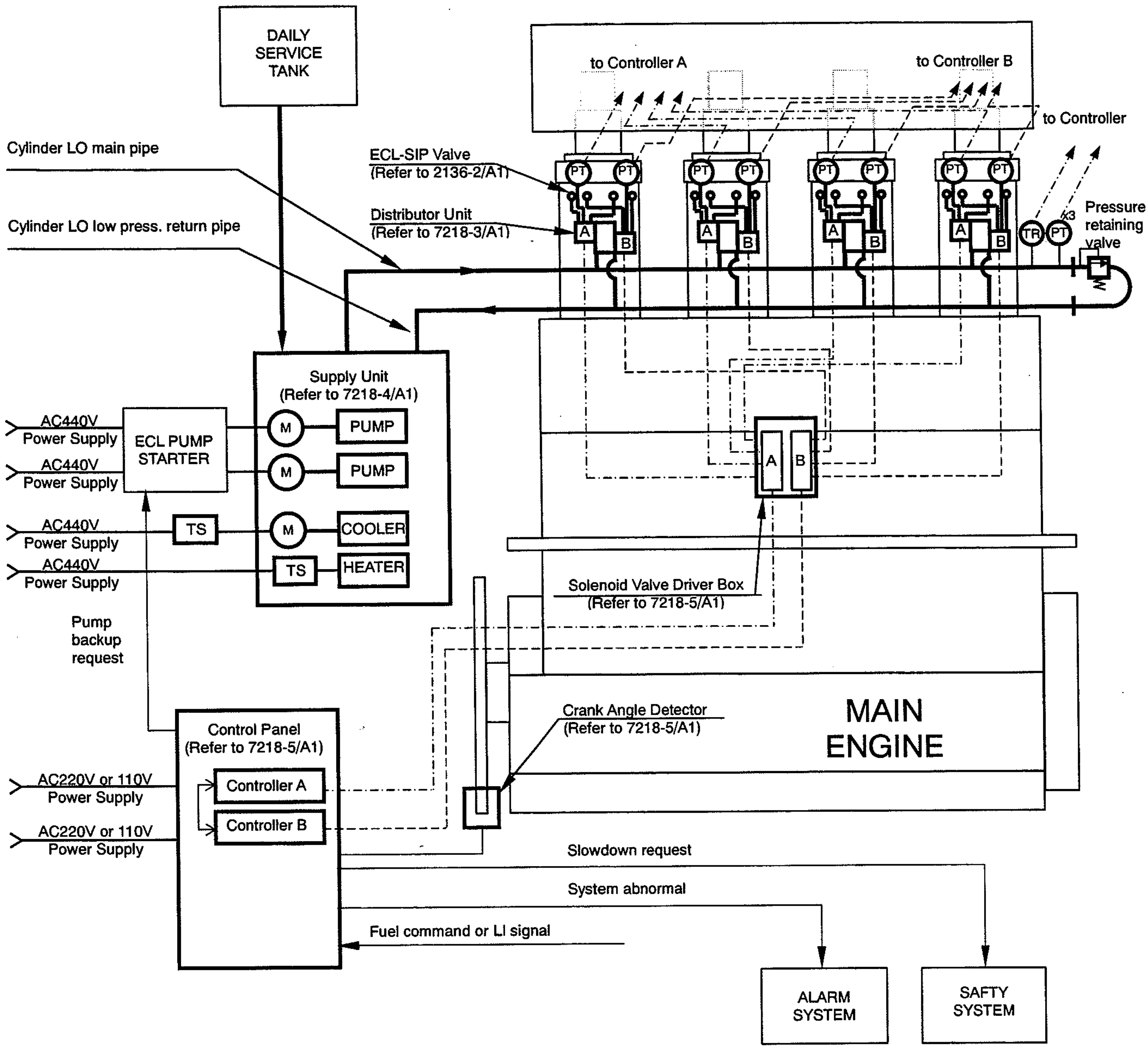
7

Cylinder Lubrication

Group 7

1. General

The outline of ECL system is shown as below figure.



ECL system consists of Supply Unit, Pressure retaining valve, Distributor Unit, ECL-SIP valve, Control Panel, Solenoid Valve Driver Box and Crank Angle Detector.
Cylinder lubricating oil is pressurized to 8MPa and controlled temperature within 45- 60 degree C by the Supply Unit. The pressurized and temperature controlled lubricating oil passes through the main pipe. And, the lubricating oil is decompressed by the pressure relief valve and returns to the Supply Unit. The orifice is installed each Distributor Unit in order to pass a small quantity of the cylinder lubricating oil through the Distributor Unit and keep warm the Distributor. The cylinder lubricating oil which is decompressed by the orifice is collected by the Low Pressure Return Pipe and returns to Supply Unit.

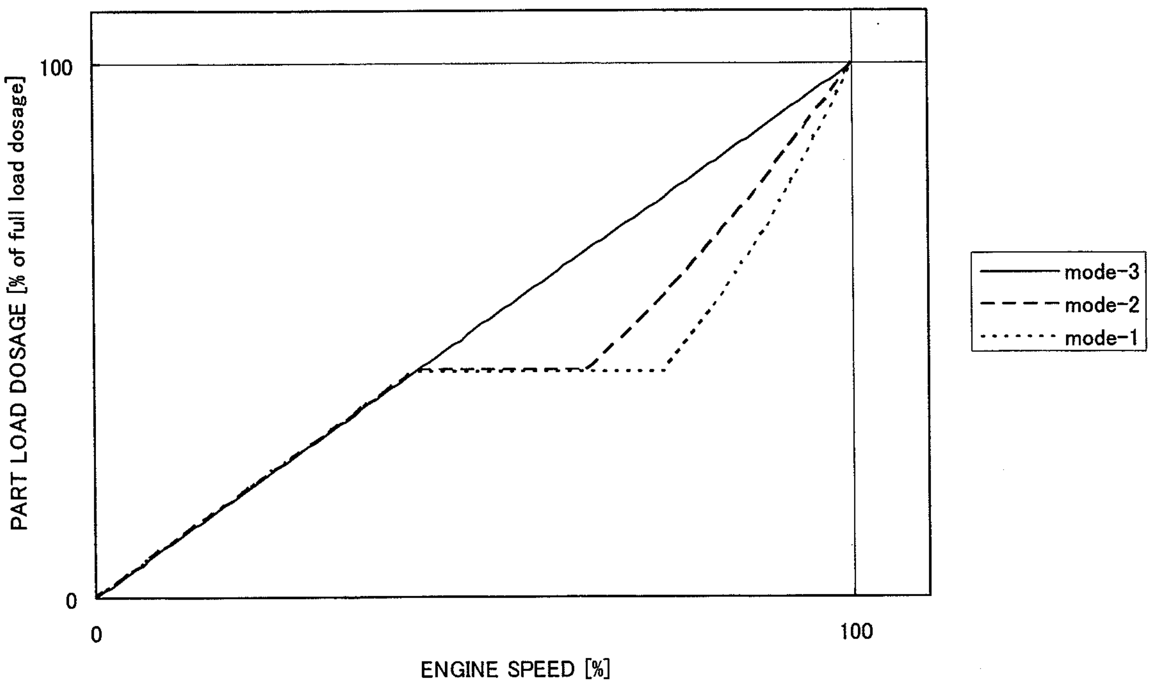
The distributor unit is equipped in each cylinder. The distributor unit consists of two solenoid valves (herein-after called Distributor). Distributor is energized by the solenoid valve driver and delivers cylinder lubricating oil into the cylinder liner via ECL-SIP valve according to the order from the Control Panel.

Remark The Distributor located on the main engine driving end is called "System A", the Distributor located on the main engine free end is called "System B".

Two controller cards are equipped in the control panel and the solenoid valve driver box. Each controller card controls distributors of system A and system B respectively.

2. Working Principle

- The Control Panel recognizes the main engine speed and crank angle on the basis of the signal of the Crank Angle Detector and recognizes the engine power on the basis of the Fuel Command signal from WECS9520 (or Load Indicator signal for RTA engines) and main engine speed.
- It is possible to set the cylinder oil feed rate at MCR to the respective cylinder by means of the control panel. The control mode for the part load dosage of cylinder lubricating oil can be selected from 3 modes.
  First of 3 modes is that the part load dosage of cylinder lubricating oil is proportional to the engine load. (mode1)
  Second is that the part load dosage is proportional to the mean effective pressure. (mode2)
  Third is that the part load dosage is proportional to the engine speed. (mode3)
  The control panel controls the part load dosage of cylinder lubricating oil automatically on the basis of the respective mode.
  (Regarding the characteristics of the part load dosage of cylinder oil, please refer to the following figure.)



- The quantity of the cylinder lubricating oil delivered from the distributor is adjusted by changing of the opening period of the distributor.
  The opening period of the distributor is corrected automatically according to the pressure and temperature deviations of the main pipe (common rail) from set points.
- The injection frequency is normally controlled one time per one revolution of main engine. When the injection quantity per one time is calculated less than the specified value, the injection quantity per one time is increased automatically and two distributors are operated intermittently and alternately.
- The injection timing of lubricating oil is controlled by the ECL controllers to inject predetermined crank angle.
- When some trouble occurs in the system, the system abnormality is notified to the ship's alarm system. The details of system abnormality are indicated on the control panel.
- When serious trouble occurs in one controller, only another controller continues injection. In that case, injection quantity of the normal controller side is automatically increased to keep the demanded dosage for backup.
  Please watch the condition of each cylinder carefully during backup operation.
  (Ex. inspection of the cylinder liner and piston rings from scavenge air port during anchorage.)
  Since it is not in a normal state, please make it the minimum as much as possible about the operation load and running hours.
- When a trouble occurs in both controller System A and B, the engine slowdown signal is transmitted to the safety system.

1. Adjusting of Cylinder Oil Feed Rate

It is possible to set the basic cylinder oil feed rate at CMCR to the respective cylinder with the ten-key on the operation panel.
The control panel controls cylinder oil feed rate at the partial load according to the basic cylinder oil feed rate at CMCR.

Regarding the operating instructions of the ten-key on the operation panel, refer to 7218-5/ A1 "ECL System Control System".

Addresses of the basic cylinder oil feed rate at CMCR to the respective cylinder are shown in the following table.

Address	LCD comment	Setting range
101	#1CYL FEED RATE	0.30 to 1.50 (g/PSh) by 0.01
102	#2CYL FEED RATE	
103	#3CYL FEED RATE	
104	#4CYL FEED RATE	
105	#5CYL FEED RATE	
106	#6CYL FEED RATE	
107	#7CYL FEED RATE	
108	#8CYL FEED RATE	
109	#9CYL FEED RATE	
110	#10CYL FEED RATE	
111	#11CYL FEED RATE	

CAUTION: Notice that the unit of the basic cylinder oil feed rate at MCR is described in g/PSh in ECL system.

2. Change of Control Mode for Partial Load

The ECL system automatically controls the cylinder oil feed rate at respective partial load according to the basic cylinder oil feed rate at MCR.

The ECL system has three modes (functions) to control the cylinder oil feed rate at respective partial load as mentioned below.

It is possible to change the modes (functions) to control the cylinder oil feed rate at respective partial load with the ten-key on the operation panel. The address of the mode setting is shown in the following table.

Address	LCD comment	Setting range
100	MODE SELECT	1 to 3 by 1 1: mode1, 2: mode2, 3: mode3

Mode 1

The cylinder oil dosage of partial load is directly proportional to the main engine power.

However, when the main engine speed is less than 70%, the cylinder oil dosage keeps constant independent of engine speed.

Mode 2 (standard)

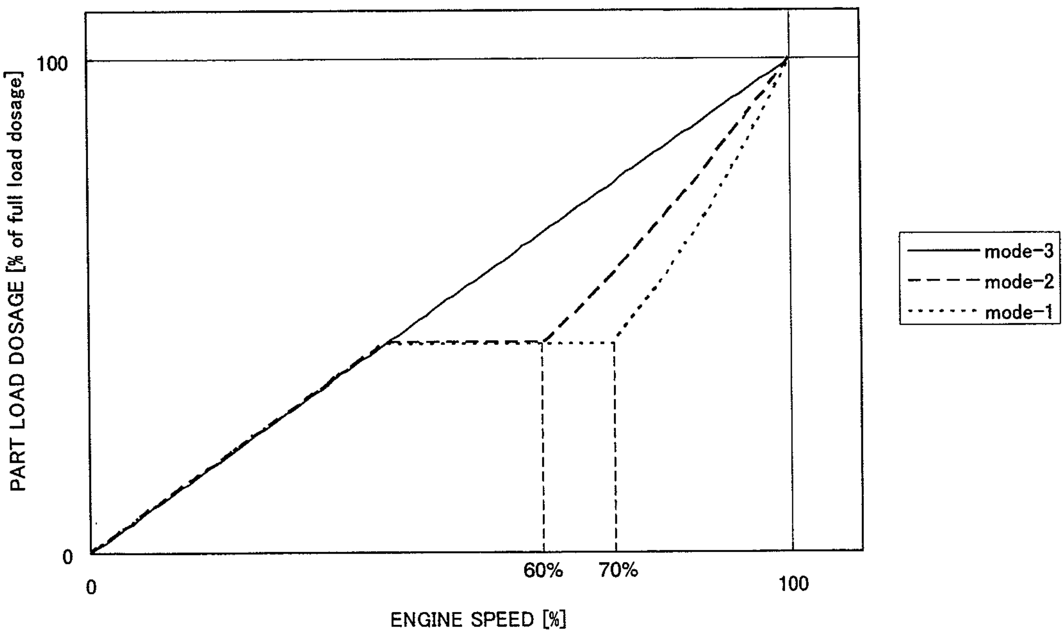
The cylinder oil dosage of partial load is directly proportional to mean effective pressure of main engine.

However, when the main engine speed is less than 60%, the cylinder oil dosage keeps constant independent of engine speed.

Mode 3

The cylinder oil dosage of partial load is directly proportional to main engine speed.

More details are shown in below figure.



3. Sulphur Limit

ECL system has the function, as called "Sulphur Limit", which can set the lower limit value of cylinder oil feed rate according to the quantity of sulphur content in the bunkered fuel.

Address of sulphur content in the bunkered fuel is shown in the following table.

Address	LCD comment	Setting range
117	Fuel Sulphur	0.00 to 5.00 (%) by 0.01

If this function is not needed, the above address should be set to 0.00 %.

4. Calculating for Actual Cylinder Oil Feed Rate

Actual cylinder oil feed rate at respective partial load can be calculated by the following expression.

$qa = Q \times \gamma / (24 \times L)$

Here,

- qa: Actual cylinder oil feed rate, g/KWh (g/PSh)
- Q: Actual cylinder oil dosage, l/Day
- γ: Density of cylinder oil, kg/m^3 (g/L)
- L: Main engine power, kW (PS)

5. Normal Consumption and Calculation Method

Mode 1

In case of mode 1, actual cylinder oil feed rate qa should be equal to the basic cylinder oil feed rate CLO_1 set by the section1. However, the above can be applied when the main engine speed is less than 70%

Mode 2

In case of mode 2, actual cylinder oil feed rate qa should be equal to CLO_2 calculated by the following formula. However, the above can be applied when the main engine speed is less than 60%

$CLO_2 = CLO_1 \times N_{CMCR} / N_E$

Mode 3

In case of mode 3, actual cylinder oil feed rate qa should be equal to CLO3 calculated by the following formula.

$CLO_3 = CLO_1 \times N_E \times PW_{CMCR} / (N_{CMCR} \times PW_E)$

Here,

- CLO_1: Normal feed rate of partial load in case of Mode 1, KWh (g/PSh)
- CLO_2: Normal feed rate of partial load in case of Mode 2, KWh (g/PSh)
- CLO_3: Normal feed rate of partial load in case of Mode 3, KWh (g/PSh)
- PW_E: Main engine power, kW (PS)
- N_E: Main engine speed, min^{-1}
- PW_{CMCR}: Main engine power at CMCR, kW (PS)
- N_{CMCR}: Main engine speed at CMCR, min^{-1}

1. General

Distributor unit is equipped at the exhaust side of each cylinder.

Distributor unit consists of two solenoid valves (herein-after called Distributor), two pressure transmitter, one base and one orifice. The base is arranged between two distributors.

Remark The distributor located on the driving end of main engine is called "System A", the distributor located on the free end of main engine is called "System B".

Two controllers are equipped inside the control panel. The controller A controls the distributor of System A, and the controller B controls the distributor of System B.

The distributor unit is supplied the pressurized lubricating oil from the main pipe. The orifice is arranged at lower side of base in order to pass a small quantity of the cylinder lubricating oil through the distributor unit and keep warm the distributor. The cylinder lubricating oil decompressed by the orifice is collected by the low pressure return pipe.

The pressure transmitter is installed to watch the pressure at outlet of distributor in order to detect the state of the distributor and lubricating valves.

A flow limiter is equipped between distributor and base to stop lubrication forcibly when excessive quantity of lubricating oil was delivered.

The distributor has 5 outlet ports to distribute the cylinder oil to each lubricating valve evenly. The distributor has a green LED which shows that the solenoid is energized.

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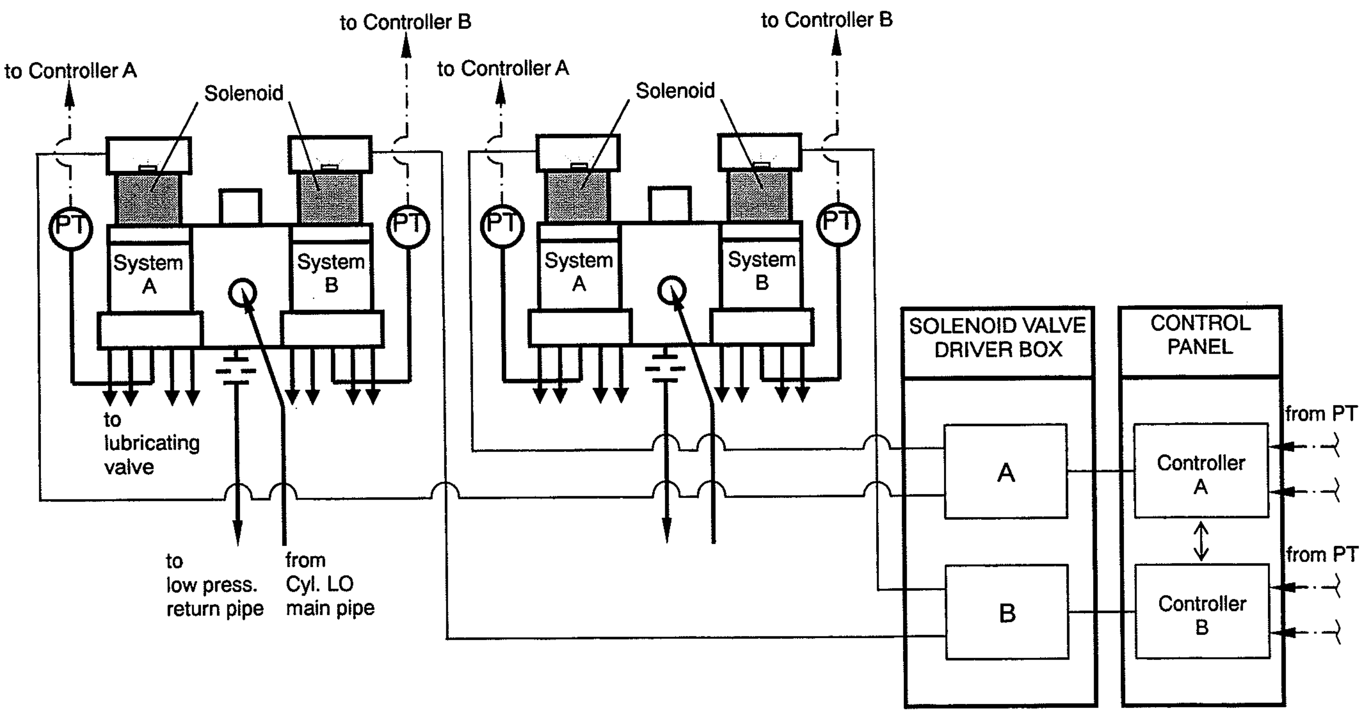
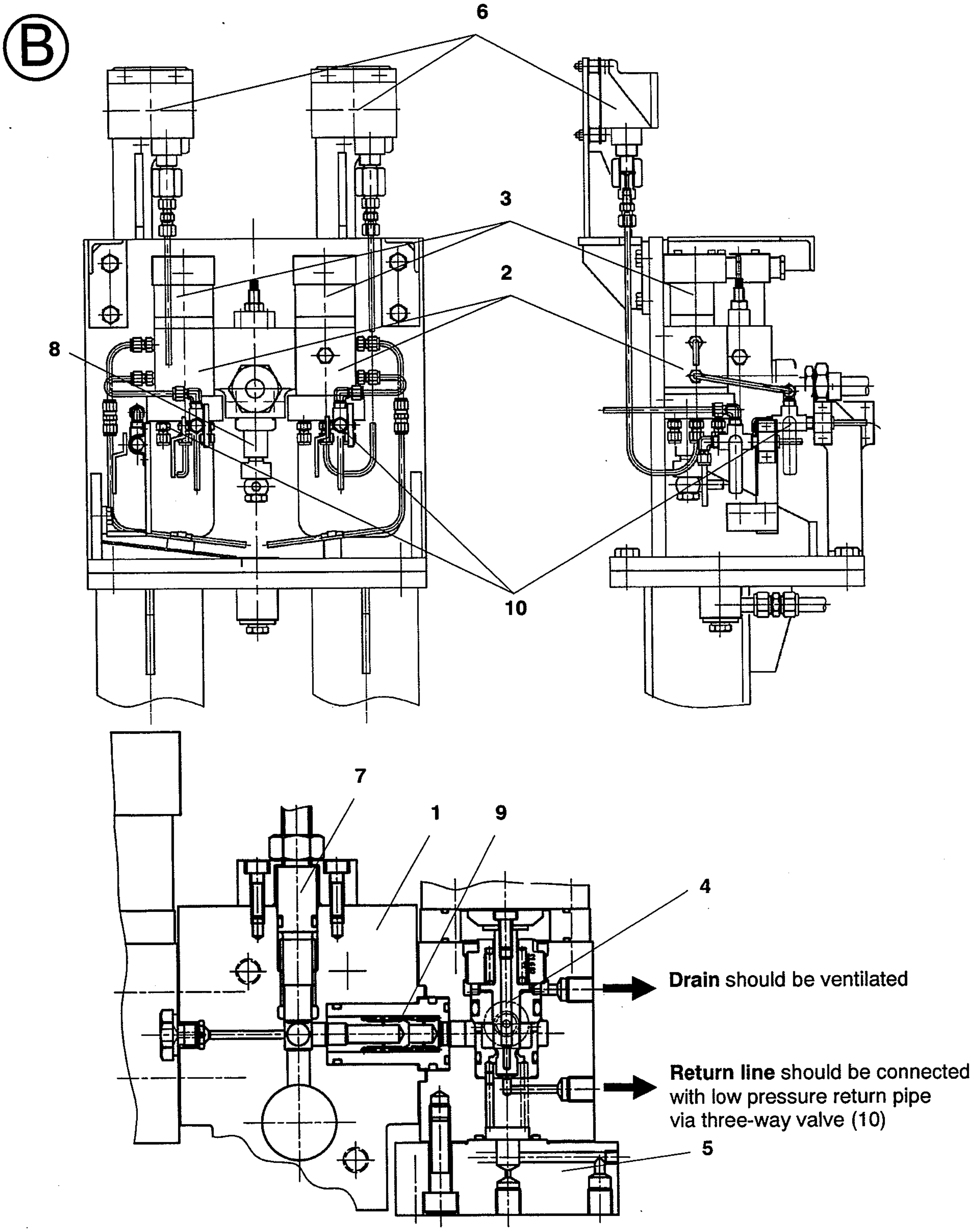


Key to Illustration:

1 Base
2 Distributor
3 Solenoid
4 Valve
5 Distributing piece
6 Pressure transmitter
7 Shut off valve
8 Orifice
9 Flow limiter
10 Three-way valve for distributor return line



2. Function

The distributor system A and B usually operate simultaneously.

The quantity of the cylinder lubricating oil which the distributor delivers per one time is adjusted by the energizing period of the distributor.

The injection frequency is normally controlled to one time per one revolution of main engine. When the calculated injection quantity per one time is less than the specified value, the injection quantity per one time is increased automatically and two distributors operate intermittently and alternately

If the distributor of one side breaks down, alarm is given out to the ship's alarm system and ECL control panel, and ECL control panel stops the operation of the distributor which breaks down, and increases the injection quantity of the distributor at the other side.

CAUTION

In this case, tighten the shut off valve of the side of the broken down distributor.

Regarding the removal, fitting and inspection of the distributor unit, refer to 7218-1/A1 in the maintenance manual.

WARNING

When the distributor unit is inspected or dismantled, please break a circuit of the solenoid.

