

Technical Documentation

G60ME-C9

Preface

MAN B&W G60ME-C9

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**For all engines:**

It is important that all MAN Diesel & Turbo engines are operated within the given specifications and performance tolerances specified in the engines' Technical Files and are maintained according to the MAN Diesel & Turbo maintenance instructions, in order to comply with given emission regulations, including, but not limited to, the instructions to that effect included in the Technical File, *see also 0220-0100, "Introduction" and 0760-0300 and 0760-0301, "Maintenance Schedule"*.

**Additionally for U.S. Flag Vessels:**

In accordance with Chapter I of the Code of Federal Regulations, CFR, Part 1042, Subpart B, §1042.125, NOTICE is hereby given, that:

- A repair shop or person of the owner's choosing may maintain, replace, or repair emission control devices and systems.

NOTE: see more information on page 2(2)

**Additionally for U.S. Flag Vessels:**

In accordance with Chapter I of the Code of Federal Regulations, CFR, Part 1042, Subpart B, §1042.104, NOTICE is hereby given, that:

- The engine must meet the exhaust emission standards over its full useful life.
- The requirement does not affect the requirement of the operator to keep the engine operating properly.
- The minimum useful life value is 3 years or 10,000 hours of operation, whichever comes first.
- The latest applicable MAN Diesel & Turbo Service Letter determines the useful life.
- Based on SL09-509 (as of 31 October 2013) the following useful life should be used, based on the recommended interval for overhaul of cylinder liners:
 - Engines with high topland pistons: 32,000 hours
 - MC/MC-C, 26-46 bore: 23,000 hours
 - ME-B, 35-46 bore: 16,000 hours
 - MC/MC-C, 50-98 bore: 16,000 hours
 - ME/ME-C/ME-B, 50-70 bore: 16,000 hours
 - ME/ME-C, 80-98 bore: 24,000 hours
- In case the engine manufacturer offers longer mechanical warranty or in other ways deviates from the MAN Diesel & Turbo recommendations the useful life must be adjusted accordingly.
- If the engine is designed, advertised, marketed or the basic mechanical warranty is for a longer life, the useful life must be specified longer.

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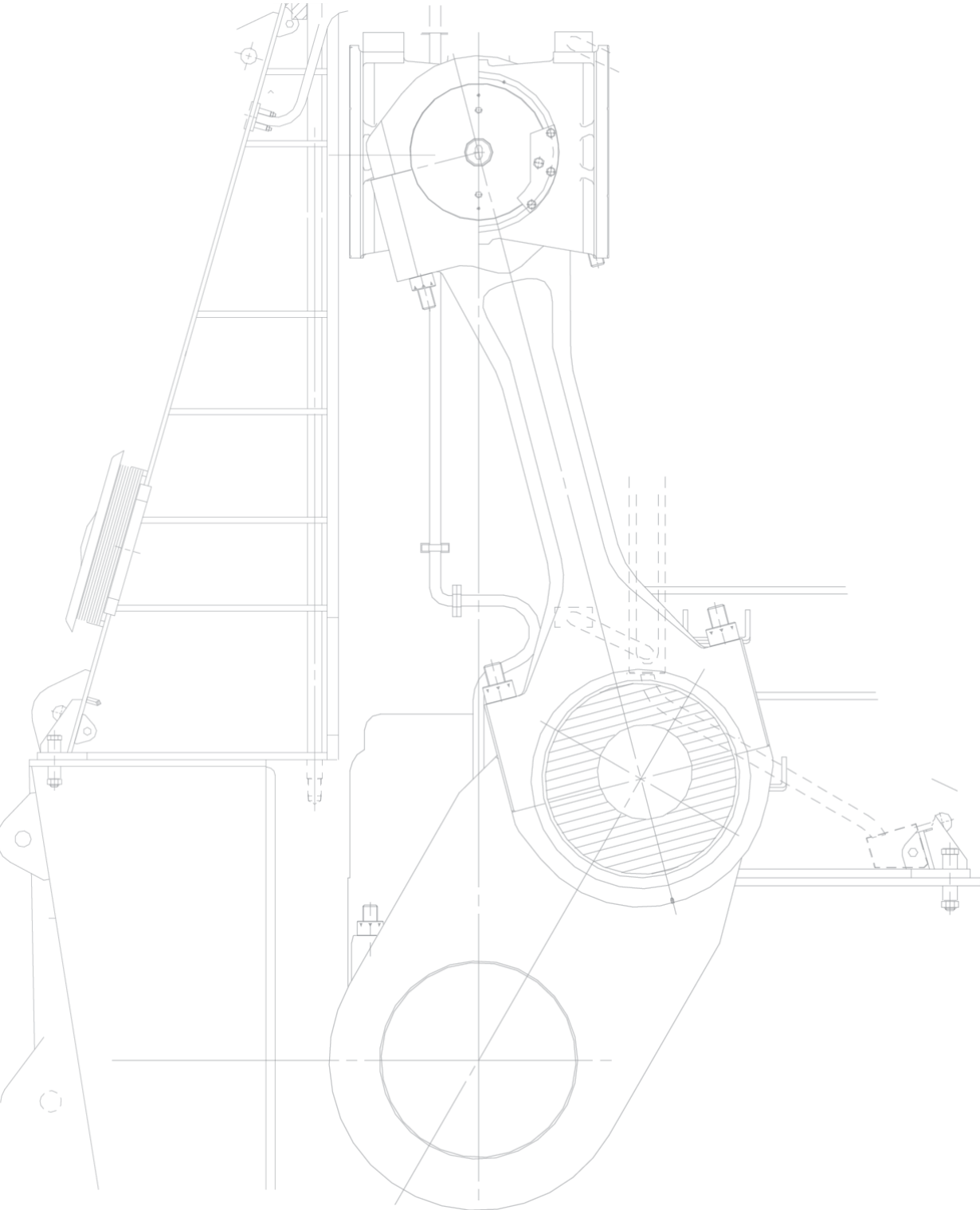
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Introduction