1. General

Supply unit consists of two middle pressure pumps (1), three low pressure filters (2), two middle pressure filters (3), two safety valves (5), one line heater (6) and one oil cooler (7). Furthermore, one pressure retaining valve (4) with by-pass valve is equipped on the upper platform of the main engine.

Three low pressure filters (2) are arranged in parallel. Two low pressure filters (2) are normally operating and the other one is on stand by.
Two middle pressure pumps (1) are arranged in parallel. One middle pressure pump (1) is normally operating.
Two middle pressure filters (3) are arranged in parallel. One middle pressure filter (3) is normally operating.

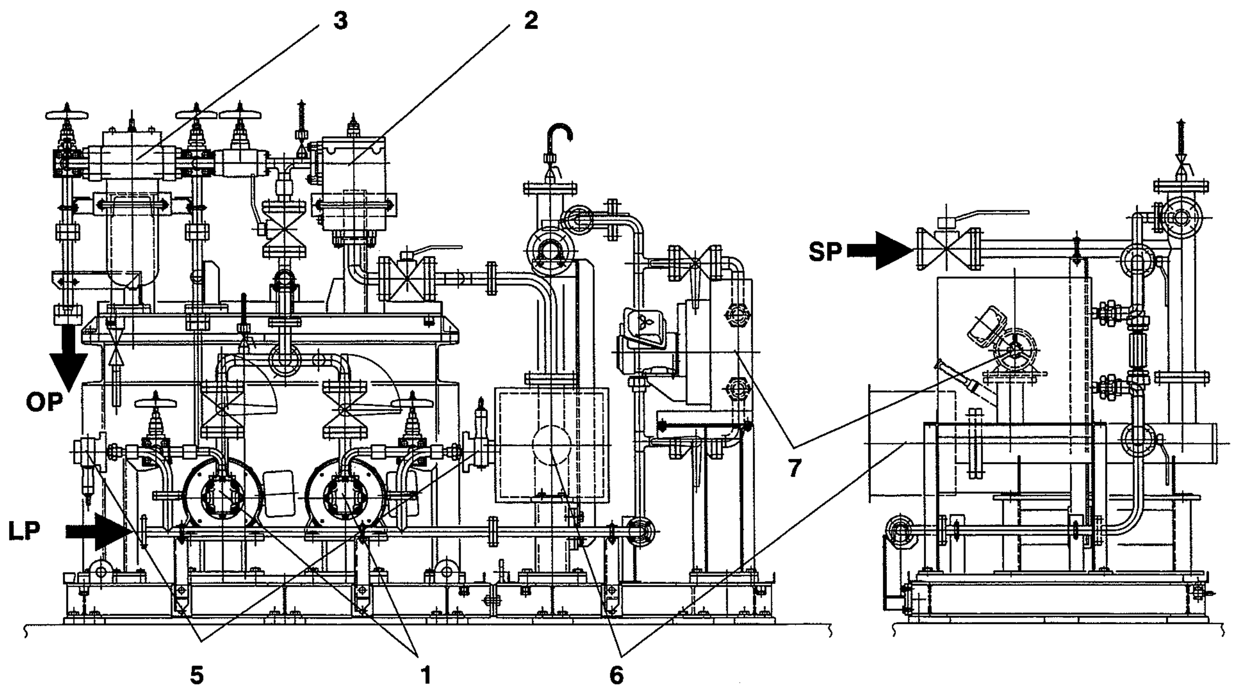
The cylinder lubricating oil supplied from the service tank is heated by the line heater (6). The heated oil is filtrated by the low pressure filters (2) and is pressurized by the middle pressure pump (1). The pressurized oil is filtrated by the middle pressure filter (3). The filtrated oil is delivered from outlet of supply unit OP to the main pipe.
The cylinder lubricating oil passes through the main pipe and is decompressed by the pressure retaining valve (4) which is equipped on the upper platform. The low pressure oil returns to the supply unit through the low pressure return line. After being cooled by the oil cooler (7), it returns to the line heater (6).

Regarding the cylinder lubricating oil piping system, refer to 8016-2/A1.

Regarding details of each equipment, refer to corresponding sections.

Key to Illustration:

1	Middle pressure pump	SP	Inlet of supply oil
2	Low pressure filter	OP	Outlet of pressurized supply oil
3	Middle pressure filter	LP	Inlet of low pressure return oil
4	Pressure retaining valve		
5	Safety valve		
6	Line heater		
7	Oil cooler		



2. Middle Pressure Pump

2.1 General

Two middle pressure pumps (1) are arranged in parallel. The middle pressure pump (1) is driven by the electric motor which is connected directly.

All inlet (2) and outlet (4) valves of the middle pressure pumps are normally opened.

The safety valves (5) are installed at the outlet of each pump to relieve the pressure and protect the pump when the discharge pressure of the pump rises abnormally.

2.2 Operation

Regarding more detail instructions of the pump starter panel, refer to the instruction manual of the pump starter panel.

Regarding more detail instructions of the middle pressure pump (1), refer to the instruction manual of the middle pressure pump manufacturer.

CAUTION

Only when the middle pressure pump (1) is inspected, inlet (2) and outlet (4) valves of the pump can be closed.

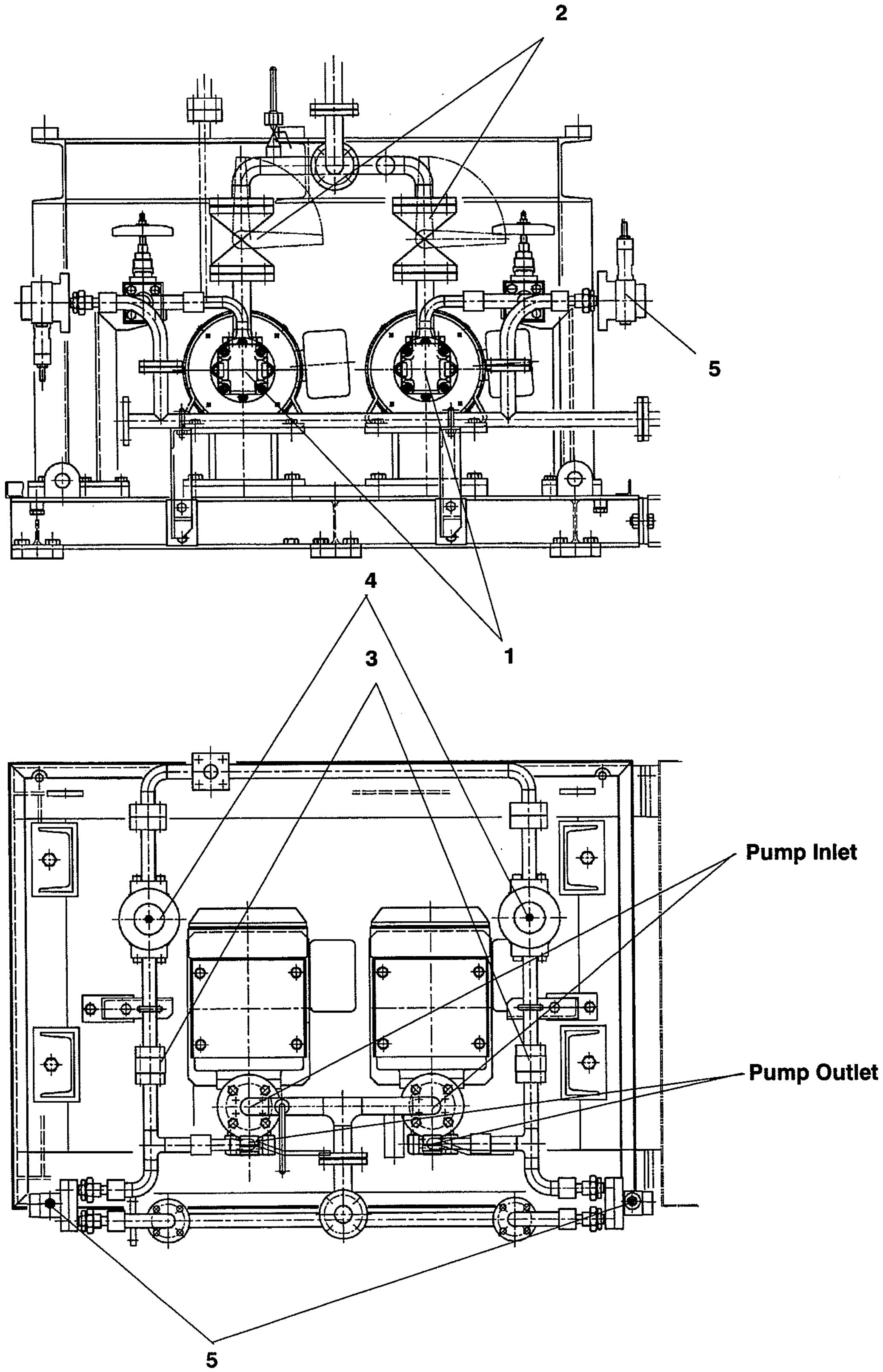
The middle pressure pump must not be operated when all the inlet (2) and outlet (4) valves of pumps are closed.
If the outlet valve of the middle pressure pump (4) is closed while the pump works, the safety valve (5) at the outlet of the pump works to protect the pump. At this time, the lubricating oil is not supplied to the main pipe.
If the inlet valve of the middle pressure pump (2) is closed while the pump works, inlet pressure of the pump becomes vacuum. At this time, the pump may be damaged due to the shortage of lubricating oil.

WARNING

When the middle pressure pump (1) is inspected, turn off the main power of the middle pressure pump (1).

Key to Illustration:

1 Middle pressure pump
2 Inlet valve of middle pressure pump
3 Check valve of middle pressure pump
4 Outlet valve of middle pressure pump
5 Safety valve


2
5
4
3
1
Pump Inlet
Pump Outlet
5

3. Low Pressure Filter

The low pressure filter (1) consists of filter element, pressure relief valve and indicator (5), etc.

Three low pressure filters (1) are arranged in parallel. Two low pressure filters (1) are normally operating and the other one is on stand by. Therefore, the inlet (2) and outlet (3) valves of the low pressure filter which is on stand by must be closed.

CAUTION

The middle pressure pump must not be operated when the inlet (2) and outlet (3) valves of all the low pressure filters are closed.
If the inlet (2) and outlet (3) valves of all the low pressure filters are closed while the pump works, inlet pressure of the middle pressure pump (1) becomes vacuum. At this time, the pump may be damaged due to the shortage of lubricating oil.

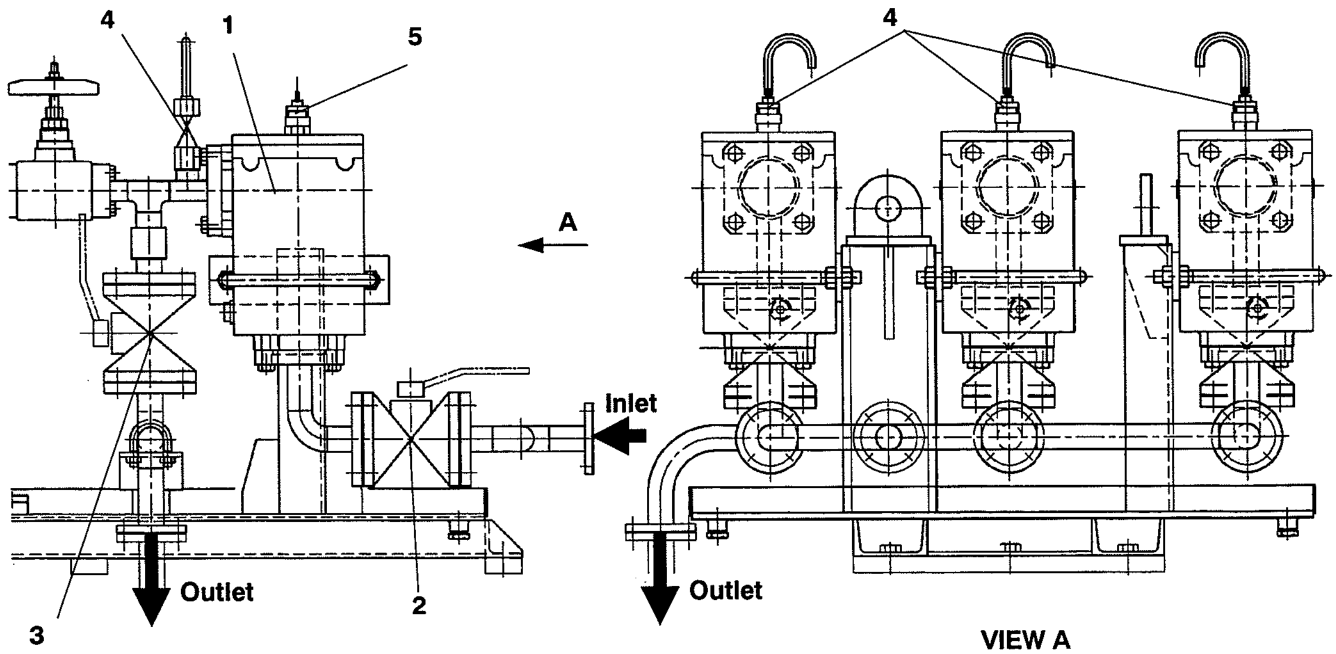
CAUTION

Plugging up of the filter element can be checked by the indicator (5).
When the indicator (5) shows red, open the inlet (2) and outlet (3) valves of the low pressure filter on stand by. In this case, main engine can continue operation. And, clean the filter element at the next time of the main engine shutdown.
When the filter element which is plugged up is used continuously, the pressure relief valve built into the filter opens to prevent the damage of filter element. Therefore, the rubbish flows out to the downstream of filter. It becomes cause of breakdown of the ECL system.

Regarding more detail instructions of the low pressure filter (1), refer to the instruction manual of the low pressure filter manufacturer.

Key to Illustration:

1 Low pressure filter
2 Inlet valve of low pressure filter
3 Outlet valve of low pressure filter
4 Air vent valve
5 Deferential pressure indicator



VIEW A

4. Middle Pressure Filter

The middle pressure filter (1) consists of filter element, pressure relief valve and indicator (5), etc.

Two middle pressure filters (1) are arranged in parallel. One middle pressure filter (1) is normally operating and the other one is on stand by. Therefore, the inlet (2) and outlet (3) valves of the middle pressure filter which is on stand by must be closed.

CAUTION

> The middle pressure pump must not be operated when the inlet (2) and outlet (3) valves of all the middle pressure filters are closed.
> If the inlet (2) and outlet (3) valves of all the middle pressure filters are closed while the pump works, the safety valve at the outlet of the pump works to protect the pump. At this time, the lubricating oil is not supplied to the main pipe.

CAUTION

> Plugging up of the filter element can be checked by the indicator (6).
> When the indicator (6) shows red, open the inlet (2) and outlet (3) valves of the middle pressure filter on stand by. In this case, main engine can continue operation. And, exchange the filter element at the next time of the main engine shutdown.
> When the filter element which is plugged up is used continuously, the pressure relief valve built into the filter opens to prevent the damage of filter element. Therefore, the rubbish flows out to the downstream of filter. It becomes cause of breakdown of the ECL system.
> The filter element of the middle pressure filter cannot clean because of paper element. Please be sure to exchange.

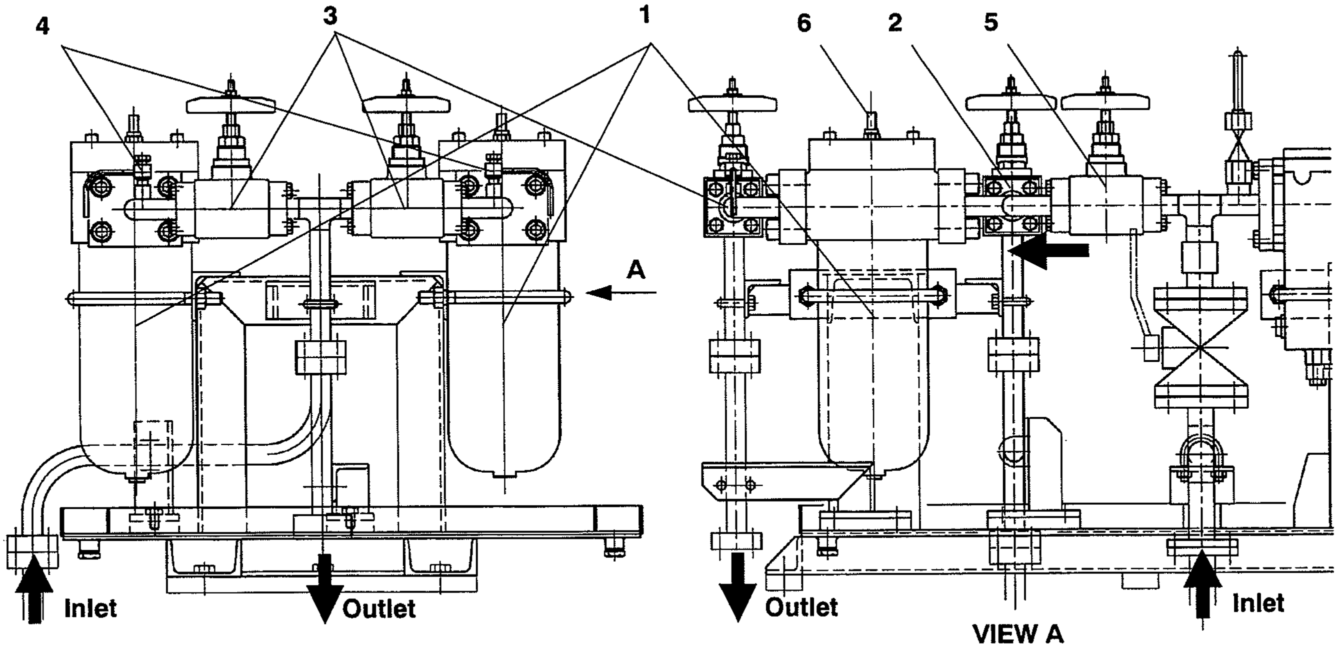
CAUTION

> While the pressure in the middle pressure filter (1) is high, the oil filling valve for middle pressure filter (6) must NOT be opened. It becomes the cause of the damage of the low pressure filter. (Refer to Maintenance Manual 7218-2/A1)

Regarding more detail instructions of the middle pressure filter (1), refer to the instruction manual of the middle pressure filter manufacturer.

Key to Illustration:

1 Middle pressure filter
2 Inlet valve of middle pressure filter
3 Outlet valve of middle pressure filter
4 Air vent valve for middle pressure filter
5 Oil filling valve for middle pressure filter
6 Deferential pressure indicator



5. Pressure Relief Valve

Two type of pressure relief valve are used in ECL system.

One is the pressure retaining valve (1) used for retaining main pipe pressure.
Another one is the safety valve (3) used for system protection.

Regarding more detail instructions of the pressure relief valve, refer to the instruction manual of the pressure relief valve manufacturer.

5.1 Pressure Retaining Valve

The pressure retaining valve (1) is equipped on the upper platform of the main engine to retain the main pipe pressure. The pressure retaining valve (1) has a by-pass valve (2) in parallel.

The pressure retaining valve (1) automatically retains the pressure of the main pipe to specified value.

When the main pipe pressure must be lower in an emergency, the by-pass valve of the pressure retaining valve (2) must be opened immediately.

CAUTION

In general, the setting of the pressure retaining valve (1) should not be changed.
In case that the pressure of main pipes deviates from the specified pressure of 8.0 ± 0.1MPa (Refer to Operating Manual 0250-1/A1), the pressure retaining valve (1) should be re-adjusted.(Refer to Maintenance Manual 7218-2/A1)

5.2 Safety Valve

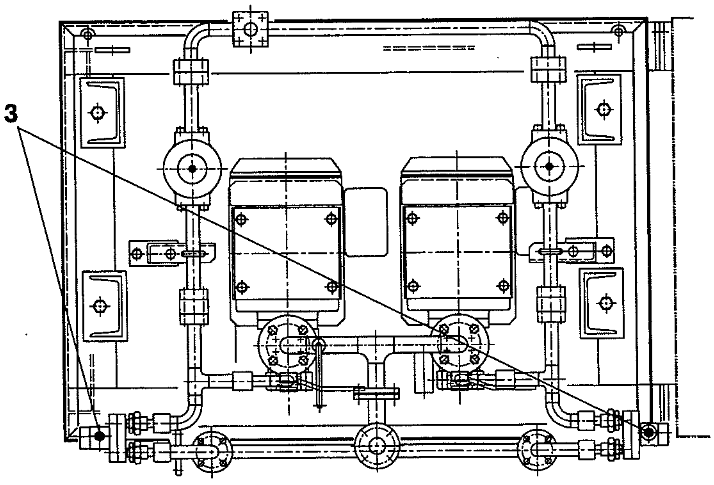
If the circulation system of the cylinder lubricating oil is blocked, this safety valve (3) works to prevent abnormal rise of system pressure.

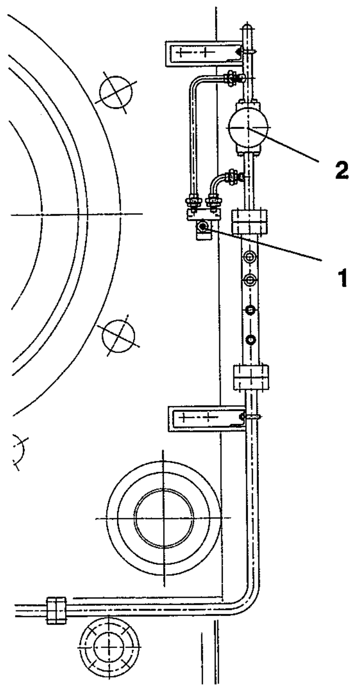
CAUTION

The setting of safety valve (3) has executed and locked by the locking nut at the initial installation.
Do not change the setting of the safety valve (3).

Key to Illustration:

1 Pressure retaining valve
2 Bypass valve for pressure retaining valve
3 Safety valve





6. Line heater

The line heater is the electric heater with thermostat. It heats up the cylinder lubricating oil to appropriate temperature.

Temperature of the cylinder lubricating oil is automatically controlled with the thermostat equipped in the line heater. The set point of the temperature can be changed by the control panel of the heater.
Accordingly, the line heater leaves normally power turned on.

Set value of control thermostat: 55 degrees C

The line heater has the safety thermostat which can detect the excessive heating and alarm to ship's alarm system.

Set value of safety thermostat: 70 degrees C

CAUTION

When the middle pressure pump is not operating, please push "OFF" push-button to prevent excessive heating of the heater. There is some possibility that the cylinder lubricating oil which stays inside the line heater is overheated and deteriorated. Once the safety thermostat detects the excessive heating, the heater does not work unless "ON" push-button is pushed again.

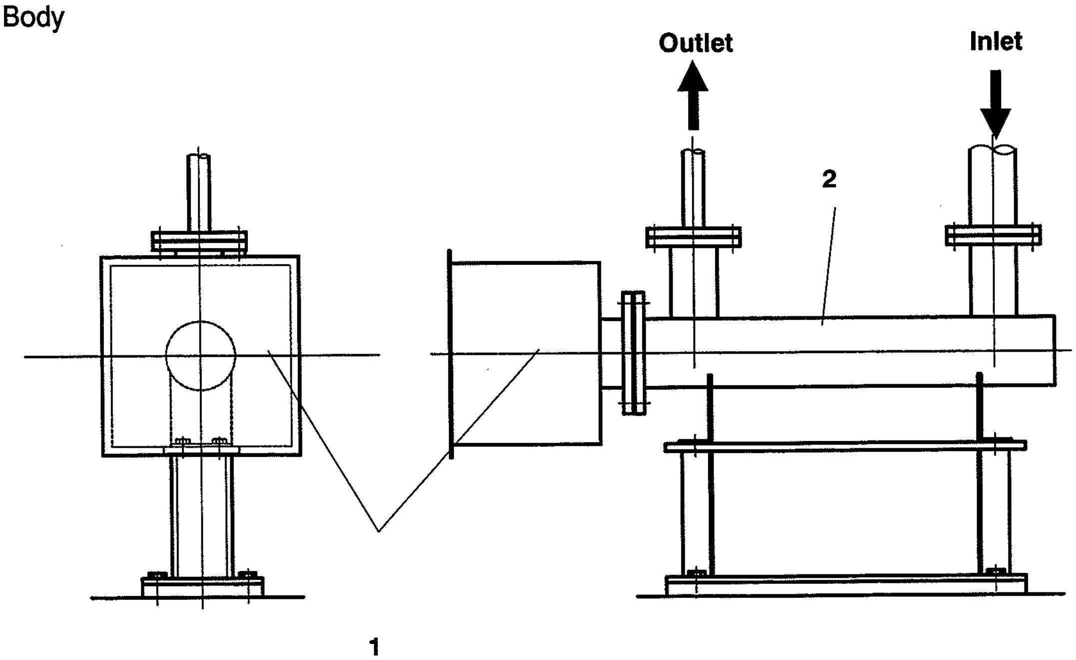
WARNING

When the line heater is inspected, turn off the main power of the line heater.

Regarding more detail instructions of the line heater, refer to the instruction manual of the line heater manufacturer.

Key to Illustration:

1 Control panel with heater element
2 Body



7. Oil Cooler

The oil cooler is the air cooled type radiator (1) with an electromotive fan (2).
The oil cooler cools the heated cylinder lubricating oil which is decompressed by the pressure relief valve to appropriate temperature.
The electromotive fan (2) operates automatically according to the thermostat (6) which is installed at outlet of the oil cooler.
Accordingly, the oil cooler leaves normally power turned on.

Set value of thermostat: 55 degrees C

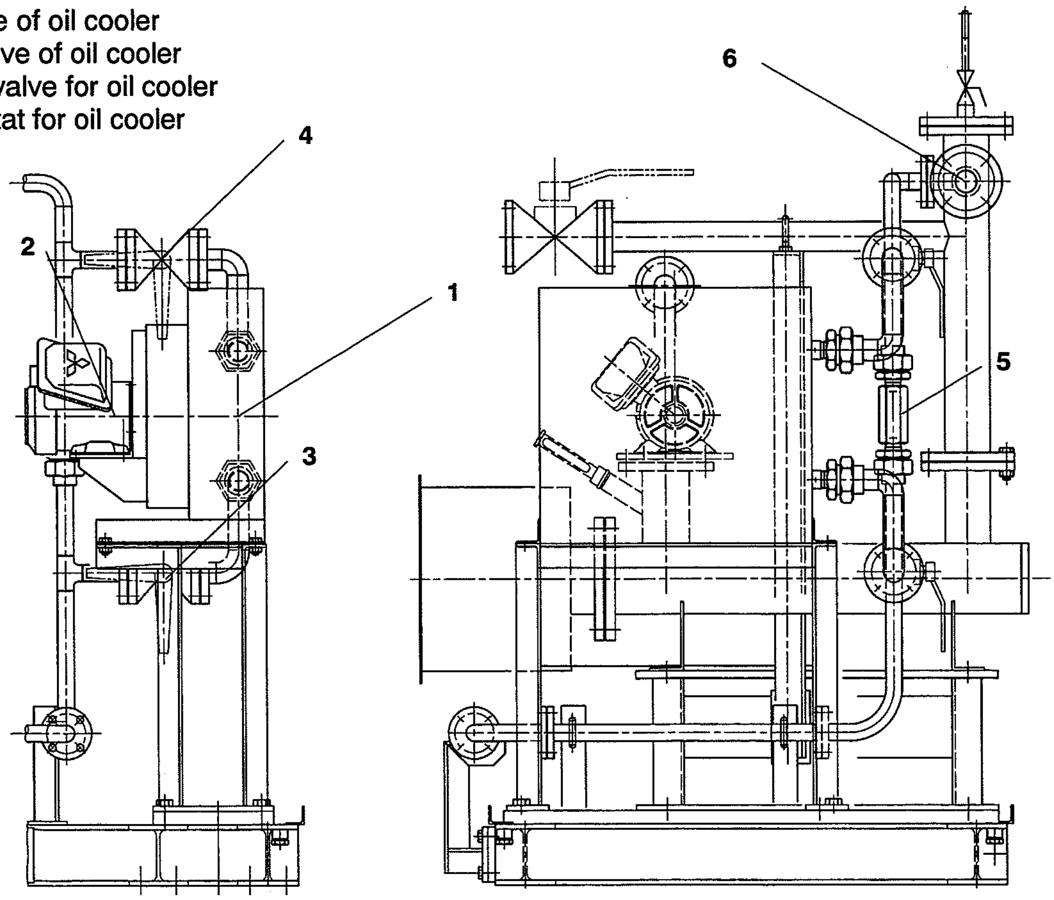
At the starting of the middle pressure pump, the differential pressure of the oil cooler becomes high because of high viscosity of the cylinder lubricating oil.
The by-pass valve (5) is equipped in parallel of the cooler to relieve excessive differential pressure of the cooler automatically.

WARNING: When the oil cooler is inspected, turn off the main power of the electromotive fan.

Regarding more detail instructions of the oil cooler, refer to the instruction manual of the oil cooler manufacturer.

Key to Illustration:

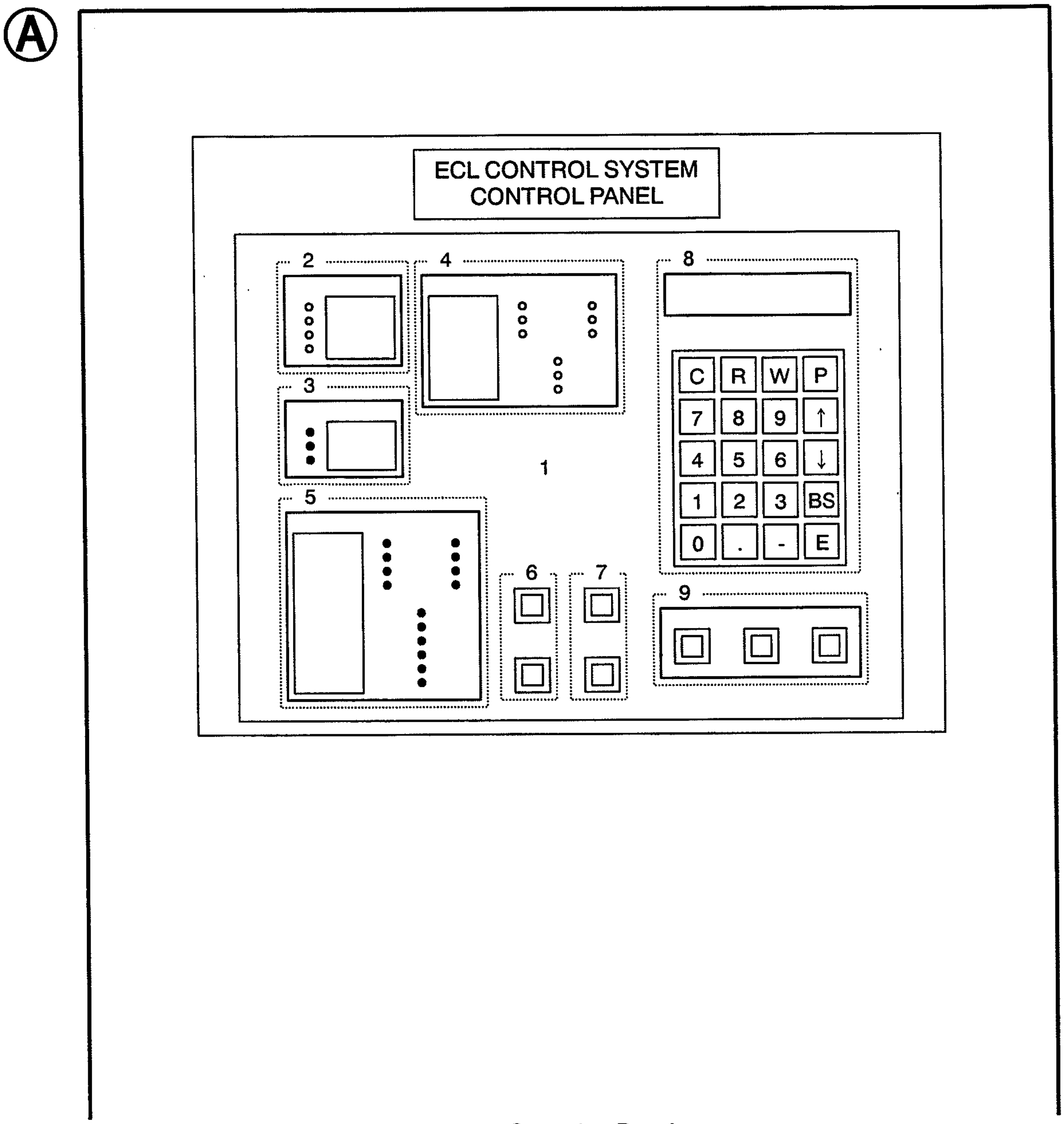
1 Radiator
2 Fan with motor
3 Inlet valve of oil cooler
4 Outlet valve of oil cooler
5 By-pass valve for oil cooler
6 Thermostat for oil cooler



1. General

1.1 CONTROL PANEL

The outline of the control panel is shown in the Fig. A to C.



Operation Panel

Key to Illustration:

1 Operation panel card
2 Indication of condition of power source
3 Indication of slowdown signal segment
4 Indication of control state
5 Indication of failure segment
6 Control of the priming
7 Lamp test / Alarm reset
8 Ten-Key
9 Monitor select

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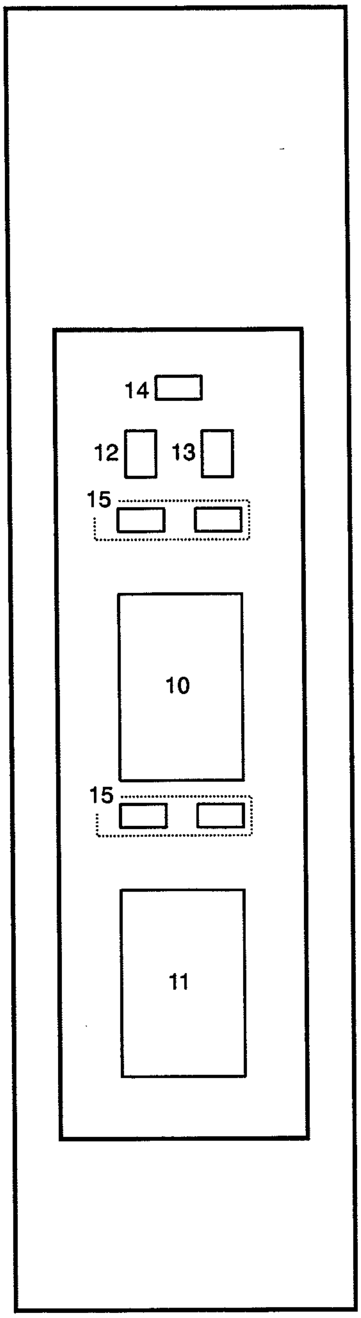

Right side view of the inside of the CONTROL PANEL

Key to Illustration:

10 Controller card (for system A)
11 Controller card (for system B)
12 Noise filter (for control)
13 Noise filter (for sensor)
14 Terminal board
15 Terminal board

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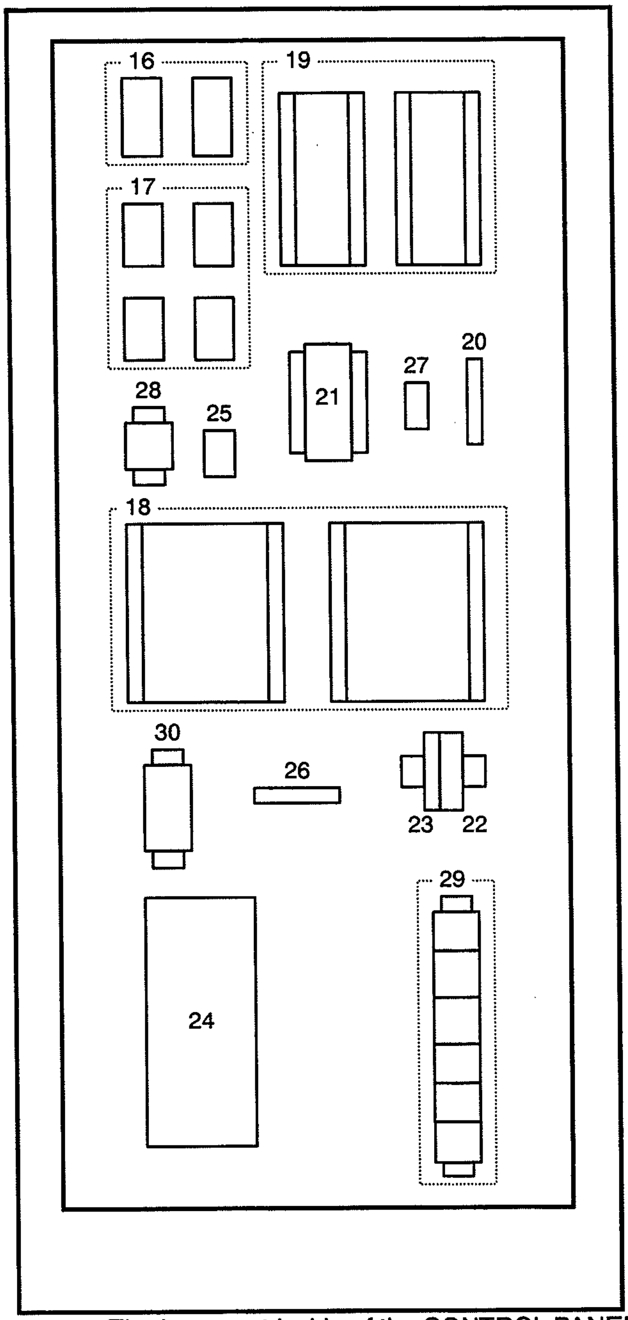

The base part inside of the CONTROL PANEL

Key to Illustration:

16 Breaker for main power source
17 Noise filter (for main power source)
18 AC/DC converter
(for drive of the solenoid valve)
19 AC/DC converter (for control)
20 Diode unit
21 DC/DC converter (for sensor)
22 Isolating Amplifier
23 Temperature Transducer for PT100
24 Relay terminal card
25 Outlet AC110V
26 Lug board
27 Terminal board
28 Terminal board for power source
of the control panel
29 Terminal board for wiring between the box
30 Terminal board for power source
for drive of solenoid valve

The control panel consists of the following devices.

Operation panel (Fig. A "1-9")
Controller card (Fig. B "10, 11")
AC/DC converter (Fig. C "18, 19")

Control panel has the function which inputs the pulse signal from crank angle detector, and outputs the timing controlled solenoid valve drive order signal according to the engine speed and load of the main engine.

How to supply the power source inside the control panel.

-Turn on both breakers for main power source (Fig. C "16").

How to shut out the power supply to the control panel.

CAUTION

Prior to shutting out the power supply, confirm that injection of the cylinder lubricating oil is not executed.

-Turn off both breakers for main power source (Fig. C "16").

1.2 SOLENOID VALVE DRIVER BOX

The outline of the solenoid valve driver box is shown in the Fig. D.
The solenoid valve driver box has the function which inputs the solenoid valve driving order signal from the control panel, and outputs the amplified solenoid valve drive signal to the distributor of each cylinder.

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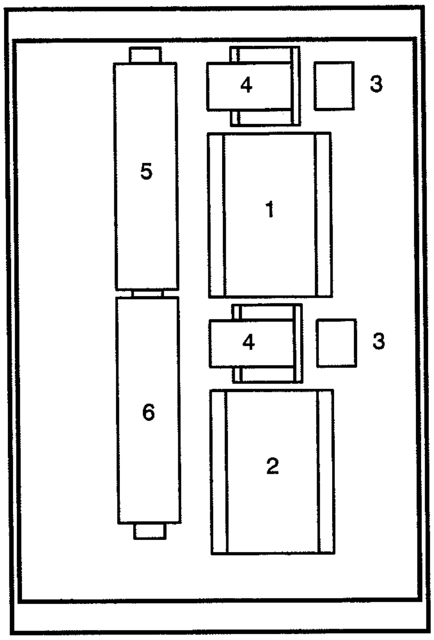


The base part inside of the SOLENOID VALVE DRIVER BOX

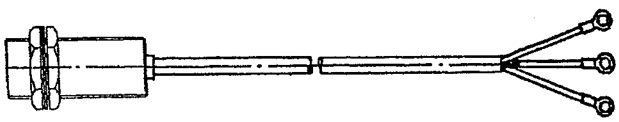
Key to Illustration:

1 Driver card (for system A)
2 Driver card (for system B)
3 Noise filter
4 Capacitor
5 Terminal board for (for system A)
6 Terminal board for (for system B)

1.3 CRANK ANGLE DETECTOR

The control panel recognizes the main engine speed, rotation direction and crank angle according to the pulse signal from the crank angle detector.
The crank angle detector consists of five proximity switches (two proximity switches are for detection of TDC, and three are for detection of engine speed and rotation direction).
More detailed information is show in Operating Manual 4628-1/A1.

Ⓔ



2. Indication of the Control Panel

2.1 The indication of the control state

There are six different types of LEDs on the operation panel to indicate the control state.

- STOP (SYSTEM A / SYSTEM B)

It shows that the respective controllers (system A / system B) stops injection.

- INJECTION(AH) (SYSTEM A / SYSTEM B)

It shows that the respective distributors (system A / system B) are operated as ahead (AH) timing.

Remark If the injection is forcibly stopped at one or more cylinders, this indication LED is flickering. More detailed information is described in the section 3.3.

- INJECTION(AS) (SYSTEM A / SYSTEM B)

It shows that the respective distributors (system A / system B) are operated as astern (AS) timing.

Remark If the injection is forcibly stopped at one or more cylinders, this indication LED is flickering. More detailed information is described in the section 3.3.

- SUPHUR LIMIT ON

It shows that the controller restricts reducing of injection quantity according to the quantity of sulfur content in the bunkered fuel.

- MIN. LIMIT ON

It shows that the controller restricts reducing of injection quantity according to preset minimum value.

- PRIMING

It shows that the distributors are operated on priming mode.

Remark If the injection is forcibly stopped at one or more cylinders, this indication LED is flickering. More detailed information is described in the section 3.3.

2.2 The indication of the slowdown signal segment

There are three LEDs on the operation panel to indicate the slowdown signal separately. When any LEDs of these three emit, the slowdown signal is send to safety system.

- CYL. LUB. OIL PRESS. LOW

It shows that the pressure of main pipe is lower than specified minimum value (refer to Operating Manual 0250-1/A1).
This alarm is reposed to detect in main engine stop condition.
This signal is latched until the "RESET" key button on the operation panel is pushed.

- CYL. LUB. OIL NON-FLOW

It shows that the controllers detect both distributors of one or more cylinders do not work or failure of both pressure transmitter at distributor outlet of one or more cylinders.
This signal is latched until "RESET" key button on the operation panel is pushed.
When the main engine stops, it is normal that this LED emits. In this case, this signal is not latched.

When "NON-FLOW" key button of "MONITOR SELECT" is pushed, the LCD shows all cylinders condition. More detailed information is shown in section 2.4.

- **BOTH CONTROLLER ABN.**

  It shows that CPU abnormality of both controllers occurs.

2.3 The indication of the failure segment

There are nine different types of LEDs on the operation panel to indicate the failure of system separately.
When one or more LEDs emit, the system abnormal alarm signal is send to the ship's alarm system.

- **CONTROLLER ABN. (SYSTEM A)**

  It shows that CPU abnormality of the controller A occurs.
  When this failure occurs, the relevant system stops injection and the injection quantity of the pair to the relevant system is increased automatically.

- **CONTROLLER ABN. (SYSTEM B)**

  It shows that CPU abnormality of the controller B occurs.
  When this failure occurs, the relevant system stops injection and the injection quantity of the pair to the relevant system is increased automatically.

- **DRIVER ABN. (SYSTEM A)**

  It shows that abnormality of driver card for system A in the solenoid valve driver box occurs.
  When this failure occurs, the relevant system stops injection and the injection quantity of the pair to the relevant system is increased automatically.

- **DRIVER ABN. (SYSTEM B)**

  It shows that abnormality of driver card for system B in the solenoid valve driver box occurs.
  When this failure occurs, the relevant system stops injection and the injection quantity of the pair to the relevant system is increased automatically.

- **DISTRIBUTOR OUT OF WORK (SYSTEM A)**

  It shows that the controller detects one or more distributors of system A do not work or failure of one or more pressure transmitter at distributor outlet of system A.
  When this failure occurs, the controller stops injection of the relevant distributor and the injection quantity of the pair to the relevant distributor is increased automatically.

  This signal is latched until "RESET" key button on the operation panel is pushed.

  When "DISTRIBUTOR OUT OF WORK" key button of "MONITOR SELECT" is pushed, the LCD shows all cylinders condition. More detailed information is described in the section 2.4.

- **DISTRIBUTOR OUT OF WORK (SYSTEM B)**

  It shows that the controller detects one or more distributors of system B do not work or failure of one or more pressure transmitter at distributor outlet of system B.
  When this failure occurs, the controller stops injection of the relevant distributor and the injection quantity of the pair to the relevant distributor is increased automatically.

  This signal is latched until "RESET" key button on the operation panel is pushed.

  When "DISTRIBUTOR OUT OF WORK" key button of "MONITOR SELECT" is pushed, the LCD shows all cylinders condition. More detailed information is described in the section 2.4.

- **VALVE/DISTRIBUTOR ABN. (SYSTEM A)**

It shows that the controller detects abnormality in one or more distributors or lubricating valves of system A. As if this failure occurs, the controller continues injection of the relevant distributor.
This signal is latched until "RESET" key button on the operation panel is pushed.
When "VALVE/DISTRIBUTOR ABN." key button of "MONITOR SELECT" is pushed, the LCD shows all cylinders condition. More detailed information is described in the section 2.4.

- **VALVE/DISTRIBUTOR ABN. (SYSTEM B)**

It shows that the controller detects abnormality in one or more distributors or lubricating valves of system B. As if this failure occurs, the controller continues injection of the relevant distributor.
This signal is latched until "RESET" key button on the operation panel is pushed.
When "VALVE/DISTRIBUTOR ABN." key button of "MONITOR SELECT" is pushed, the LCD shows all cylinders condition. More detailed information is described in the section 2.4.

Detail of "**VALVE/DISTRIBUTOR ABN.**"is shown as follows.
(refer to section 6 "Error Code Table")

- **Clogging of ECL Valve**

  It shows that the controller detects the clogging or abnormal injection of one or more ECL valves.

- **Malfunction of ECL Valve Seat**

  It shows that the controller detects the malfunction of one or more ECL valve seat.

- **Abnormal Operation of Distributor**

  It shows that the controller detects abnormal valve stroke of distributor.

- **Malfunction of Distributor Valve Seat**

  It shows that the controller detects the malfunction of one or more distributor valves seat.

WARNING

During main engine stopping when the **Malfunction of Distributor Valve Seat** is detected, because there is a possibility the excessive cylinder oil being injected inside the cylinder liner, before the main engine starting please be sure to inspect inside the cylinder liner from the scavenge air port.

- **OPERATION PANEL ABN.**

It shows that abnormality of the operation panel occurs.

As if this failure occurs, the controller continues injection.

- SIGNAL ABN.

It shows that the controller detects the following signal abnormality. In this case, the controllers continue the operation by using the preset value.
When the relevant signal abnormal is restored, the controllers continue the normal operation. But this signal is latched until the "RESET" key button on the operation panel is pushed.

The item of abnormality could be confirmed in the LCD on the operation panel.
(refer to section 6 "Error Code Table")

Abnormal signal of Fuel Command
Failure in detection of crank angle
Failure in detection of rotating direction
Abnormal signal of thermo sensor
Abnormal signal of pressure transmitter
Communication failure between controllers

- DC POWERSOURCE FAIL

It shows that one or more power sources for drivers and controllers are failed.

- CYL. L.O. TEMP. ABN.

It shows that the temperature of main pipe deviates from specified range (refer to Operating Manual 0250-1/A1).
This alarm is reposed to detect in low load operation of main engine.
This signal is latched until "RESET" key button on the operation panel is pushed.

- CYL. L.O. PRESS. ABN.

It shows that the pressure of main pipe deviates from specified range (refer to Operating Manual 0250-1/A1).
This alarm is reposed to detect in main engine stop condition.
This signal is latched until "RESET" key button on the operation panel is pushed.

2.4 The Monitor Select

There are three shortcut key buttons on the operation panel to jump to the ten-key address which shows the state of each cylinder.

- **NON-FLOW**

If "NON-FLOW" shortcut key button is pushed, ten-key address is momentarily changed to "060" which shows the state of "NON-FLOW" on each cylinder.

If the LCD shows "OXOOXOOOOOX−", the controller detects the "NON-FLOW" on No.2, No.5 and No.11 cylinder.

- **VALVE/DISTRIBUTOR ABN.**

If "VALVE/DIST ABN." shortcut key button is pushed, ten-key address is momentarily changed to "061" which shows the stated of "VALVE/DISTRIBUTOR ABN." on each cylinder.

Ten-key address "062" shows the stated of "VALVE/DISTRIBUTOR ABN." on each cylinder of system A.

Ten-key address "063" shows the stated of "VALVE/DISTRIBUTOR ABN." on each cylinder of system B.

If the LCD shows "OXOOXOOOOOX−", the controller detects the "VALVE/DISTRIBUTOR ABN." on No.2, No.5 and No.11 cylinder.

- **DISTRIBUTOR OUT OF WORK**

If "DIST. OUT OF WORK" shortcut key button is pushed, ten-key address is momentarily changed to "064" which shows the stated of "DISTRIBUTOR OUT OF WORK" on each cylinder.

Ten-key address "065" shows the stated of "DISTRIBUTOR OUT OF WORK" on each cylinder of system A.