MAN Diesel & Turbo | PrimeServ

The MAN Diesel & Turbo Group offers worldwide round-the-clock service, 365 days a year. Apart from the MAN Diesel & Turbo service headquarters in Augsburg, Copenhagen, Frederikshavn, Holeby, Stockport, St. Nazaire, Turbocharger and service centres on all continents provide comprehensive and continuous support. The long service life associated with MAN Diesel & Turbo engines dictates a spare parts programme that ensures components are available for engines in operation for decades. Based on high-capacity machines, MAN Diesel & Turbo service production facilities are able to comply with special customer requests with the utmost precision and flexibility.

24-hour hotline number: +49 1801 15 15 15

Homepage: <http://primeserv.man.eu/>

The Manual

The purpose of this manual is to provide general guidance regarding the operation and maintenance of a standard version of a MAN Diesel & Turbo product, e.g. a main engine, auxiliary engine or propeller as well as to describe the design features of such a product. This manual is for guidance only and if any doubt should arise regarding any data stated in this manual then the engine builder's documentation should be referred to and/or MAN Diesel & Turbo contacted.

Deviations from a MAN Diesel & Turbo product may be found in a specific plant. If so, such deviations should be noted when ordering spare parts.

Reliable and economical operation of the MAN Diesel & Turbo product is conditional upon its correct operation and maintenance in accordance with MAN Diesel & Turbo's instructions and recommendations/guides. Consequently, it is essential that the engine room personnel are fully acquainted with the content of this manual.

Furthermore, to ensure optimum efficiency, reliability and lifetime of the product and its components, only original spare parts should be used when replacing parts of the engine.

The Manual Structure

This manual is divided into several chapters. Each chapter covers the complete documentation for its relevant content.

Each chapter is made up from several document types e.g. 1065-0100-0001. The documentation type number is the third and fourth digit.

Examples of document types are as follows.

40 - Chapter **Preface**

45 - **Description**

55 - **Drawing**

65 - Maintenance **Work Card**

70 - Tool **Plate**

72 - Spare part **Plate**

The following 5-8 digits are the Identification (ID) number of the document in the relevant chapter of a certain document type.

The last 4 digits form the edition number.

Example:

2272-0420-0028

22	72	0420	0028
Chapter	Document Type	ID Number	Edition

Data Designations

Designations in a work card starting with a "T" refer to the information given on the data sheets inserted in the beginning of the relevant work card.

Referring to This Manual

When contacting MAN Diesel & Turbo referring to this instruction manual, please include title, edition no., and, if relevant, page no.

Example:

Piston - 2265-0401-0028 - Page 2

For a specific engine, also specify the name of the vessel, IMO number, engine number and engine builder.

Example:

Bow Firda - 9250751 - 052024 - MAN Diesel & Turbo - 2272-0420-0028

Ordering of Spare Parts

When ordering/requesting spare parts for any product by MAN Diesel & Turbo, add the following information to ensure delivery of correct parts for the specific engine: Document ID, Part Number, quantity and description. Notice that a part number can also be a sensor code identification number (e.g. PT 8501) as described in *chapter 70 – Control System*.

Example: Bow Firda - 9250751 - 052024 - MAN Diesel & Turbo - 2272-0420-0028-017 - 8 pcs - (Piston ring no. 1)

NB! Item no. “000” orders the complete assembly as displayed on the plate.

Service Letters

In order to ensure up-to-date manuals on operation and maintenance, MAN Diesel & Turbo and its licensees, regularly send out service letters, containing first-hand information regarding accumulated service experience.

Service letters can be accessed via the link below:

<http://marine.man.eu/two-stroke/service-letters>

Service letters can either deal with specific product types or contain general instructions and recommendations for all products in a product range, and are used as a reference when we prepare up-dated instruction manual editions.

Therefore, since new service letters could be of great importance to the operation of the plant, we recommend that the engine staff file them to supplement the relevant chapters of this manual or add them to chapter 88 - *Service Info*.

Internet Services

MAN Diesel & Turbo is always working on new and better ways to provide up-to-date information and documentation for its customers. Visit our homepage for further details about the current services offered and how to access these.

Additional Information

Further details may be found in:

- Sub-supplier manuals
- Plant Installation drawings

- Shop trial report
- Sea trial report
- EIAPP Technical File

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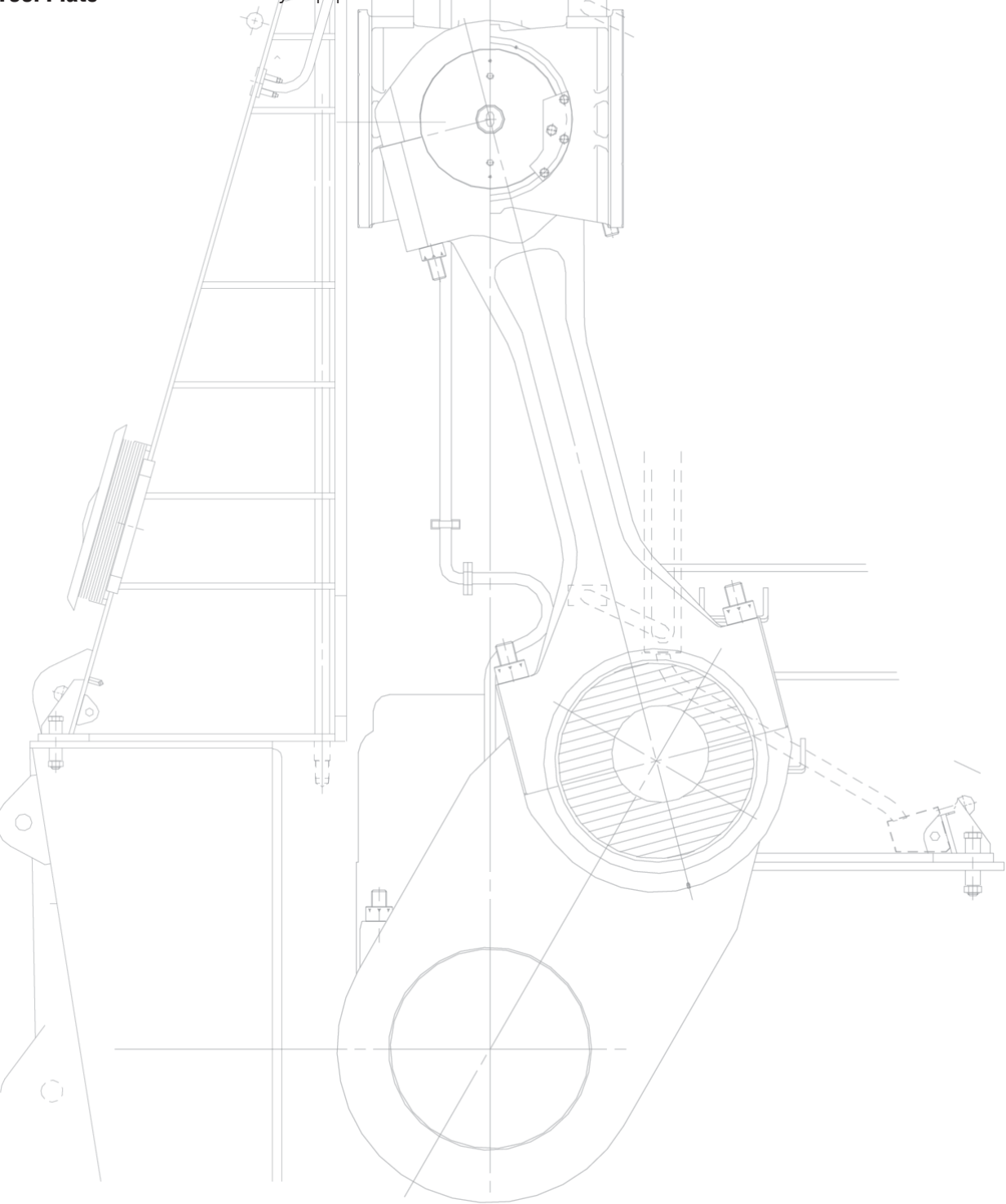
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This chapter of the instruction book is intended to provide the user with a table of contents, which shows where the various instructions are located.