Ten-key address "066" shows the stated of "DISTRIBUTOR OUT OF WORK" on each cylinder of system B.

If the LCD shows "OXOOXOOOOOX−", the controller detects the "DISTRIBUTOR OUT OF WORK" on No.2, No.5 and No.11 cylinder.

3. Operating Procedure

3.1 Control Procedure for Priming

Regarding the procedure for priming, refer to 0630-1/ A1.

3.2 Procedure for Lamp Test

Push “LAMP TEST” key button on the operation panel and check whether all LEDs emit.

3.3 Procedure for Adjusting of Cylinder Oil Feed Rate

Regarding the procedure for adjusting of cylinder oil feed rate, refer to 7218-2/ A1.

3.4 Procedure for Stop Injection Forcibly

It is possible to stop injection of each cylinder by using the ten-key on the operation panel.

Addresses of the stop injection of the respective cylinder are shown in the following table.

Address	LCD comment	Setting range
125	#1CYL LUB.STOP	0 or 1 0 : Injection permitted 1 : Stop injection
126	#2CYL LUB.STOP	
127	#3CYL LUB.STOP	
128	#4CYL LUB.STOP	
129	#5CYL LUB.STOP	
130	#6CYL LUB.STOP	
131	#7CYL LUB.STOP	
132	#8CYL LUB.STOP	
133	#9CYL LUB.STOP	
134	#10CYL LUB.STOP	
135	#11CYL LUB.STOP	
136	#12CYL LUB.STOP	

Remark Prior to change these above data, cancel protection with a password. For more details refer to section 3.4.

CAUTION

The ECL controller stops detection of abnormal on the cylinder which stops injection forcibly.

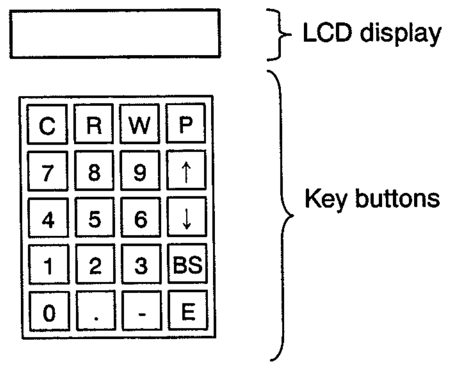
If the injection is forcibly stopped at one or more cylinders, during the injection, the indication LED (Injection AH or Injection AS or Priming) is flickering.

If no cylinders which should be stopped injection, be sure to restore these above ten-key parameters to “0”.

3.5 Operating Procedures for Portable Keypad

Inside data of the ECL control system can be checked and changed by operating the ten-key.
ECL control system has two controllers (system A and B) which control the distributors of the respective system.
However, the operation panel has only one ten-key which can set and check the stored data of both controllers.

Ⓕ

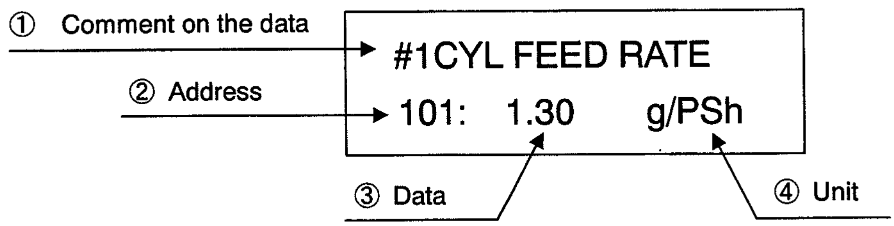


Appearance of Ten-Key

- LCD display

  The LCD display consist of four contents "Comment on the data", "Address", "Data", and "Unit", which are shown in Fig. G.

Ⓖ



The LCD display

- Part of key buttons

『C』	: cancel writing mode
『R』	: designate an address
『W』	: writing data
『P』	: cancel a protection
『0』 ～ 『9』	: Input number of address and data
『. 』	: a decimal point for input a data
『 - 』	: a minus sign for input a data
『↑』, 『↓』	: number of address decrement, increment
『BS』	: clear of input data
『E』	: enter key

• The relation between address and content

Ten-key data are divided into indicating data and setting data by address.

Indicating data can not be changed.

Furthermore, the setting data are divided into 5 levels and protected by the individual passwords as shown in "Table 1".

"Table 2" is showing about the relation between address and content.

For more details refer to "TEN-KEY DATA LIST".

Table 1

Level		Password [Ten-key add. "600"]	Territory	Remarks
Hi	prt1	private	ECL system manufacturer	for manufacturer's data
↕	prt2	private	Engine manufacturer	for initial setting in shop test or sea trial
Low	prt3	**"2648"**	user	for user settings (maintenance)
	prt4	not use	ECL system manufacturer	for manufacturer's data
	no protection	**"0"**	user	normal settings

Table 2

Address	Division	Content	Territory
[000] - [099]	Indicating data	Basic control item for ECL control system and information of detecting abnormal	–
[100] - [199]	Setting data for user	The cylinder oil feed rate, number of times of priming, etc.	user
[200] - [399]	Indicating data	Parameter of controller A	–
[400] - [599]	Indicating data	Parameter of controller B	–
[600] - [999]	Setting data for user or manufacturer	–	user or manufacturer

· Reading Data

Method 1 Directly designate an address

【Step1】 Press the key button 『R』 (designate an address) .
In this time the address is flickering.
【Step2】 Input the number of address for using key buttons 『0』 ~ 『9』 .
If you input a wrong number, you can clear it at the key button 『BS』 .
【Step3】 Press the key button 『E』 (enter key), and the address will become effective.

For example. Reading the data of Ten-key address [212]
"CYL LO PRESS (A) "

· 『R』

Address is flickering

M/E SPEED
0 : 0 rpm

⇩

· 『2』 『1』 『2』 『E』

CYL LO PRESS (A)
212 : 8.05 MPa

Method 2 Change an address for using the key button 『↑』、『↓』
(It is convenient for continuous address)

【Step1】 Press the key button 『↑』 (address decrement)、『↓』 (address increment) .

· Writing Data

【Step1】 Read the present data that you need to change the Ten-key address.
【Step2】 Press the key button 『W』 (writing data) . In this time the data is flickering.
(If "READ_ONLY" or "PROTECT_ERR" are indicated in the LCD display by Step2,
an error is occurring. Please confirm the next item "error message".)
【Step3】 Input the data for using key buttons 『0』 ~ 『9』 , 『.』, 『-』 .
If you input a wrong data, you can clear it at the key button 『BS』 .
【Step4】 Press the key button 『E』 (enter key), and the data will become effective.
(If "DATA_ERR" is indicated in the LCD display by Step4, an error is occurring.
Please confirm the next item "error message".)

※ If you press the key buttons『C』 (cancel writing mode) on the way to【Step2】or【Step3】, you can cancel the writing mode.

For example. How to change the data of Ten-key address [101] into “0.95”.

- 『R』 『1』 『0』 『1』 『E』

#1 CYL FEED RATE
101 : 1.00 g/PSh

⇩

- 『P』 『W』

#1 CYL FEED RATE
101 : 1.00 g/PSh

Data is flickering

⇩

- 『0』 『.』 『9』 『5』 『E』

#1 CYL FEED RATE
101 : 0.95 g/PSh

- Error message

1) Content of error

READ_ONLY : You are writing down in the territory of indicating data. Please confirm the number of address.

PROTECT_ERR : You are writing down in the maker territory.

DATA_ERR : Some data have the upper and lower limit values. Your input data is greater than the upper limit value or smaller than the lower limit value. Please confirm the number of data.

2) Recover from error

If any of errors occurs, press the key button 『E』 (enter key). So the display is changed to normally.

4. The connection between ECL CONTROL SYSTEM and outside system

Table 3

Signal	From	To	Contents	Note
SLOW DOWN REQUEST	CONTROL PANEL	SAFETY SYSTEM	State of the "CYL.LUB.OIL.PRESS.LOW" State of the "CYL.LUB.OIL.NON-FLOW" State of the "BOTH CPU ABN."	Relay contact / Open at normal
NON-FLOW	CONTROL PANEL	ALARM SYSTEM	State of the "CYL.LUB.OIL.NON-FLOW" of each cylinder	Relay contact / Close at normal
SYSTEM ABNORMAL	CONTROL PANEL	ALARM SYSTEM	State of the "CPU ABN." at one system State of the "DISTRIBUTOR OUT OF WORK" at one system State of the "VALVE/DISTRIBUTOR ABN." State of the "CYL.LO.TEMP.ABN." State of the "CYL.LO.PRESS.ABN." State of the "HEATER ABN." State of the "SIGNAL ABN." State of the "DC POWER SOURCE FAIL." State of the "PUMP STARTER ABN." State of the "BACK UP PUMP RUN"	Relay contact / Close at normal
PUMP CHANGE OVER REQUEST	CONTROL PANEL	PUMP STARTER	State of main pipe pressure is lower	Relay contact / Close at low pressure

5. Troubleshooting

Table 4

Abnormal	Causes	Checks
CYL.LUB.OIL.PRESS.LOW	Pump out of work The cylinder LO leaks out of main pipe connections. Failure or incorrect setting of pressure relief valve By-pass valve of pressure relief valve open	Confirm operation of the pump Check and repair the pipeline Check the pressure relief valves and by-pass valve of pressure relief valve.
CYL.LUB.OIL.NON-FLOW	In both system distributors out of work In both system flow limiters of distributor work In both system pressure transmitter in distributor unit out of work Main engine stop	Check the wiring of solenoid. Check or replace the distributors Restore flow limiters Check the wiring Normal condition(The slowdown signal should be canceled during main engine stopping)
BOTH CONTROLLER ABN.	In both system controller cards out of work In both system controller cards failures	Check the wiring of power source Re-turn on the main power source
CONTROLLER ABN.	In one system controller card out of work In one system controller card failure	Check the wiring of power source Re-turn on the main power source
DRIVER ABN.	In one system driver card out of work In one system driver card failure Over current detection for solenoid valve signal	Check the wiring of power source Re-turn on the main power source Check the wiring of solenoid valve drive signal.
DIST. OUT OF WORK	In one system distributor out of work In one system flow limiter of distributor works In one system pressure transmitter in distributor unit out of work	Check the wiring of solenoid. Check or replace the distributor Restore flow limiter. Check the wiring
VALVE / DIST. ABN.	ECL-SIP valve failure Distributor failure	Check or replace the ECL-SIP valves Check or replace the distributor
OPERATION PANEL ABN.	Operation panel card out of work Operation panel card failure	Check the wiring of power source Re-turn on the main power source
SIGNAL ABN.	Disconnection in fuel command signal line WECS-9520 out of work Disconnection in temperature signal line of main pipe Disconnection in pressure signal line of main pipe Disconnection in TDC pulse signal line Disconnection in revolution pulse signal line Communication error between controller cards	Check the wiring of fuel command signal Turn on main power source of WECS Check the wiring of temperature sensor for main pipe. Check the wiring of pressure sensor for main pipe. With the M/E being turned by the turning gear, check the emitting condition of proximity switches LED. - If LEDs do not flicker Check the proximity switch for oil fouling or readjust the clearance (3 ±1mm) - if LEDs flicker, check the wiring. Check the wiring
DC POWER SOURCE FAIL.	In one system not supply main power source to the control panel In one system the breaker for main power source turn off or trip	Supply main power source to the control panel Turn on the breaker for main power source
CYL.LO.TEMP.ABN.	Sensor abnormal The oil heater out of work The oil cooler out of work	Check local temperature. If local temp. is normal, check temperature sensor for main pipe Confirm operation of the oil heater Confirm operation of the oil cooler
CYL.LO.PRESS.ABN.	Sensor abnormal Pump out of work The cylinder LO leaks out of main pipe. The pressure relief valve failure By-pass valve of pressure relief valve open	Check local pressure. If local pressure is normal, check pressure sensor for main pipe. Confirm operation of the pump Check the piping line Check the pressure relief valve and by-pass valve of pressure relief valve.

6. Error Code Table

In case any failure is detected, you can confirm the detail abnormal cause by the ten-key data. Each error codes and abnormal causes are shown the flowing tables.

Table 5.1

	Ten-key address	Error code	Item	Operation at failure		
				Alarm	Slow-down	Remarks
DC power source fail.	Error code is not indicated and only LED emits.	-	DC power source for driver No.1 fail	○	-	Injection quantity of normal side is increased
			DC power source for driver No.2 fail	○	-	
			Both DC power sources for driver fail	-	○	
			DC power source for control No.1 fail	○	-	
			DC power source for control No.2 fail	○	-	
			Both DC power sources for control fail	-	○	
Controller abnormal	Error code is not indicated and only LED emits.	-	Controller system A abnormal	○	-	Injection quantity of normal side is increased
		-	Controller system B abnormal	○	-	
		-	Both controllers abnormal	-	○	
Operation panel abnormal	Error code is not indicated and only LED emits.	-	Operation panel abnormal	○	-	
Driver abnormal	LED	-	Solenoid valve driver A abnormal	○	-	Injection quantity of normal side is increased
		-	Solenoid valve driver B abnormal	○	-	
		-	Both solenoid valve drivers abnormal	-	○	
	252 (system A) 452 (system B)	0	Normal	-	-	
		1	Solenoid driver abnormal	○	-	Injection quantity of normal side is increased
Slowdown	10 (229, 429)	0	Normal	-	-	
		1	Slowdown (Non-flow or cylinder lub. oil press. low)	-	○	
Non-flow*	230 (430)	0	Normal	-	-	
		1	Non-flow	-	○	
	60	12 digit character	"O" means normal, "X" means "NON-FLOW" Ex.) "OXOOXOOOOOX−" "NON-FLOW" occurs at No.2, No.5 and No.11 cylinder.	-	-	

* "Non-flow" means that both distributors out of work occur in one or more cylinders.

Table 5.2

	Ten-key address	Error code	Item	Operation at failure: Alarm	Operation at failure: Slow-down	Operation at failure: Remarks
System abnormal	233 (433)	0	Normal	-	-	
		1	System abnormal	○	-	
Injection abnormal	19 (No.1 system A) 20 (No.1 system B) · · · 41 (No.12 system A) 42 (No.12 system B)	0	Distributor and ECL valve normal	-	-	
		1	Distributor out of work	○	-	Injection quantity of normal side is increased
		2	Failure of pressure transmitter at distributor outlet	○	-	
		10	Abnormal operation of distributor	○	-	
		100	Clogging of ECL valve	○	-	
		1000	Malfunction of ECL valve seat	○	-	
		10000	Malfunction of distributor valve seat	○	-	
Valve / Distributor abnormal	61	12 digit character	"O" means normal, "X" means "Valve / Dist. out of work" Ex.) "OXOOXOOOOOX−" "Valve / Dist. out of work" occurs at No.2, No.5 and No.11 cylinder.	-	-	
	62 (system A)			-	-	
	63 (system B)			-	-	
Distributor out of work	64	12 digit character	"O" means normal, "X" means "Distributor out of work" Ex.) "OXOOXOOOOOX−" "Distributor out of work" occurs at No.2, No.5 and No.11 cylinder.	-	-	
	65 (system A)			-	-	
	66 (system B)			-	-	
Signal abnormal	49 (257, 457)	0	Normal	-	-	
		1	Signal abnormal	○	-	
	50 (258, 458)	0	LI or Torque signal normal	-	-	
		1	LI or Torque signal abnormal	○	-	Continue to injection using calculated "LI" based on M/E speed
	51 (259, 459)	0	Temperature signal normal	-	-	
		1	Temperature signal abnormal	○	-	
	52 (260, 460)	0	Pressure signal normal	-	-	
		1	Disconnection in Press. signal No.1	○	-	
		10	Disconnection in Press. signal No.2	○	-	
		100	Disconnection in Press. signal No.3	○	-	
		11	Disconnection in Press. signal No.1 and No.2	○	-	
		101	Disconnection in Press. signal No.1 and No.3	○	-	
		110	Disconnection in Press. signal No.2 and No.3	○	-	
		111	Disconnection in Press. signal No.1, No.2 and No.3	-	○	

Table 5.3

	Ten-key address	Error code	Item	Operation at failure		
				Alarm	Slow-down	Remarks
Signal abnormal	53 (261, 461)	0	TDC pulse normal	-	-	
		1	Disconnection in TDC pulse No.1	○	-	
		10	Disconnection in TDC pulse No.1	○	-	
	54 (262, 462)	0	Revolution pulse normal	-	-	
		1	Disconnection in revolution pulse No.1	○	-	
		10	Disconnection in revolution pulse No.2	○	-	
		100	Disconnection in revolution pulse No.3	○	-	
	57	0	Normal	-	-	
		1	Failure in detection of crank angle	○	-	
	58	0	Normal	-	-	
		1	Failure in detection of rotating direction	○	-	
	55 (251, 451)	0	Communication normal	-	-	
		1	Communication abnormal	○	-	Injection quantity of normal side is increased
Cyl. LO temp.	LED	0	Cyl. LO temp. normal	-	-	
		1	Cyl. LO temp. abnormal (H or L)	○	-	
	44 (253, 453)	0	Cyl. LO temp. normal	-	-	
		1	Cyl. LO temp. High	○	-	
	45 (254, 454)	0	Cyl. LO temp. normal	-	-	
		1	Cyl. LO temp. Low	○	-	
Cyl. LO press.	LED	0	Cyl. LO press. normal	-	-	
		1	Cyl. LO press. abnormal	○	-	
	230 (430)	0	Cyl. LO press. normal	-	-	
		1	Cyl. LO press. Low-Low	-	○	
	46 (255, 455)	0	Cyl. LO press. normal	-	-	
		1	Cyl. LO press. No.1 High	○	-	
		10	Cyl. LO press. No.2 High	○	-	
		100	Cyl. LO press. No.3 High	○	-	
		11	Cyl. LO press. No.1 and No.2 High	○	-	
		101	Cyl. LO press. No.1 and No.3 High	○	-	
		110	Cyl. LO press. No.2 and No.3 High	○	-	
		111	Cyl. LO press. No.1, No.2 and No.3 High	○	-	
	47 (256, 456)	0	Cyl. LO press. normal	-	-	
		1	Cyl. LO press. No.1 Low	○	-	
		10	Cyl. LO press. No.2 Low	○	-	
		100	Cyl. LO press. No.3 Low	○	-	
		11	Cyl. LO press. No.1 and No.2 Low	○	-	
		101	Cyl. LO press. No.1 and No.3 Low	○	-	
		110	Cyl. LO press. No.2 and No.3 Low	○	-	
		111	Cyl. LO press. No.1, No.2 and No.3 Low	○	-	

Group 8

8

Piping Systems Group 8

Overview

1. General

The oil necessary for the engine control and lubrication (with the exception of cylinder and exhaust valve spindle lubrication) is raised by pump (1) to the necessary bearing oil pressure and by crosshead lubricating oil pump (4) to the pressure necessary for the crosshead lubrication (pressure values see Operating Data Sheet 0250-1).

The oil distribution to the various lubricating points is shown on the following schematic lubricating oil diagrams.

The cylinder lubrication is described in 8016-2.

The arrangement of pumps, filters, heat exchangers, etc. is shown on the plant diagram which is supplied separately from the engine documentation.

2. Bearing and turbocharger oil system (Fig. (A)

Bearing oil is supplied to oil pipe (10) and main bearings (9) through bores in the bearing girders via oil inlet pipe (5) on exhaust side.
Bearing oil is also used to cool the piston via toggle lever (15).

For actuating the exhaust valves, oil ('hydraulic rod') is led to the exhaust valve drives via oil supply pipe (26) and oil distributing pipe (27) (see also Fig. 'C').
From distributing pipe (18) oil is also used for the function of fuel pressure control valve (3.06) at the intermediate fuel accumulator (see also Fig. 'C', 8019-1 'High pressure circuit' and Control Diagram 4003-2).

The integrated axial damper (8) and if there is a vibration damper (25) are supplied and cooled with bearing oil.

Via distributing pipe (18) and internal bores in supply unit (20) ensuring oil supply of the bearings, spray nozzles and fuel pumps (see Supply Unit 5552-1 and Fuel Pump, Intermediate Fuel Accumulator and Fuel Pressure Control Valve 3.06 5556-1).
The bearing oil and crosshead bearing oil systems are interconnected through non-return valve (6).

Bearing oil is supplied to the turbochargers (29) through the oil inlet pipe (28) via the oil inlet pipe (5)on exhaust side. The oil is returned via the mist separator (30) (air separator integrated in the charging module) and the outlet pipe (31) back to the crankcase.

A device (ball valves (37) & (37a)) for taking oil samples is arranged in the outlet (drain) for dirty oil (35) from piston underside (see also 0750-1).
A device (three-way valve (36)) for taking oil samples is arranged in the outlet (drain) for dirty oil from piston rod gland (see also 0750-1).

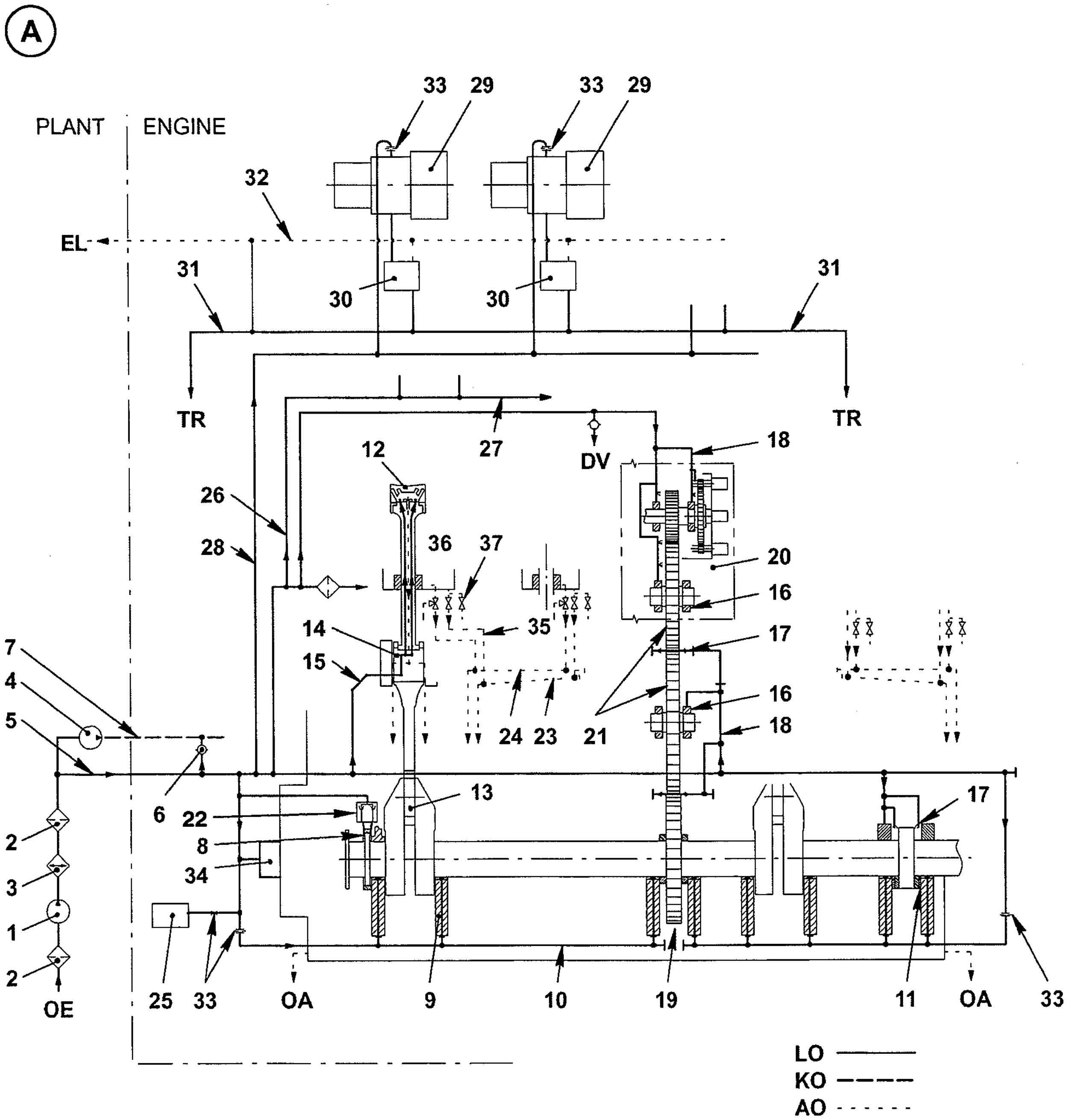
Remark: Ball valves (36) and three-way valve (37) remain open and ball valves (37a) closed during operation.

Taking dirty oil samples (for drain from piston under side) :

⇒ Close ball valve (37).
⇒ Open ball valve (37a) and take dirty oil sample.
⇒ Close ball valve (37a) and reopen ball valve (37) (operating position).

Taking dirty oil samples (for drain from piston rod glands) :

⇒ Close three-way valve (36).
⇒ take dirty oil sample.
⇒ Reopen three-way valve (36) (operating position).



Key to Illustration: 'A' Bearing and turbocharger oil system

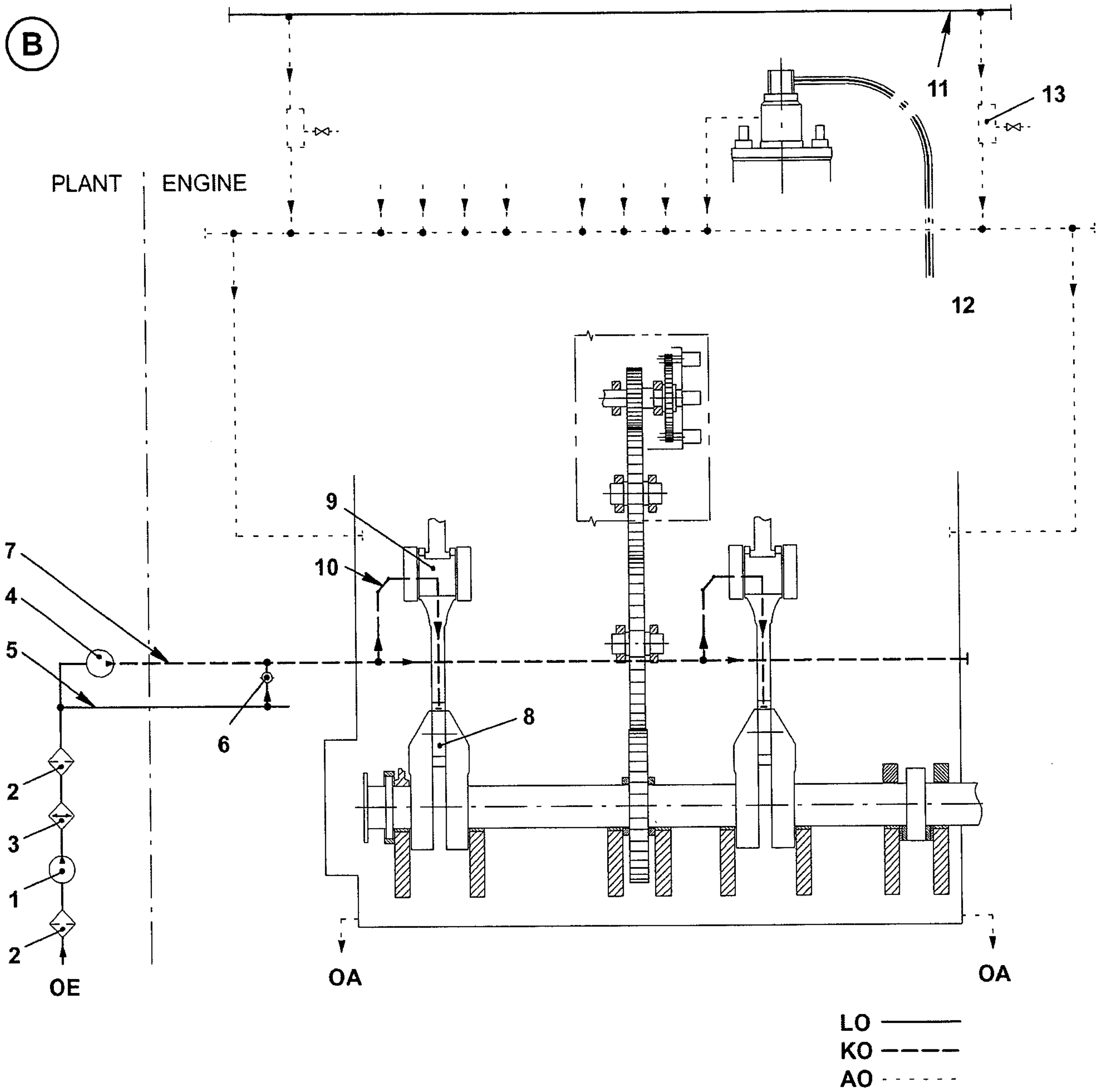
1 Oil pump
2 Oil filter
3 Oil cooler
4 Crosshead lubricating oil pump
5 Oil inlet pipe on exhaust side
6 Non-return valve
7 Oil distributing pipe, crosshead lubrication
8 Axial damper
9 Main bearing
10 Oil inlet to main bearing
11 Thrust bearing
12 Piston
13 Bottom end bearing
14 Crosshead pin
15 Toggle lever for piston cooling and crosshead lubrication
16 Intermediate wheel bearing
17 Spray nozzle
18 Distributing pipe
19 Drive supply unit
20 Supply unit
21 Lower and upper intermediate wheels
22 Axial damper monitoring
23 Dirty oil collector main from piston underside
24 Leakage oil collector main from piston rod gland
25 Vibration damper
26 Oil supply pipe
27 Oil distributing pipe
28 Oil inlet pipe
29 Turbocharger
30 Mist separator
31 Outlet pipe
32 Venting pipe
33 Throttle
34 Crank angle sensor unit
35 Outlet (drain) for dirty oil
36 Three-way valve
37 Ball valve
37a Ball valve (for taking oil samples)

AO Drain and vent
DV to fuel pressure control valve (3.06)
EL Vent
KO Crosshead bearing oil
LO Bearing and turbocharger oil
OA to oil drain tank
OE from oil drain tank
TR Turbocharger oil return

3. Crosshead lubricating oil system (Fig. 'B')

The lubrication of crosshead pins (9) and bottom end bearings (8) to the connecting rods is effected through toggle levers (10).

Remark : Should the crosshead lubricating oil pump (4) fail, then the crosshead lubricating oil system is supplied with bearing oil pressure. Under such conditions the engine can only be operated at **reduced load of 40%.**



Key to Illustration: 'B' Crosshead lubricating oil system

1 Oil pump
2 Oil filter
3 Oil cooler
4 Crosshead lubricating oil pump
5 Oil inlet pipe on exhaust side
6 Non-return valve
7 Oil distributing pipe, crosshead lubrication
8 Bottom end bearing
9 Crosshead pin
10 Toggle lever for piston cooling and crosshead lubrication
11 Leakage pipe from air spring
12 Leakage collecting pipe from exhaust valve and air spring
13 Leakage oil return

AO Drain
KO Crosshead lubricating oil
LO Bearing oil
OA to oil drain tank
OE from oil drain tank

4. Servo and control oil system (Fig. 'C' and 'D')

The servo and control oil system is provided for controlling the exhaust valve movement and the injection control units. The required oil is branched off from the main bearing oil system.

4.1 Control oil pump

One of the two electrically-driven control oil pumps (6), (6a) provides the control oil pressure of 20.0 MPa, maintaining it over the entire load range.

Prior to engine start a servo oil rail pressure of 7.5 MPa is produced via pressure reducing valve (29) till the engine-driven servo oil pumps (5) deliver the required pressure. Moreover they increase the pressure in the fuel rails when required via tool 94583 (see 8019-1 'High pressure circuit' and 0120-1 'Priming the fuel system on the engine').

Upon failure of a control oil pump the second pump ensures the correct pressures.

CAUTION

The control oil pump must not be put into operation with the oil supply shut off. The stop valve (20) must be open prior to start-up! (see 0130-1 'Checks to be carried out on servo and control oil system').

4.2 Servo oil system

Oil reaches the servo oil pumps (5) via automatic filter (1), supply pipe (7) and distributing pipe (18).

CAUTION

Do **not** operate the engine with the oil supply to the servo oil pumps interrupted. The stop valve (20) must always be open during operation!

Dependent on the electrically controlled pressure regulating system (nominal pressure value depending on engine load), the servo oil pumps deliver oil to servo oil rail (9) via collector block (3) and rising pipe (8), (8a). The stop valves (23), (23a) of connecting pipe (19) must always be open! Leakage control points (34) are arranged at flanges of rising pipes and collector block (3) (see section 5).

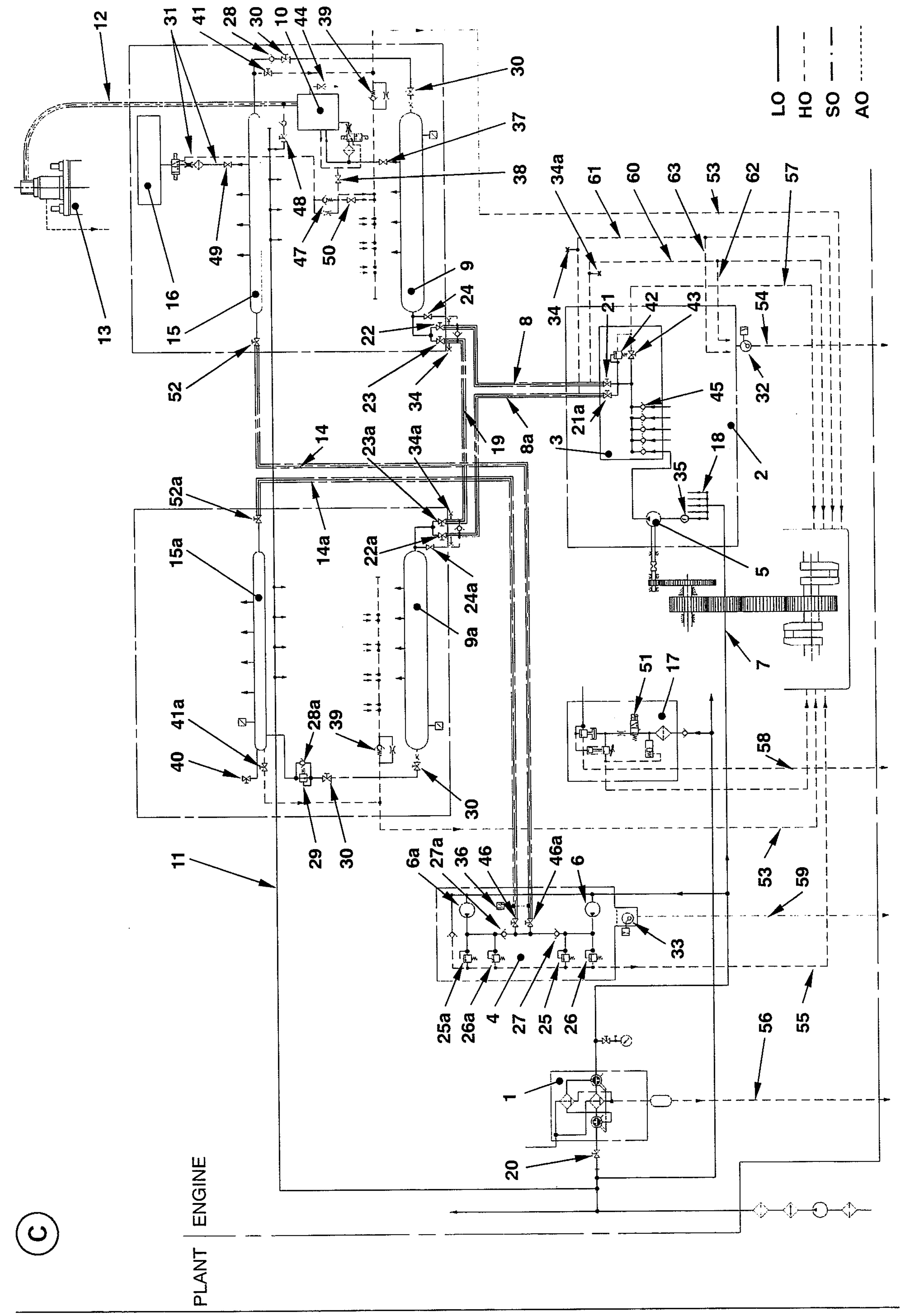
Remark : In every inlet pipe there are flow sensors (35) monitoring the oil supply through the servo oil pumps. A possible failure of a pump is indicated in the alarm and monitoring system.

For controlling the exhaust valve spindle movement ('hydraulic cam') servo oil is used which flows to exhaust valve drives (10) and their control valves (rail valves) via the servo oil rail, and back to the engine via return (53).

4.3 Control oil system

Control oil which is branched off from supply pipe (7) after the automatic filter feeds the control oil pumps.
The control oil pressure of 20.0 MPa is maintained over the entire load range to ensure actuation ('hydraulic cam') of injection control units (16).

If both control oil pumps fail, the injection control units are controlled with servo oil pressure via non-return valves (28), (28a).


LO
HO
SO
AO
ENGINE
PLANT
C

Key to Illustration: 'C' Servo and control oil system

1	Automatic filter (4.20)
2	Servo oil supply [D]
3	Collector block (4.52)
4	Control oil pump unit [L]
5	Servo oil pump (4.15)
6, 6a	Control oil pumps (3.72-1 & 2)
7	Supply pipe (4.51)
8, 8a	Servo oil rising pipe (4.55)
9, 9a	Servo oil rail (4.11)
10	Exhaust valve drive (4.10)
11	Supply pipe ('hydraulic rod')
12	Actuator pipe (4.66)
13	Exhaust valve (4.01)
14, 14a	HP control oil piping (3.74)
15, 15a	Control oil rail (3.75)
16	Injection control unit (3.02)
17	Fuel pressure control valve (3.06)
18	Distributing pipe
19	Connecting pipe servo oil rail
20	Stop valve (4.37)
21, 21a	Stop valves (4.25-1 & 2)
22, 22a	Stop valves (4.26-1 & 2)
23, 23a	Stop valves (4.26-3 & 4)
24	Drain screw
25, 25a	Pressure retaining valves (3.73-1A & 2A)
26, 26a	Safety valves (3.73-1B & 2B)
27	Non-return valve (3.56)
28, 28a	Non-return valve (4.29)
29	Pressure reducing valve (4.27)
30	Stop valves (4.30-1 to 4)
31	Flexible hose
32	Level switch LS2055A
33	Level switch LS2085A
34	Leakage inspection point (4.14)
35	Flow sensor FS2061 ~ 65A
36	Pressure transmitter PT2083A
37	Plug (4.32)
38	Plug (4.33)
39, 39a	Pressure retaining valves (4.64-1 & 2)
40	Stop valve (3.40)
41	Drain valve (3.68)
42	Safety valve (4.23)
43	Drain screw (4.72)
44	Plug (4.34)
45	Non-return valve (4.24)
46, 46a	Stop valves (3.79-1 & 2)
47	Non-return valve with throttle (3.34)
48	Stop valve (4.36)
49	Plug 3.37 (only for emergency operation)
50	Plug 3.38 (only for emergency operation)
51	Fuel shut-down pilot valve (3.08)
52, 52a	Stop valves (3.80-1 & 2)
53	Servo and control oil return piping (4.63)
54	Leakage drain from servo oil supply
55	Return piping (3.71) from control oil pumps
56	Dirty oil drain from automatic filter
57	Drain from safety valve & drain screw (43)
58	Drain from fuel pressure control valve (3.06)
59	Leakage drain from control oil pump unit
60	Leakage drain from rising pipe (4.55) (DE)
61	Leakage drain from rising pipe (4.55) (FE)
62	Control pipe of leakage drain (60)
63	Control pipe of leakage drain (61)
AO	Drain
HO	Hydraulic oil
LO	Bearing oil
OE	from oil drain tank
SO	Servo and control oil

Remark: If necessary plugs (37) and (38) can be replaced with shut-off plugs (tools) at engine standstill for cut out the exhaust valve drive (see 0520-1 'Emergency operation with exhaust valve closed').
If necessary flexible hoses (31) can be removed and the openings in control oil rails be closed using plugs (49) and (50) (tools) at engine standstill for cut out the injection control unit (see 0510-1 'Shut-off the injection control unit').

5. Servo and control oil leakage system

5.1 Leakage and oil drains

Part of the drains with clean oil is led back to the bearing oil system via the engine. The other drains with dirty oil flows back to the sludge tank in the plant (see Fig. 'C').

Drains into the column on fuel side:

- Servo and control oil return piping (53) from rail unit.
- Return piping (55) from control oil pumps via pressure retaining and safety valves.

Drains into the housing of the supply unit:

- Drain (58) from fuel pressure control valve (3.06).
- Drain (57) from safety valve and drain screw at the collector block.
- Leakage drain (60) from rising pipe (4.55) (DE)
- Leakage drain (61) from rising pipe (4.55) (FE)

Drains back to the plant:

- Drain from control pipe (62) of leakage drain (60)
- Drain from control pipe (63) of leakage drain (61)
- Leakage drain (54) from servo oil supply via level switch LS2055A.
- Leakage drain (59) from control oil pump unit via level switch LS2085A.
- Drain (56) of dirty oil from automatic filter.

All important leakages in the servo and control oil system are monitored by level switches (LS).
In case of excessive quantity the corresponding alarm is triggered:

Level switch	Location	Monitored components
LS3444A LS3445A	driving end free end	Leakages (fuel, servo and control oil) from rail unit, by leaky hydraulic piping between exhaust valve drive (check bore in cover) and exhaust valve
LS2055A		A part of leakage from rising pipes and connecting pipe, leakage from collector block and servo oil supply
LS2085A		Leakages from control oil pump unit

5.2 Leakage inspection points

Two leakage inspection points (34) are provided for the proper leakage localization of rising pipes (8), (8a) and connecting pipe (19) (see Fig. 'C').

If an alarm has been triggered by level switch (21) (LS2055A), the leakage inspection points allow the location of the leakage and corresponding measures can be taken.

Procedure:

WARNING

> Always use gloves when working on hot components! Always wear safety goggles; oil may spurt out when opening covers and loosening drain screws.

⇒ Carefully open plugs (4) and (5) by max. one turn and check whether oil flows out or not, take also notice of the name plate (see Fig. 'D').

- If oil flows out at one of the two plugs (4)/(5), i.e. the corresponding servo oil rising pipe (8)/(8a) (DE/FE) is defective.

⇒ In this case stop valves (21), (21a) and (22), (22a) must be closed.

Remark : If oil flows out from both plugs, this indicates a defect in connecting pipe (19).

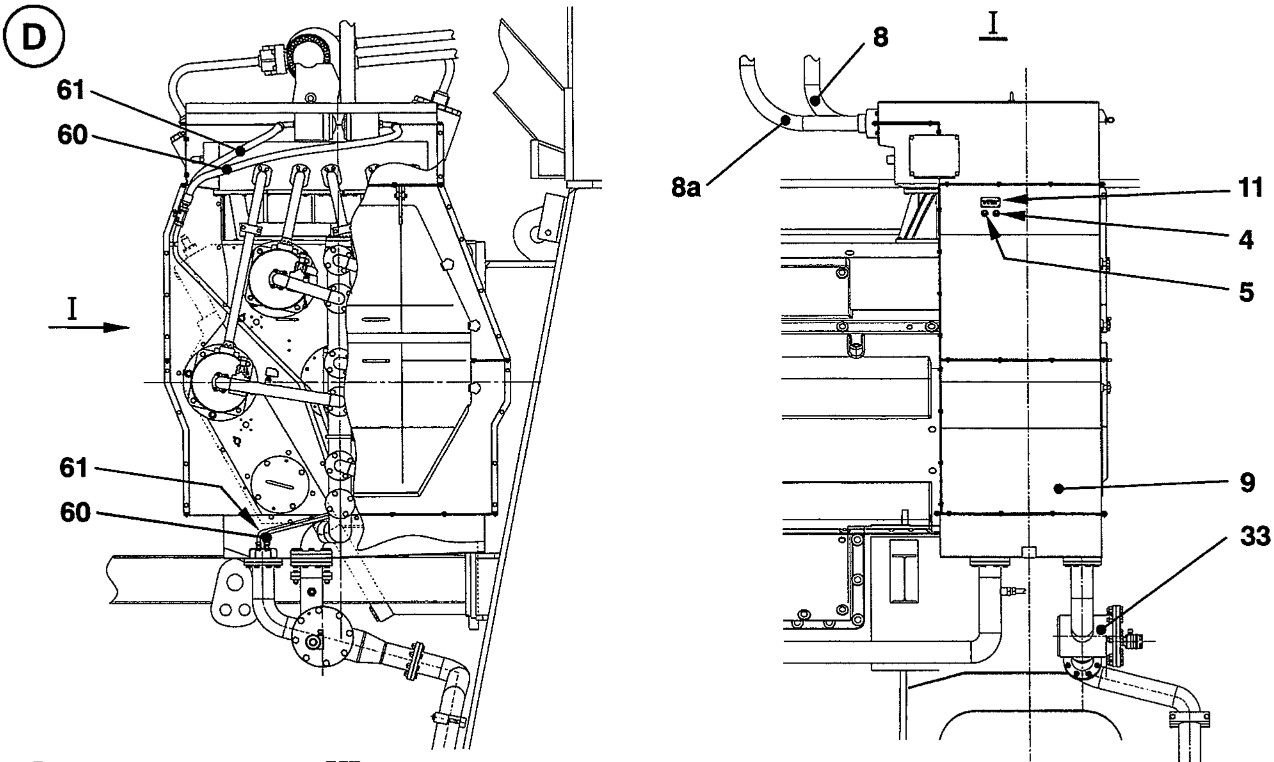
⇒ To be sure whether the leakage is from the connecting pipe, loosen at the upper inspection point one of the two drain screws (1) or (2) by approx. two turns and check whether oil flows out, yes or no (see Fig. 'E').

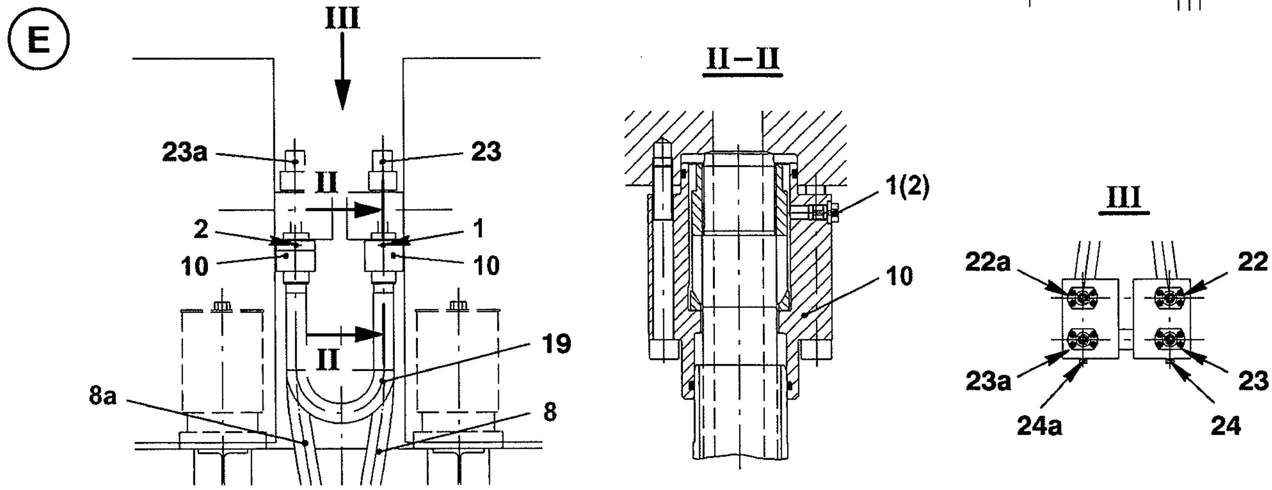
- If oil flows out, i.e. connecting pipe (19) is defective.

⇒ In this case both stop valves (23) and (23a) must be closed.

Remark : The stop valves must be **opened or closed till the stop** and tightened with a torque of 200 Nm in both positions.
Pay attention that the stop valves of the **same rising pipe** are closed.
The engine may be maintained in unrestricted operation at the required operating temperature with only one rising pipe, until the defective pipe has been replaced.
At a servo oil temperature of <35 °C the engine can only be operated at reduced load.

- Leakages from distributing pipes (18), outlet pipes (12) or their connections can be detected by opening cover (11).





Key to Illustrations: 'A' **Lower leakage inspection point**
'B' **Upper leakage inspection point**

1	Drain screw LI2056L	19	Connecting pipe servo oil rail
2	Drain screw LI2058L	21	Stop valve (4.25-1)
3	Collector block (4.52)	21a	Stop valve (4.25-2)
4	Plug LI2057L (rising pipe DE)	22	Stop valve (4.26-1)
5	Plug LI2059L (rising pipe FE)	22a	Stop valve (4.26-2)
6	Cover	23	Stop valve (4.26-3)
7	Supply pipe (4.51)	23a	Stop valve (4.26-4)
8	Servo oil rising pipe (DE) (4.55)	24	Drain screw
8a	Servo oil rising pipe (FE) (4.55)	24a	Drain screw
9	Casing	33	Level switch LS2055A
10	Flange	60	Leakage drain from rising pipe (4.55) (DE)
11	Name plate	61	Leakage drain from rising pipe (4.55) (FE)
12	Outlet pipe	62	Control pipe pf leakage drain (60)
18	Distributing pipe	63	Control pipe of leakage drain (61)

6. Filling, draining of servo and control oil system

6.1 Filling and venting (see Fig. 'C', 'E' to 'I')

⇒ Check whether stop valve (20) is open before automatic filter (1).

⇒ Check whether drain screw (43) is tightened in collector block (3).