Introduction

In addition this chapter is intended to provide the user with a guide on how to use the instruction book as well as a description of the logical structure of the instruction book.

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Description	Safety Precautions	0545-0100-0008
	Safety Precautions Hydraulic Tools	0545-0110-0001
Tool Plate	Safety Equipment.....	0570-0100-0002



Safety

This chapter of the instruction book is intended to provide the user with relevant details of all the safety precautions which must be observed during operation and maintenance of the engine in order to obtain safe and reliable conditions.

Safety

Preface

0540-0100-0002

General

Correct operation and maintenance, which is the aim of this book, are crucial points for obtaining optimum safety in the engine room. The general measures mentioned here should therefore be routine practice for the entire engine crew.

WARNING

Maintenance

- Read and follow all instructions given in work cards.
- Only use original spare parts.
- Only use appropriate tools.
- Always inspect the engine when maintenance work is completed.

Engine Room Staff

Operation and maintenance of MAN B&W engines is to be carried out exclusively by qualified professional personnel.



Minimum personal safety equipment requirements:

1. Safety shoes
2. Hearing protection
3. Boiler suit or other similar protective wear

Special Dangers



A number of situations may lead to risk of serious injury to the body. The following recommendations must always be observed:

- Keep clear of the space below a crane with load.
- Before opening of cocks, always observe which way liquids, gases or flames will move, and keep clear.
- Dismantling of parts may cause the release of springs.
- Removal of plugs may cause the release of pressurized fluids or gasses.
- Do not stand near turbochargers in case of any abnormal running.
- Do not stand near crankcase doors or relief valves – nor in corridors near doors to the engine room – if an alarm sets off for oil mist, high lube oil temperature, no piston cooling oil flow, or scavenge box fire.

See description 6645-0290 and 6645-0300.

Turning Gear

Before engaging the turning gear, ensure that the starting air supply is shut off, the main starting and slow turning valves are blocked, and that the indicator cocks are open.

When the turning gear is engaged, check that the indicator lamp “Turning gear in” has switched on.

The turning gear remote control is a critical device and should always be kept in optimal working condition. Any fault in the device or cable must be rectified before use.

When operating the turning gear it is important to note the following:

The turning gear must be operated by the remote control and only by the person working on the engine.

Warnings must be given before each turning. Operation of the turning gear from the switchboard must not take place while maintenance work is in progress inside the engine.