⇒ Check whether stop valves (21) and (21a) in the collector block and stop valves (22), (22a), (23) and (23a) before servo oil rails (9), (9a) are open till the stop and tightened with a torque of 200 Nm in this position.

⇒ Check whether stop valves (30), (30a) are opened in the connection between servo oil rails (DE and FE) and control oil rails (DE and FE).

⇒ Start bearing oil pump.

Bearing oil is delivered to the collector block via automatic filter and servo oil pumps. The non-return valves (45) are opened due to the delivery pressure in the distributor block and oil flows into the servo oil rails (DE and FE) through rising pipes (8), (8a).

⇒ Loosen screws (64) by three turns in connecting element "VE" between servo oil rail (9), (9a) and exhaust valve drives (10) of the first and last cylinders (see Fig. 'G').

⇒ If oil flows out, close the screws (64) and tighten them with a torque of 130 Nm. Oil reaches the control oil rails (DE and FE) via non-return valves (28), (28a).

⇒ Open drain screws (41) and (41a) in valve block "VB" of the control oil rails (DE and FE), (see Fig. 'H' and 'I').

⇒ After approx. one minute, close the drain screws (41), (41a)and tighten them with a torque of 200 Nm.

6.2 Draining (see Fig. 'C', "F' to 'I')

Servo oil system:

The servo oil system can be drained with drain screw (43) in collector block (3).

⇒ Open drain screw (43).

CAUTION

After draining the servo oil system retighten drain screw (43).

- If, However, only the servo oil rail must be emptied, drain screw (24) or (24a) can be used.

Control oil system:

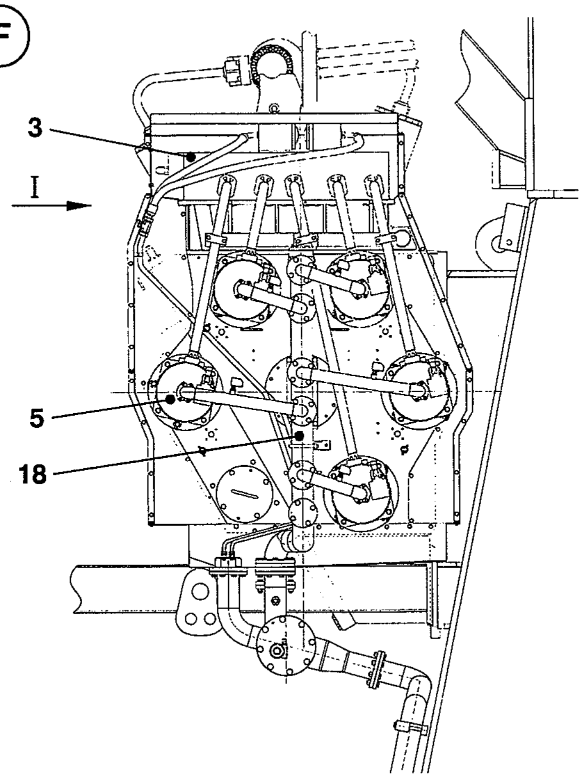
The control rails (15), (15a) can be drained with drain screw (41) or (41a) (see Fig. 'H' and 'I').

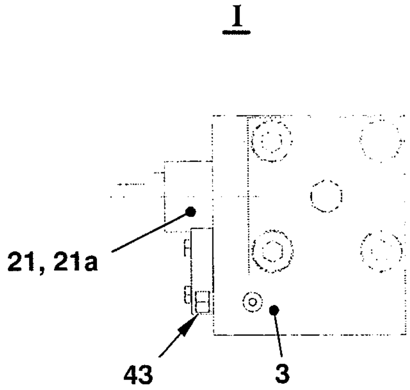
⇒ Open the drain screws (41), (41a) in valve block "VB" of the control oil rails (DE and FE) and leave them in this position until the system drained.

CAUTION

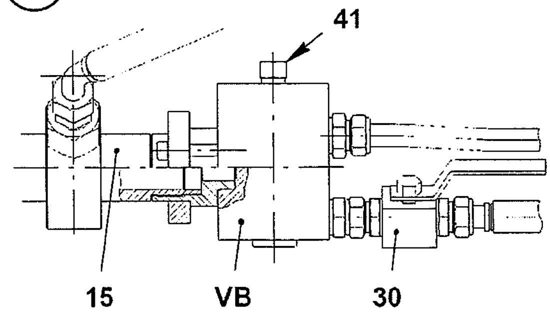
After draining the control oil system the drain screw must be closed and tightened with a torque of 200 Nm.

F

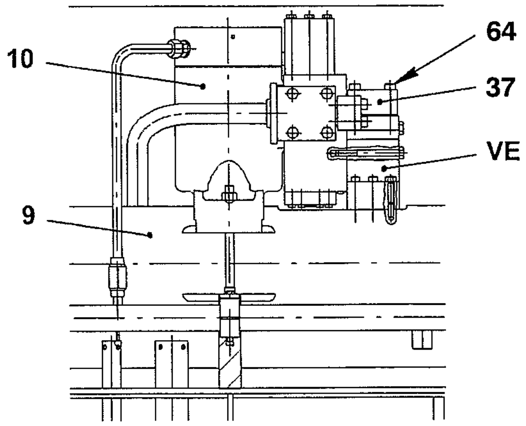




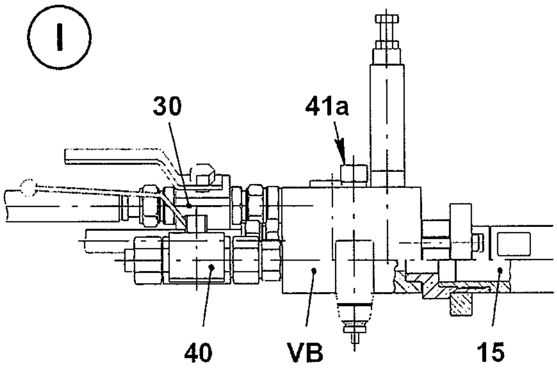
H



G



I



Key to Illustrations: **'F' Supply unit and collector block**
'G' Servo oil rail
'H' Control oil rail DE
'I' Control oil rail FE

3	Collector block (4.52)	40	Stop valve (3.40)
5	Servo oil pump (4.15)	41, 41a	Drain screw (3.68)
7	Supply pipe (4.51)	43	Drain screw (4.72)
9	Servo oil rail (4.11)	64	Screw
10	Exhaust valve drive (4.10)		
15	Control oil rail (3.75)		
18	Distributing pipe	VB	Valve block (control oil rail DE)
21, 21a	Stop valves (4.25-1 & 2)	VB	Valve block (control oil rail FE)
37	Plug (4.32)	VE	Connecting element (servo oil rail)

1. General

Cylinder lubricating oil system is independent system of the main engine lubricating oil system.

The cylinder lubricating oil is supplied from the service tank (5) to the line heater (18). Cylinder lubricating oil passes thorough the low pressure filter (13) after being heated by the line heater (18), the heated oil is pressurized by the middle pressure pump (12).

The pressurized cylinder lubricating oil passes through the line filter (14) and is distributed to each distributor unit (2) via the main pipe (7).

The cylinder lubricating oil which is supplied to the distributor unit (2) is injected into the surface of cylinder liner (1) via the ECL-SIP valve (4).

The pressure of the main pipe (7) is retained to 8 MPa by the pressure retaining valve (15).The cylinder lubricating oil is decompressed by the pressure retaining valve (15). The decompressed oil returns to the supply unit via the low pressure return pipe (8).

The orifice (3) is installed in each distributor unit (2). The distributor unit (2) is kept warm due to that the cylinder lubricating oil always passes through the distributor unit (2) even if the distributor unit is not operated. The cylinder lubricating oil which is passed through the orifice (3) is collected by the low pressure return pipe (8) and returns to supply unit again.

The return oil from ECL-SIP valve (10) and the return oil from distributor (11) are connected to the low pressure return pipe (8) through three-way valves (20), and flows together with return oil from the orifice (3) and decompressed oil by the pressure retaining valve (15).

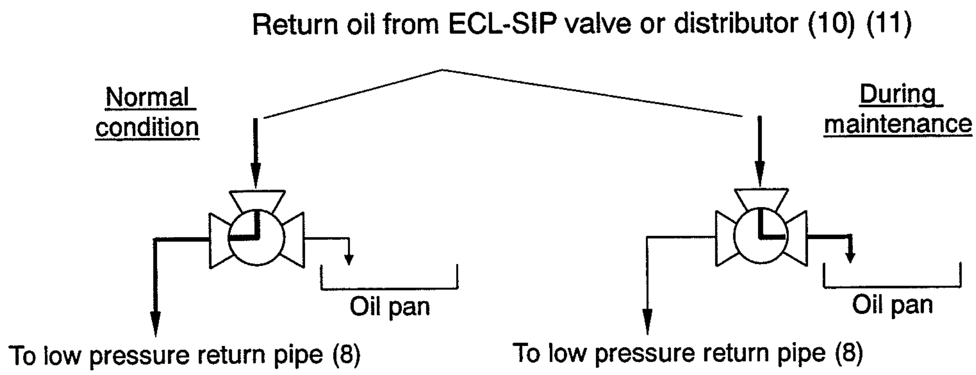
The temperature of the cylinder lubricating oil which is decompressed by the pressure retaining valve (15) comes higher than before decompressed. The heated lubricating oil is cooled by the oil cooler (19) and returns inlet of the line heater (18) and recirculate.

If the cylinder lubricating oil leaks from the connecting part of the distributor unit, the leakage oil flows into the drain pipe (21) and the leakage sensor (22) detects the leakage oil and informs to the safety system of the control room.

The drain which passes the leakage sensor is led to the oil groove on the bedplate surface.

CAUTION

When removing the ECL-SIP valve (4) or the distributor (2), the return line must be vented using three-way valve (20).
After restoration of the ECL-SIP valve (4) and distributor (2), the return line must be connect with the low pressure return pipe (8) certainly.

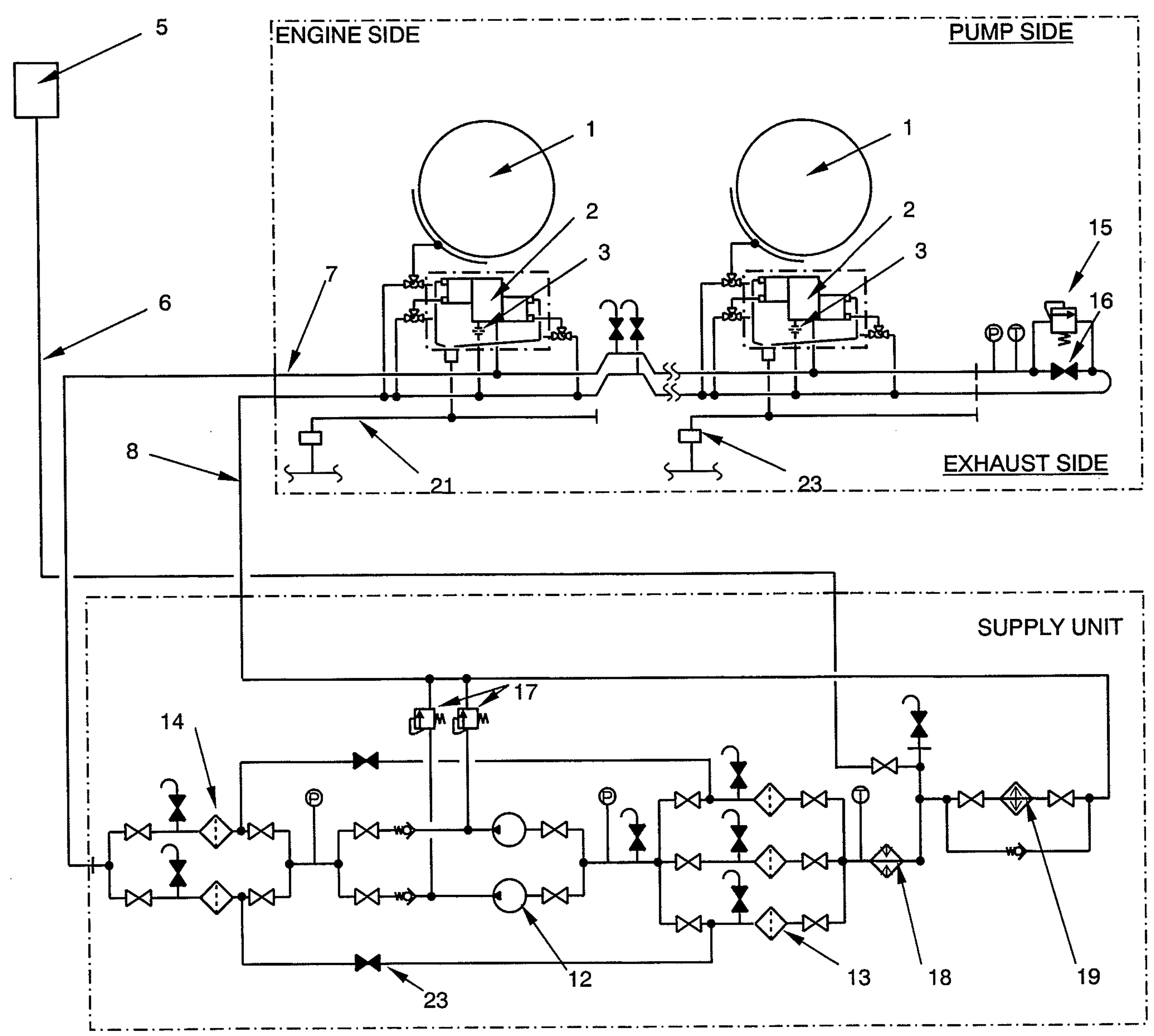


CAUTION

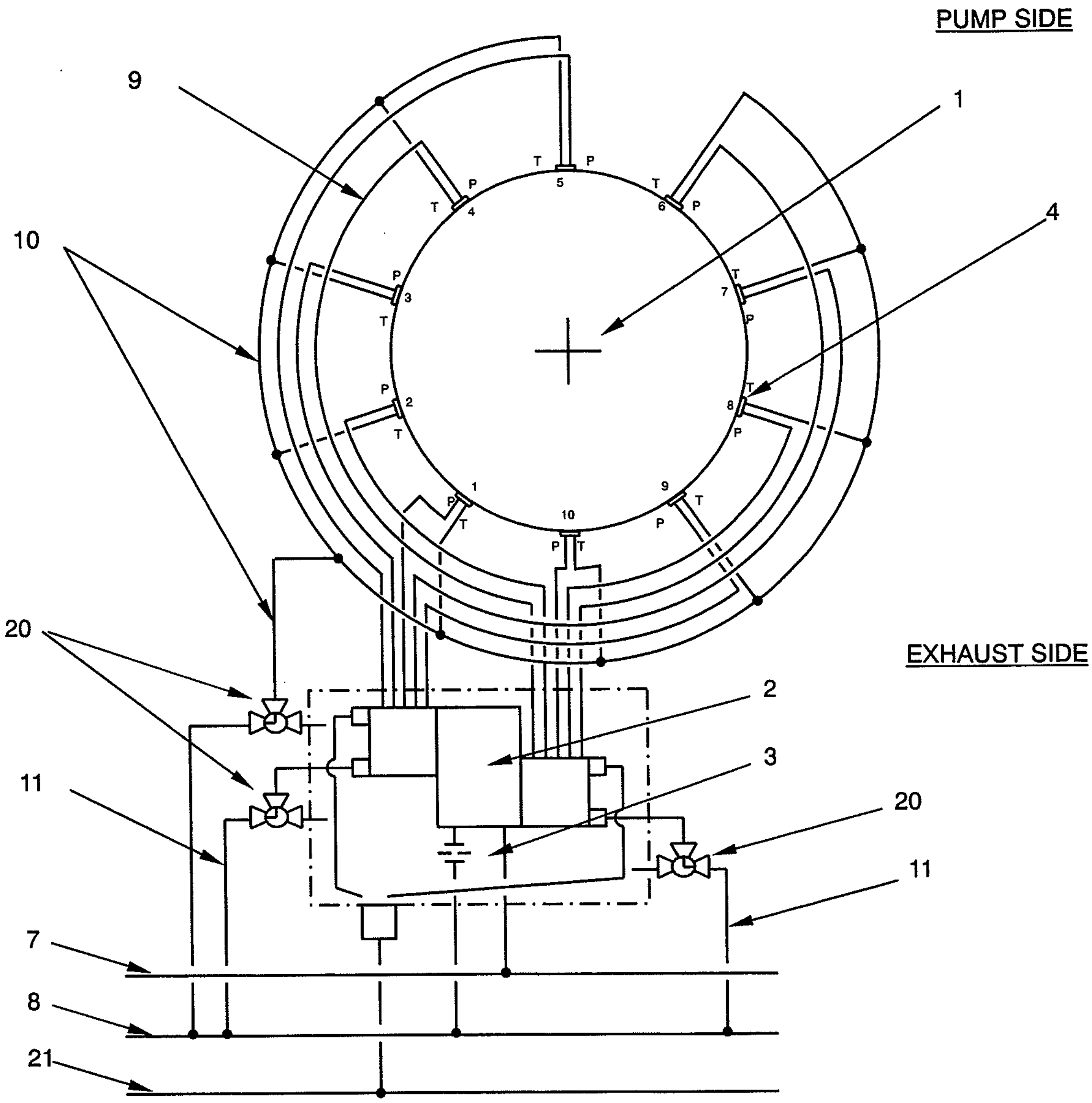
Oil filling valve (23) should not be opened except during maintenance of low pressure filter. Detailed information is described in operating manual 7218-4/A1.

Key to Illustration:

1 Cylinder liner
2 Distributor unit
3 Orifice
4 ECL-SIP valve
5 Service tank
6 Supply pipe
7 Main pipe
8 Low pressure return pipe
9 Lubricating branch pipe
10 Return pipe from ECL-SIP valve
11 Return pipe from distributor
12 Middle pressure pump
13 Low pressure filter
14 Line filter
15 Pressure retaining valve
16 Bypass valve for pressure retaining valve
17 Safety valve
18 Line heater
19 Oil cooler
20 Three-way valve
21 Drain pipe
22 Leakage sensor
23 LO filling valve



ECL System
Cylinder Lubricating Oil Piping System



1. General

The schematic diagram shows the cylinder cooling water system on the engine.

The arrangement of pumps, coolers, fresh water generator, heater, expansion tank, valves and throttling discs for flow control etc. are found in the separate documentation for the plant layout (shipyard side).

The cooling water system is a closed circuit, which, connected to an expansion tank, is subject to a static pressure. The cooling of cylinder liners, cylinder covers and exhaust valve cages is effected by treated cooling water.

In order to bring the cooling water to operating temperature even before the engine has started a cooling water heater is installed in the plant.

The cooling water must be treated with an approved cooling water inhibitor to prevent corrosive attack, sludge formation and scale deposits in the system (see Cooling Water / Cooling Water Treatment 0760-1).

CAUTION

Should the engine be taken out of operation for a longer period of time, please consider when frost threatens that the cooling water system must be drained. Thereby it must be kept in mind that it is chemically treated water which must be decontaminated in accordance with local laws or rulings. For the new filling the instructions for water treatment must be observed.

Automatic temperature control:

In order to avoid undue tensions in the combustion chamber components, such as cylinder liners and cylinder covers, the cooling water outlet temperature must be maintained under all load conditions as steady as possible; max. admissible temperature fluctuations are:

- at constant load: ±2 °C
- during load changes (transient conditions): ±4 °C

With regard to pressures, temperature ranges, alarm and safety setting points see Operating Data Sheets 0250-1.

2. Function

The cooling water pump delivers cooling water, via the distributing pipe (1) arranged on the exhaust side, to the various cylinders, where it flows successively through cylinder liner (3), water guide jacket (4), cylinder cover (5) and exhaust valve cage (6). At the end of the outlet collector main (9) outlet piping (10) is connected to the expansion tank by a vent piping providing continual venting of the system.

The water flows from the outlet piping (10) via a temperature regulating valve to the cooler and back to the pump. The suction side of the pump is joined to the expansion tank by a balance pipe. This balance pipe ensures the static pressure and also compensates any water losses and water expansion.

A throttling disc (7) is fitted in the outlet piping of each cylinder and dimensioned to let pass a certain flow of cooling water through the cylinder.

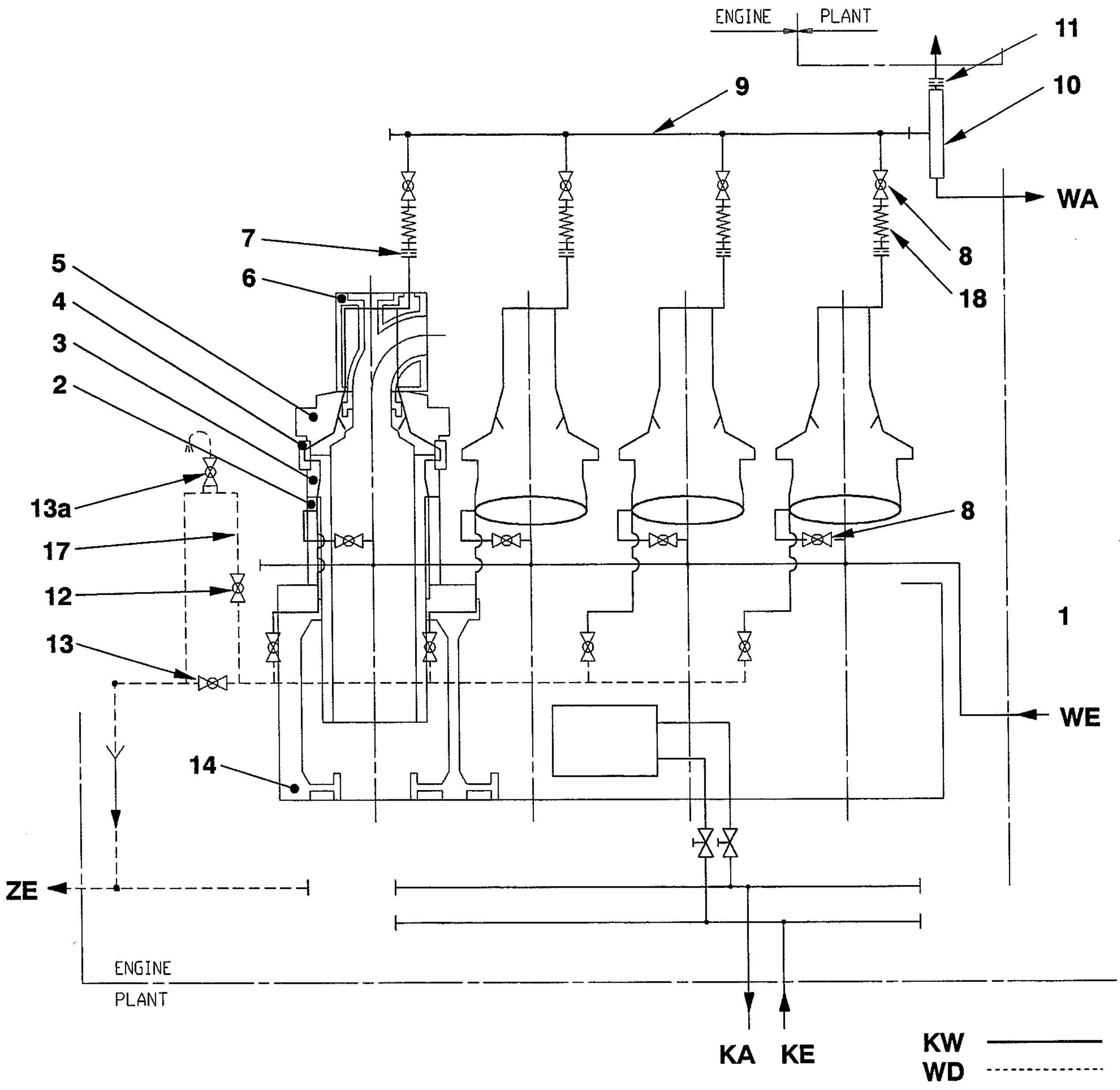
Draining:

With ball valves (8) and (12) the cylinders can be separated individually from the cooling water system and drained using ball valve (13).

☞ ***Remark*** : Ball valves (13) and (13a) do not have to be opened.

In case that cylinder cover must be removed, open the ball valve (13a) and the cooling water flows off via level bypass pipe (17).

In case that cylinder liner must be removed, open the ball valve (13) and the cooling water flow off.



Key to Diagram :

1	Distributing pipe	15	Scavenge air cooler
2	Supporting ring	16	Shut-off valve
3	Cylinder liner	17	Level bypass pipe
4	Water guide jacket	18	Flexible pipe
5	Cylinder cover		
6	Exhaust valve cage		
7	Throttling disc, cylinder outlet	EL	Vent
8	Ball valve at cylinder	KA	Cooling water outlet (SAC)
9	Outlet collecting main	KE	Cooling water inlet (SAC)
10	Outlet piping	KW	Cooling water
		WA	Cooling water outlet
12	Ball valve for draining	WE	Cooling water inlet
13, 13a	Ball valve to drain	WD	Drain pipe
14	Cylinder jacket	ZE	Cylinder drain

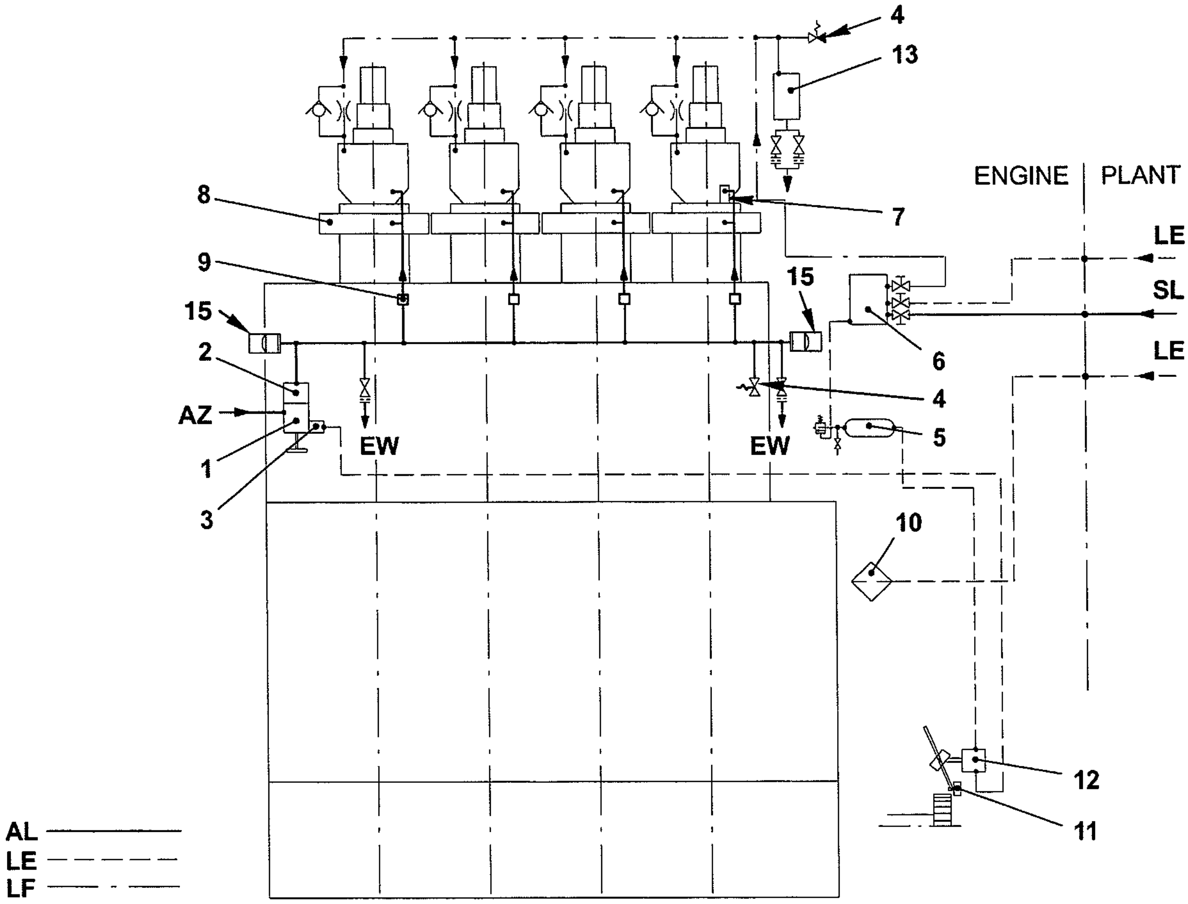
1. General

The piping arrangement of the starting air system is shown on the schematic diagram.

The control air required for the control air of the engine is supplied by control air supply unit (6) and control air bottle (5). The correlation with the engine control is depicted in control diagrams 4003-2.

The compressed air used should be clean and dry.

The starting air system must used be cleared of condensed water by opening the drain valves at regular intervals.



Key to Diagram :

1	Shut-off valve for starting air	12	Blocking valve on turning gear
2	Non-return valve	13	Starting air inlet
3	Control valve and valve unit for start [E]	14	Oil leakage return from air spring
4	Safety valve	15	Rapture disk
5	Air bottle for control air supply unit [A]		
6	Control air supply unit [A]	AL	Starting air
7	Starting valve	AZ	Starting air inlet
8	Cylinder cover	EW	Vent and drain
9	Flame arrester	LE	Control air (board supply)
10	Automatic filter	LF	Air spring air
11	Turning gear	SL	Start. air for control air stand-by supply & air spring

1. General

For heavy fuel operation the pre-heating as well as keeping warm during a short engine stop must be absolutely assured.
For this reason all pipes up to injection control units (11) are provided with heating pipes and insulated accordingly.

For safety reasons rail unit (45) is provided, and all pipes are double-walled designed in the high pressure circuit outside the rail unit.

2. Low pressure circuit

The fuel oil is delivered via inlet pipe (1) to fuel pumps (3) by a booster pump installed in the plant. The delivered fuel quantity is considerably greater than actually required by the engine. The specified booster pressure is adjusted by pressure retaining valve (5). The surplus fuel is led back to the system via return pipe (4) (see also 0720-1 'Layout of the fuel oil system').

2.1 Setting the pressure retaining valve

The setting values of the fuel pressure have to be adjusted in accordance with indications in Operating Data Sheet 0250-1 for 'fuel pump inlet'.

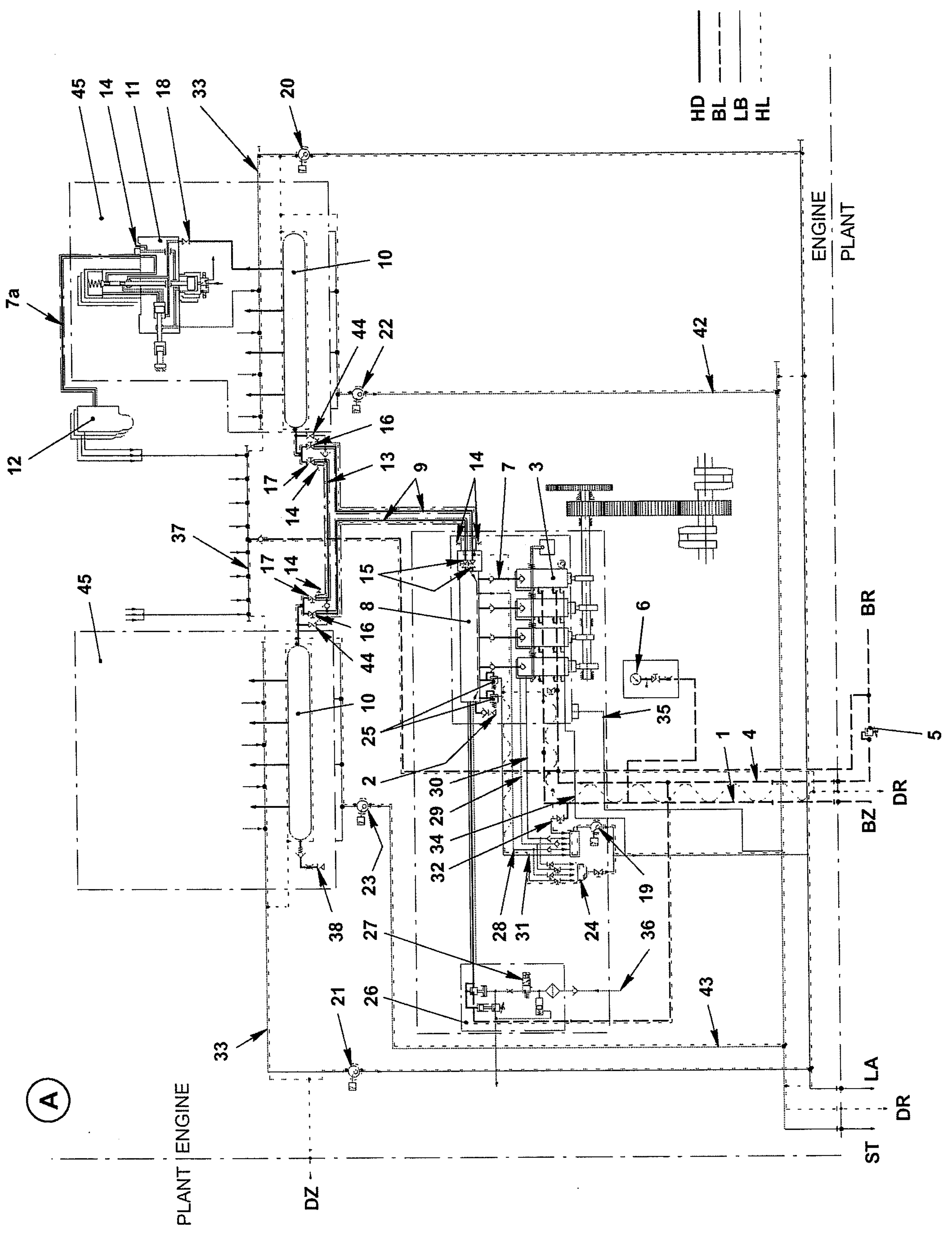
The pressure to be adjusted on the pressure gauge (6) is raised when the adjusting spindle (39) is turned in a clockwise direction (+) and, when it is turned in an anti-clockwise rotation, lowered (–). Both locking nuts (40) and (40) must be loosened for adjusting the spindle (39).

3. High pressure circuit

Prior to the first commissioning or after maintenance works on the high pressure circuit, the fuel rail (10) can be connected to the control oil rail by tool (94583). The control oil pump generates the required pressure for priming and venting the high pressure circuit (see 0120-1 'Priming the fuel system on the engine').
The fuel pumps (3) deliver fuel under high pressure into the fuel rail via HP pipes (7), intermediate fuel accumulator (8) and rising pipes (9). They supply as much fuel as necessary to maintain the required pressure (load-dependent) in the fuel rail (see Fuel Pump, Intermediate Fuel Accumulator and Fuel Pressure Control Valve 3.06 5556-1).

Pressure pulsations generated by the conveyance of the fuel pumps in the system are reduced by means of the intermediate fuel accumulator.
The injection control units (11) control the fuel injection volume to each injection valve (12).

Leakage inspection points (14) are provided on the flanges of fuel rising pipes (9) and connecting pipes (13). In this way, possible leakages may be localized easily (see section 4).


HD
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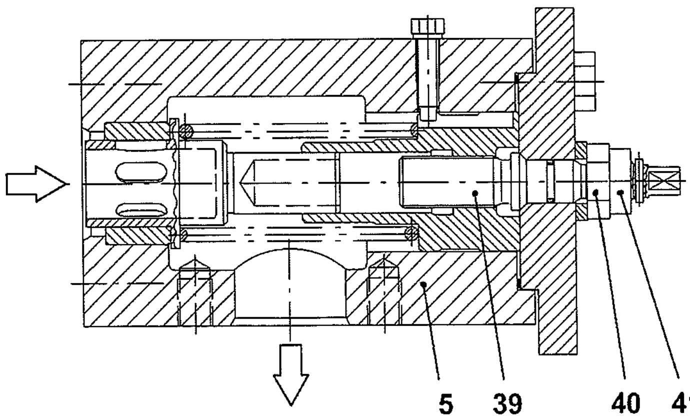
BR
DR
BZ
LA
ST
DZ
A

Key to Illustrations: 'A' Fuel oil system on engine
'B' Pressure retaining valve

1	Fuel inlet pipe (3.24)
2	Filling connection (3.54)
3	Fuel pump (3.14)
4	Fuel return pipe
5	Pressure retaining valve (3.53)
6	Pressure gauge
7, 7a	HP pipes (3.28), (3.47)
8	Intermediate fuel accumulator (3.04)
9	Fuel rising pipe (3.29) (high pressure)
10	Fuel rail (3.05)
11	Injection control unit (3.02)
12	Injection valve (3.01)
13	Connecting pipe
14	Leakage inspection point (3.12)
15	Stop valves (3.62-1 & 2)
16	Stop valves (3.33-1 & 2)
17	Stop valves (3.33-3 & 4)
18	Plug (3.35)
19	Level switch LS3426A
20	Level switch LS3446A
21	Level switch LS3447A
22	Level switch LS3444A
23	Level switch LS3445A
24	Leakage monitoring (3.12)
25	Fuel overpressure safety valves (3.52-1 & 2)
26	Fuel pressure control valve (3.06)
27	Fuel shut-down pilot valve (3.08)
28	Leakage drain pipe of rising pipe and from intermediate fuel accumulator
29	Leakage pipe of back line fuel pumps (bank A)
30	Leakage pipe of front line fuel pumps (bank B)
31	Leakage pipe from fuel overpressure safety valves
32	Drain pipe
33	Fuel leakage (collecting) pipe (3.46)
34	Fuel leakage from fuel pumps
35	Leakage pipe from supply unit
36	Connection from bearing oil system
37	Fuel leakage collecting pipe from injection valves
38	Plug (3.39)
39	Adjusting spindle
40	Locking nut
41	Locking nut
42	Leakage drain from rail unit DE
43	Leakage drain from rail unit FE
44	Drain screw
45	Rail unit (casing)
BL	Fuel piping system
BR	Fuel return
BZ	Fuel supply
DR	Steam outlet
DZ	Steam inlet
HD	High pressure piping system
HL	Heating (tracing) pipe
LA	to fuel overflow tank
LB	Fuel leakage pipe
ST	to sludge tank

Remark: If necessary plug (18) may be replaced with the one from the tool set at engine standstill for shutting off the injection control unit (see 0510-1).

B



4. Fuel leakage system

All important leakages in the fuel oil system are monitored by level switches (LS). In case of excessive leakage quantity the corresponding alarm is triggered:

Level switch	Location	Monitored components
LS3444A LS3445A	driving end free end	Leakages (fuel, servo and control oil) from rail unit
LS3446A LS3447A	driving end free end	HP pipes (7a) to injection valves, injection control unit (11) (fuel quantity piston)
LS3426A		Fuel rising pipes (9), connecting pipe (13) (8 to 14 cylinders), intermediate fuel accumulator (8), HP pipes (7), fuel pumps (3) and responding fuel overpressure safety valves (25)

4.1 Leakage monitoring

Leakage monitoring (24) and several leakage inspection points (14) are provided for proper leakage localization (see Fig. 'A').

If an alarm has been triggered by level switch (19) (LS3426A), the leakage can be localized at leakage monitoring (24), and the corresponding measures taken (see Fig. 'C').

Stop valves (56) to (59) and ball valve (60) are normally closed.

Control pipe 46, LI3427L:

- Leakages from fuel pumps (3) of fuel pump row, bank A and their HP pipes (7) (leaky seat of HP pipe and pump cover or crack in pump cover).

Control pipe 47, LI3427L:

- Leakages from fuel pumps (3) of fuel pump row, bank B and their HP pipes (7) (leaky seat of HP pipe and pump cover or crack in pump cover).

Control pipe 48, LI3428L:

- Leakages from fuel rising pipe (9), connecting pipe (13) (8 to 14 cylinders), and fuel intermediate accumulator (8) i.e. leaky sealing surface of its flanges.

Control pipe 49, LI3429L:

- Leakages from fuel overpressure safety valves (25).

Procedure:

WARNING

> Always use gloves when working on hot components! Always wear safety goggles; fuel may spurt out on casings, drain screws when opening them or loosening the screwed pipe couplings.

⇒ Open ball valve (60) at collecting trough (50).

⇒ Open and close stop valves (56) to (59) one by one till the leakage is localized.

LI3427L (e.g. break of HP pipe between fuel pump and intermediate fuel accumulator).

⇒ Open the corresponding casing after determining which of the pump row is leaky.

⇒ Carefully loosen screwed pipe coupling of leakage pipe (51) on the fuel pumps and check whether fuel flows out.

> **WARNING**
> A defective HP pipe (7) may only be replaced at engine standstill!
> If the HP pipe cannot be replaced immediately, then the corresponding fuel pump must be cut out (see Cutting Out and Cutting In of the Fuel Pump 5556-2).

- **LI3428L** (break of fuel rising pipe (9) between intermediate fuel accumulator (8) and fuel rail (10) or connecting pipe (13)).

⇒ **Upper** inspection point: Loosen one of the two drain screws (52) by approx. two turns and check whether fuel flows out, *yes* or *no* (see Fig. 'D').

- *Yes:* In this case connecting pipe (13) is defective.

⇒ Both stop valves (17) must be closed.

- *No:* In this case one of the two fuel rising pipes (9) is defective.

⇒ **Lower** inspection point: Loosen one of the two drain screws (53) by approx. two turns and check whether fuel flows out *yes* or *no*. Now it is possible to ascertain which of the fuel rising pipes (9) is leaky (see Fig. 'E').

> **CAUTION**
> Opening and closing of the shut-off valves may only be carried out in slow-down operation (fuel rail pressure max. 500 bar).

⇒ Cut out the defective fuel rising pipe by means of stop valves (15) and (16) (see Fig. 'A').

Remark: The stop valves (15), (16) and (17) must be **opened or closed till the stop** and tightened with a torque of 200 Nm in both positions.
Pay attention that stop valves (15) and (16) of the **same fuel rising pipe** are closed.
The engine may be maintained in unrestricted operation (reset slow-down) at the required fuel oil temperature and with only one rising pipe, until the defective pipe has been replaced.

In case of leaky sealing surfaces of flanges on the fuel intermediate accumulator, there are screw plugs at the relevant flanges provided for leakage localization (see 5556-1 'Fuel intermediate accumulator').

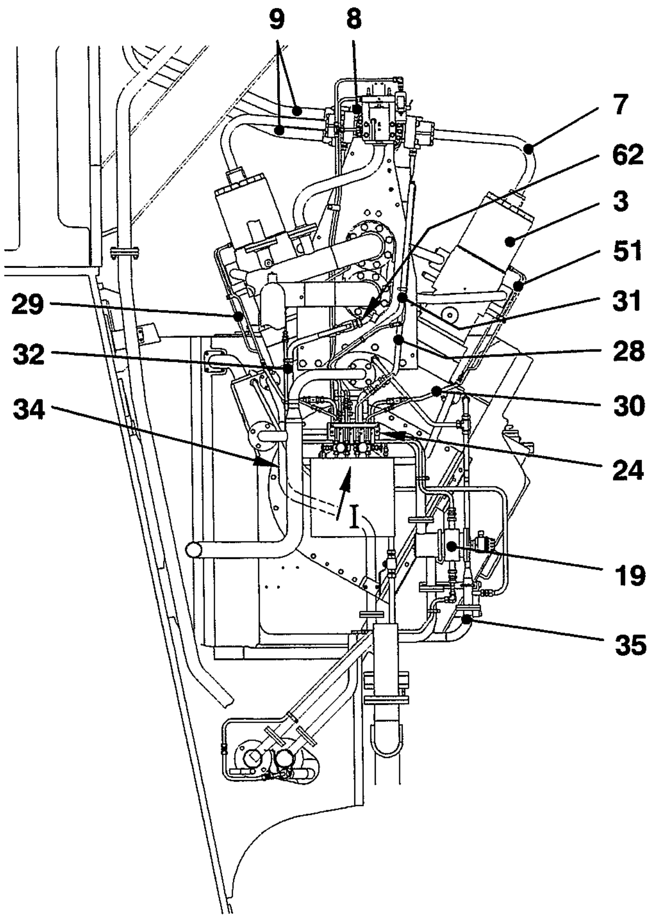
> **CAUTION**
> **Do not open these screw plugs under no circumstances on the running engine!**

Leakages may be localized on condition that:

- engine is at standstill
- stop valves (15) are closed after fuel intermediate accumulator (8).
- all screw plugs are opened in the flanges on fuel intermediate accumulator.
- fuel booster pump (3.15) is in operation.
- engine rotates with turning gear pressurizing therewith the fuel intermediate accumulator.

- If an alarm is triggered by level switch LS3446A or LS3447A, the leakage from a HP pipe (7a) can be localized by means of the corresponding drain screw (54) (see Fig. 'F').
- If the low pressure circuit must be emptied (i.e. due to removal of a fuel pump), it can be drained via drain pipe (32) by means of drain cock (62). Ball valve (60) at collecting trough (50) must be opened beforehand (see Fig. 'C').

C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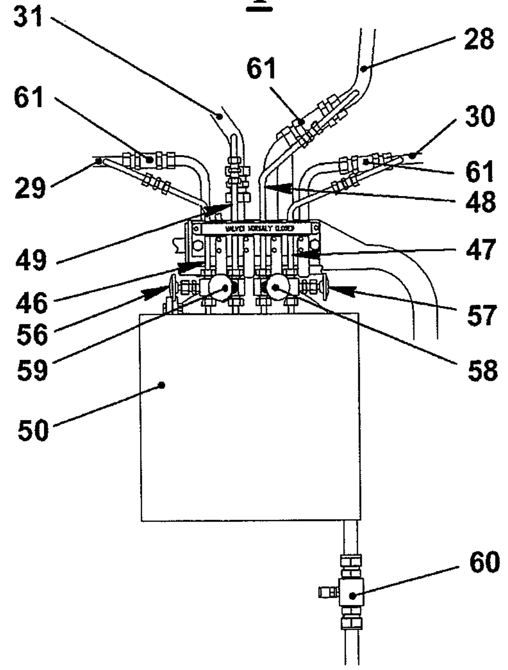
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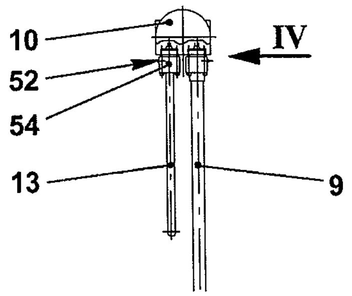
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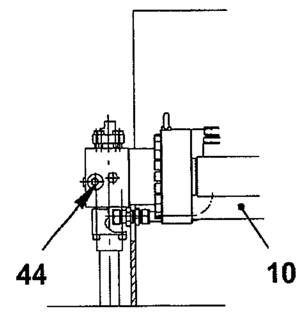
IV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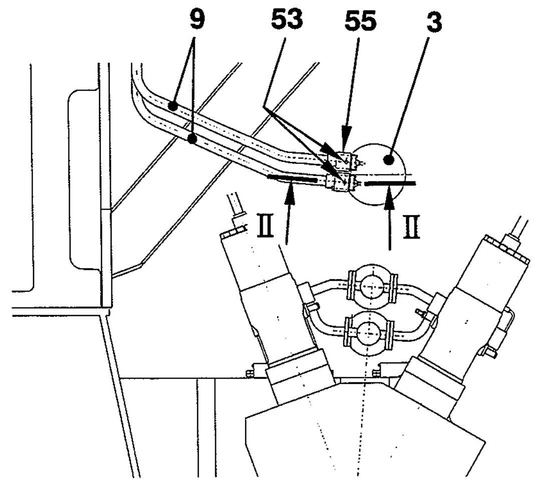
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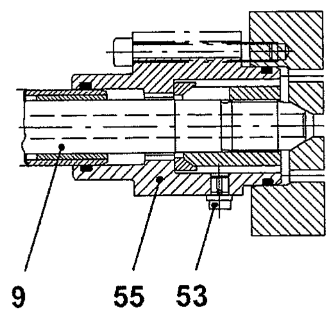
II – II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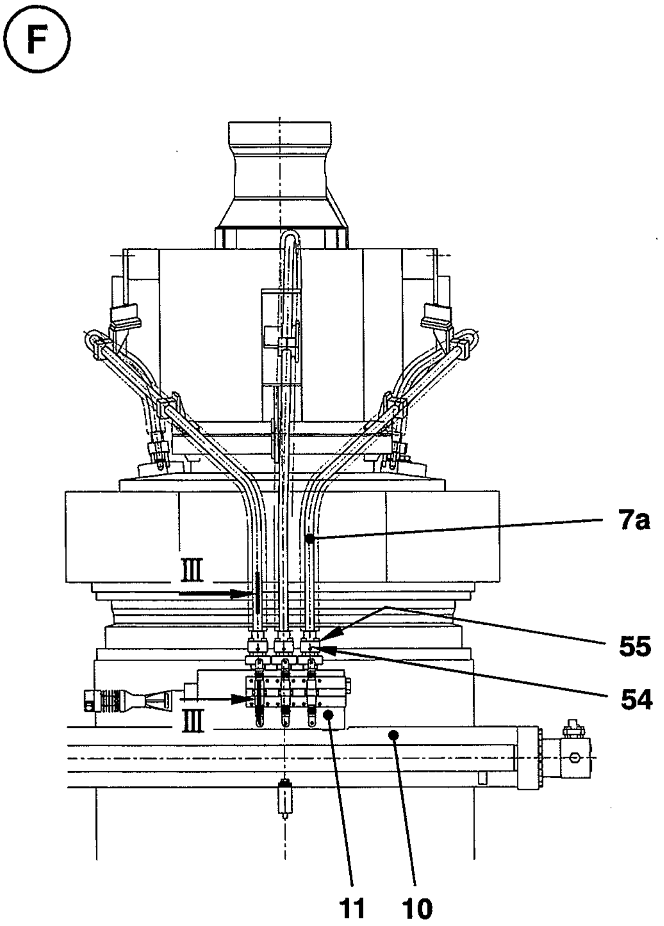
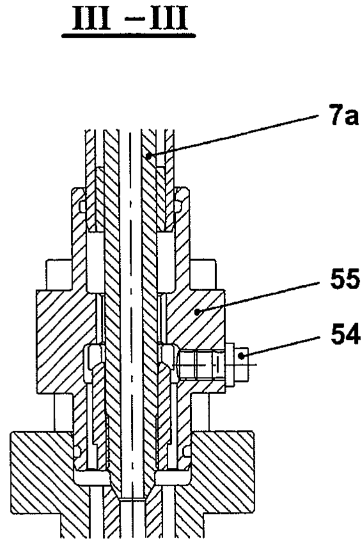




Key to Illustrations: 'C' **Leakage monitoring**
'D' **Upper leakage inspection point**
'E' **Lower leakage inspection point**
'F' **Leakage inspection point of fuel pump**

3	Fuel pump (3.14)
7	HP pipe (3.28)
7a	HP pipe (3.47)
8	Intermediate fuel accumulator (3.04)
9	Fuel rising pipe (3.29)
10	Fuel rail (3.05)
11	Injection control unit (3.02)
13	Connecting pipe
19	Level switch LS3426A
24	Leakage monitoring (3.12)
28	Leakage inspection pipe of rising pipe and from intermediate fuel accumulator
29	Leakage pipe of back line fuel pumps (bank A)
30	Leakage pipe of front line fuel pumps (bank B)
31	Leakage pipe from fuel overpressure safety valves
32	Drain pipe
34	Fuel leakage from fuel pumps
35	Leakage pipe from fuel pump
44	Drain screw
46	Control pipe LI3427L (to item 29)
47	Control pipe LI3427L (to item 30)
48	Control pipe LI3428L (to item 28)
49	Control pipe LI3429L (to item 31)
50	Collecting trough
51	Leakage pipe from HP pipe (7) and fuel pump
52	Drain screws LI3453L, LI3456L
53	Drain screws LI3452L, LI3455L
54	Drain screw
55	Flange
56	Stop valve (to item 46)
57	Stop valve (to item 47)
58	Stop valve (to item 48)
59	Stop valve (to item 49)
60	Ball valve
61	Non-return valve
62	Drain cock

1. General

The drain piping, in particular that from the working piston underside (10), from piston rod glands (9) must be periodically checked for free passage.

Condensate may flow out before and after the cooler at the water drain (6), (7), (8) depending on ambient temperature and humidity. Under extreme ambient conditions a quantity of up to 0.16 kg/kWh (0.12 kg/PSh) of condensate may result.

2. Condensate drain

A perfect functioning of this drain must be ensured.
The following important points have to be taken into account :

CAUTION

In normal operation, three-way valve (11) usually remains opened to the throttling disc (21) side. Similarly, three-way valve (12) usually remains opened to the throttling disc (23) and ball valve (19) remains closed to the throttle disc (24). In case of heavy drain on charge air duct drain line (e.g. operating in high humidity), open ball valve (19) to the throttling disc (24) with three-way valve (12) opened to the throttling disc (23).
Similarly, three-way valve (13) usually remains opened to the sight glass (20).
Drain can be confirmed at the sight glass (20).
Only at engine stand-by or if necessary, each valve on cylinder cooling water drain and scavenge air cooler drain can be opened.

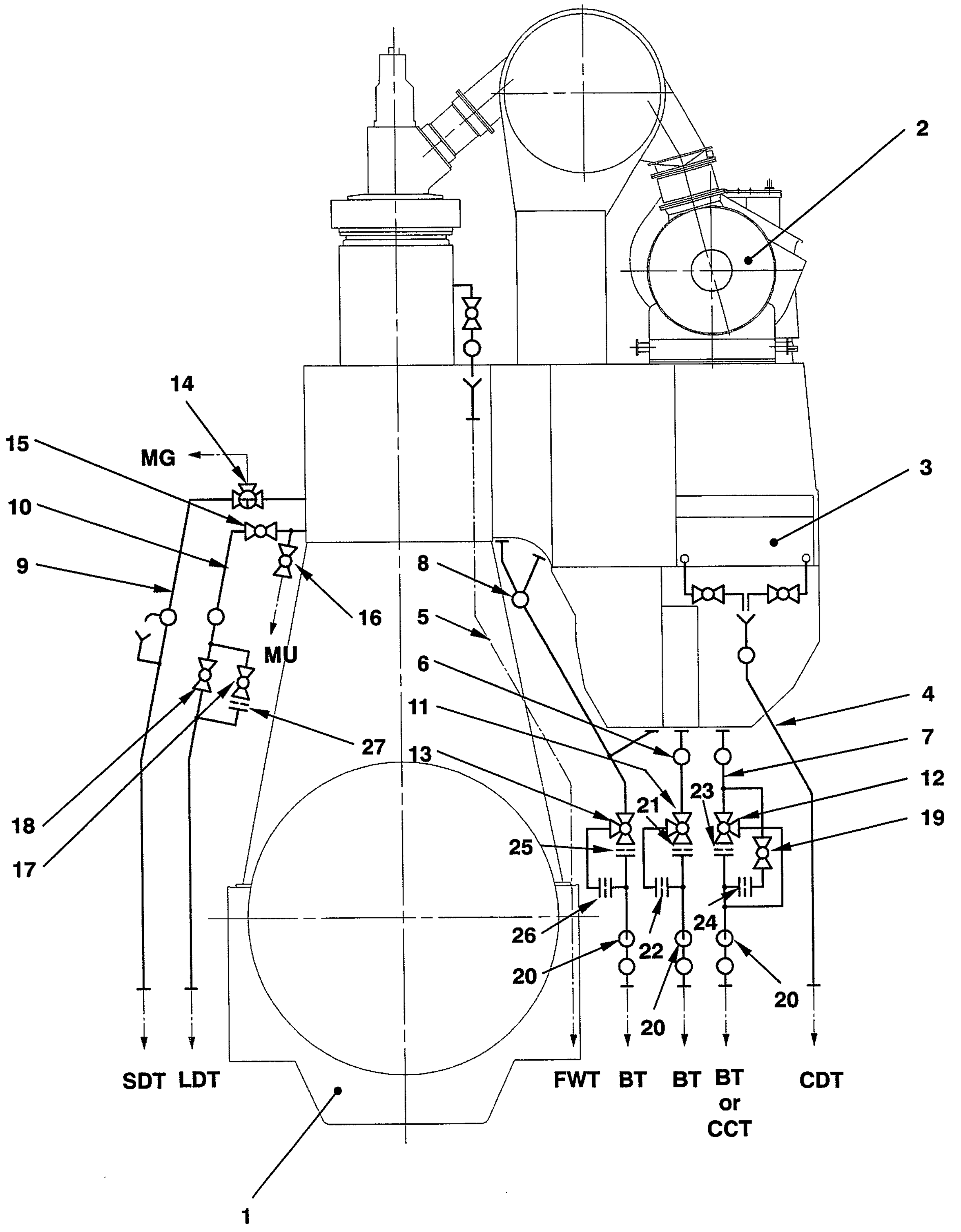
If the throttling disc (21) is chocked, immediately, open the three-way valve (11) to throttling disc (22). Then, the throttling disc (21) is dismantling and cleaned.
After the throttling disc (21) is re-assembled, open the three-way valve (11) to throttlingdisc (21).

Similarly, in case the throttling disc (23) or (25) is chocked, work the three-way valve (12) or (13) with the above procedure.

The ball valve (15), (17) on drain piping from piston underside usually remains opened and ball valve (16), (18) usually remains closed.

CAUTION

No-one or inadequate drain leads to an excessive collection of condensate in the scavenge air receiver. Water in liquid or evaporated state swept along by the air flow has a negative influence on the piston running behavior and leads to wear increase of piston rings and cylinder liners.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FWT
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BT
BT
or
CCT
CDT
1

Key to Illustration :

1 Engine
2 Turbocharger
3 Scavenge air cooler
4 Scavenge air cooler drain
5 Cylinder cooling water drain
6 Water separator drain
7 Charge air duct drain
8 Water drain from scavenge air receiver
9 Dirty oil from piston rod grand
10 Dirty oil drain from piston underside
11 Three-way valve
12 Three-way valve
13 Three-way valve
14 Three-way valve
15 Ball valve
16 Ball valve (for measuring quantity)
17 Ball valve
18 Ball valve
19 Ball valve
20 Sight glass
21 Throttling disc
22 Throttling disc
23 Throttling disc
24 Throttling disc
25 Throttling disc
26 Throttling disc
27 Throttling disc

SDT to piston rod stuff. box drain tank
LDT to lantern drain tank
FWT to cooling fresh water collect tank
BT to bilge tank
CDT to clean drain tank
CCT to chemical cleaning tank
MG Piston rod grand drain to be measured quantity
MU Piston under side drain to be measured quantity

Group 9

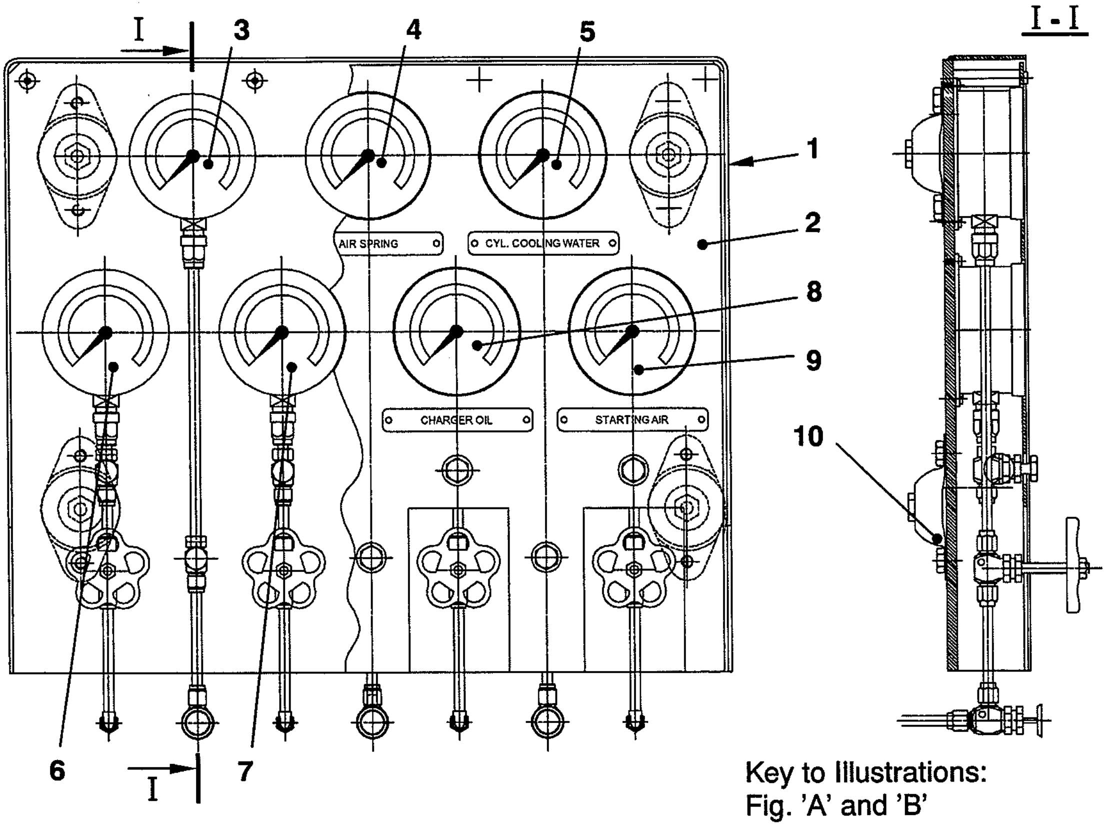
9

1. General

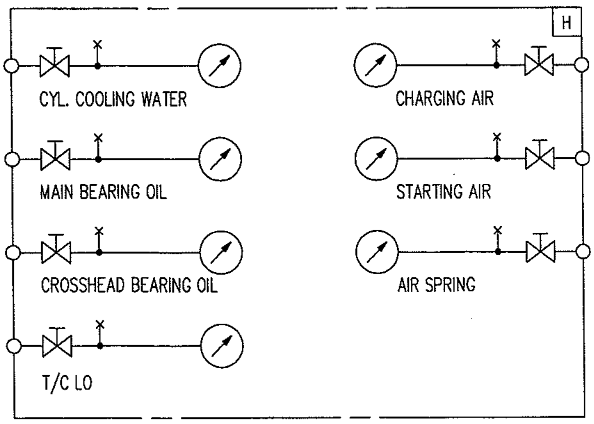
Instrument panel (1) is arranged beside to the control box. It contains important pressure gauges required for the visual observation of the pressures. Pressure indications for fuel, servo and control oil are provided in the local control panel (see 4618-1).

Fig. 'B' shows the schematic arrangement of instrument panel H with the same indications also contained in the Control Diagram 4003-2.
The corresponding pressure switches and pressure transmitters have been described in 9258-1.

A



B



Key to Illustrations:
Fig. 'A' and 'B'

1 Instrument panel
2 Cover plate
3 Press. gauge 0.4 MPa (for charging (scavenge) air)
4 Press. gauge 1.5 MPa (for air spring)
5 Press. gauge 1.0 MPa (for cylinder cooling water)
6 Press. gauge 2.0 MPa (for crosshead bearing oil)
7 Press. gauge 1.0 MPa (for main bearing oil)
8 Press. gauge 0.4 MPa (for T/C bearing oil)
9 Press. gauge 3.5 MPa (for starting air)
10 Anti-vibration mounting

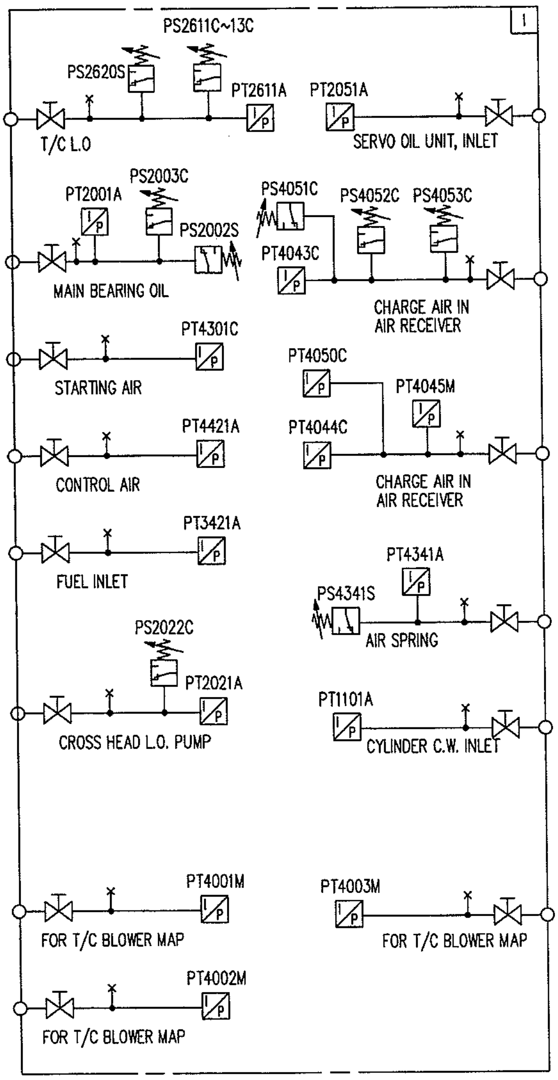
1. General

Each the pressure switch and transmitter are mounted separately on three blocks on the engine. (With regard to the arrangement and kinds of them, refer to "Instruction Manual for Electrical Equipment".)
They fulfill monitoring functions of the pressure systems in case of too low a pressure or in the case of a pressure loss.
Their control signals effect the following commands:

- Alarm (ALM)
- Slow down (SLD)
- Shut down (SHD)

Fig. 'A' gives a schematic diagram of the pressure switches and pressure transmitters [I] with the indications, as also determined in the control diagram 4003-2.

A



Key to Illustrations:
Fig. 'A'

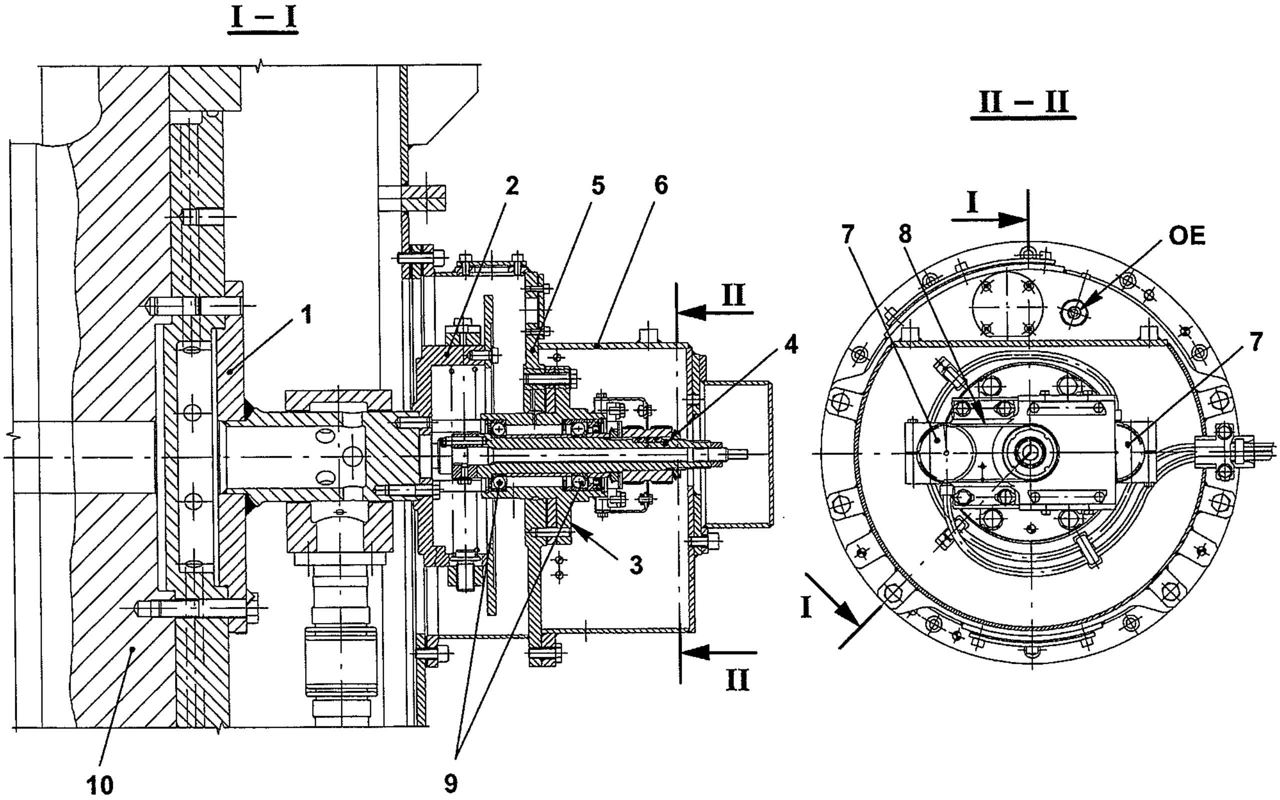
1 Press. gauge 0.4 MPa
(for charge (scavenge) air)
2 Press. gauge 1.5 MPa
(for air spring)
3 Press. gauge 1.0 MPa
(for cylinder cooling water)
4 Press. gauge 2.0 MPa
(for crosshead bearing oil)
5 Press. gauge 1.0 MPa
(for main bearing oil)
6 Press. gauge 0.4 MPa
(for T/C bearing oil)
7 Press. gauge 3.5 MPa
(for starting air)

1. General

The crank angle sensor unit is arranged at the free end. The connecting unit (2) is fastened to crankshaft (10) over driving shaft (1). It receives all unwanted radial and axial movements of the crankshaft.

Indicating the crank angle position, both crank angle sensors (7) are driven by toothed belt (8). The position of the TDC signal is monitored by a separate proximity sensor (see Pick-up for Speed Measurement 4628-1).
All deviations are monitored and indicated with an alarm, slow-down or shut-down.

Lubrication of ball bearing (9) must be ensured by carrying out periodical checks at engine standstill (see Maintenance Manual 0380-1 and 9223-1).



Key to Illustration :

1	Driving shaft	7	Crank angle sensor (GT5126C, 27C)
2	Connecting unit	8	Tooth belt
3	Shaft encoder drive	9	Ball bearing
4	Shaft	10	Crankshaft
5	Housing		
6	Protection hood	OE	Oil inlet

1. General

The electronic components required for the engine control system WECS-9520 are mainly arranged on the engine (Fig. 'A').

Exception is the power supply box which is placed nearby the engine (Fig. 'B').

2. Control boxes

The most important control and power supply boxes are described as follows :

E90 (SIB):

Control box serves as communication to the external systems and contains a FCM-20 module as 'Online Spare'.

It is arranges on the middle of the rail unit.

E95.01 to E95.11:

Control boxes (depending on number of cylinders) contain a FCM-20 module each.

They are arranged on the rail unit at every cylinder.

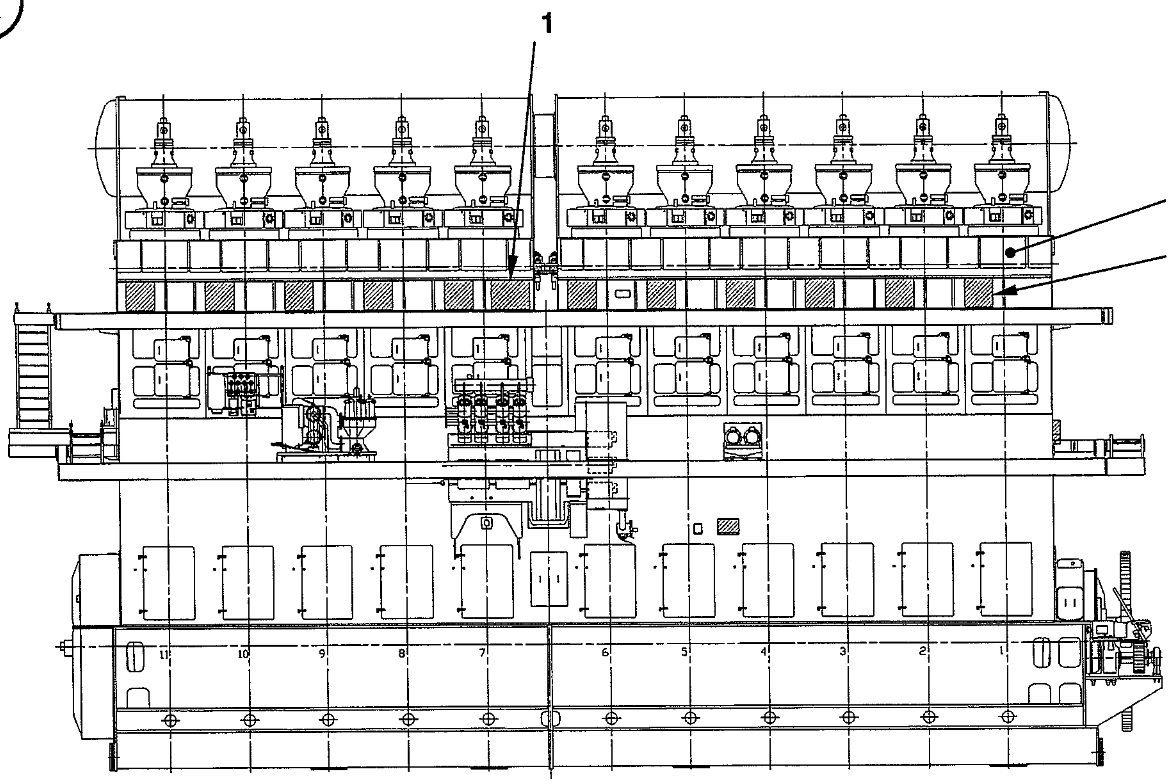
E85:

Power supply box for FCM-20 modules and fuel pump actuators is placed in the engine room nearby the engine.
Among other parts there are circuit breakers able to interrupt the power to FCM-20 modules or fuel pump actuators when required individually or completely.

Remark : The power supply is redundant. To interrupt the whole WECS-9520, make sure that both power inputs are switched off (see also Instruction Manual for Electrical Equipment "Connection wiring diagram in the control box")

Location of flex Electronic Components

(A)



(B)

Power supply box located in engine room nearby engine

Key to Illustration: Fig. 'A'

1 Control box E90
2 Control box E95.01 (Cyl. 1)
3 Rail unit

357/E