Block the switch or place a “Do not touch” sign.

Entering the Crankcase, Cylinder Liner or Scavenge Air Receiver



Always ensure that the turning gear is engaged and the brake is active, to prevent external forces or unbalance of the crankshaft from turning the crankshaft.

Check that the starting air supply to the engine and the starting air distributor is shut off and that the main starting valve is locked.

Before entering the scavenge air receiver, shut off and block the auxiliary blower main starting panel.

In case of oil mist alarm, precautions must be taken before opening the doors to the crankcase (*see description 6645-0300*). Before entering, ventilate the crankcase for about 30 minutes after stopping the engine.

Work inside the crankcase requires the use of safety harness and fall arrester equipment.

Work inside the crankcase is as minimum a two-man job, and good communication must be maintained at all times.

The turning gear must always be operated exclusively by the person(s) who enters the crankcase, cylinder liner or scavenge air receiver.

Cleanliness

The engine and engine room should always be kept clean and tidy.

Oily rags must never be left around the engine room spaces as they are highly flammable and slippery.

Remove any oil spill immediately.

If there is a risk of grit or sand blowing into the engine room, stop the ventilation and close the ventilating ducts, skylights and engine room doors.

Welding or other work that causes spreading of grit and/or swarf must not be carried out near the engine unless it is closed or protected and the turbocharger air intake filters are covered.

The exterior of the engine should be kept clean, and the paintwork maintained, so that leakages can be easily detected.

Fire



Keep the areas around the relief valves free of oil, grease, etc. to prevent the risk of fire caused by the emitted hot air/gas if the relief valves open.

Do not weld or use naked lights in the engine room until it has been ascertained that no explosive gases, vapour or liquids are present.

If the crankcase is opened before the engine has cooled down, welding and the use of naked flames will result in the risk of explosions and fire. The same applies to inspection of oil tanks and of the spaces below the floor.

Attention is furthermore drawn to the danger of fire when using paint and solvents with a low flash point. Porous insulating material, soaked with oil from leakages, is flammable and should be renewed.

See also description 6645-0290, -0300 and 'Sealing Materials' in this description.

Order/Tidiness

Hand tools should be securely fastened and placed on easily accessible tool panels. Special tools should be securely fastened close to the area of use in the engine room.

Do not store engine parts on engine galleries while the engine is running.

Do not leave major objects unfastened, and keep floor and passages clear at all times.

Spares

Large spare parts should, as far as possible, be placed near the area of use, well secured and accessible by crane.

All spares should be protected against corrosion and mechanical damage. The stock should be checked at intervals and replenished in good time.

Lighting

Ample working light should be permanently installed at appropriate places in the engine room spaces, and portable working light should be obtainable everywhere. 24v safety lamps must be available for use inside the engine.

Harmful Materials

Always follow the manufacturer's specific instructions, i.e. the material safety data sheet (MSDS).

Use protective gloves, goggles, breathing mask and any other recommended protective gear stated in the material safety data sheet.

Read the material safety data sheet regarding first aid measures in the event of skin contact.

When handling harmful materials it is important to ensure proper ventilation and shielding if needed.

In the event of leaks or spillage, spread binding agents immediately. Dispose of the binding agents according to the material safety data sheet.

Lifting Precautions

Plan lifting of engine components through all steps of the lifting procedure.

Use tackles between engine room crane and components when lifting loads below 500 kg.

Make sure lifting attachments are tightened into full contact with the component to be lifted.

All contact surfaces and threads must be clean and free of preservation.

Only use designated lifting points, see Instruction Manual for guidance.

Never exceed the lowest safe working load (SWL) of the lifting equipment in the lifting chain.

Keep lifting equipment clear of sharp edges.

Make sure to attach the load correctly on the crane hook.

Always keep clear of the space below a crane carrying a load.

Working Air

Use of working air requires safety goggles and gloves.

Avoid blowing pressurised air directly at any part of the body, especially exposed skin, eyes and ears.

Sealing Materials

Use gloves made of neoprene or PVC when removing O-rings and other rubber/plastic-based sealing materials which have been subjected to abnormally high temperatures.

Hot Surfaces

Beware of hot surfaces and always use gloves.

Alarms

It is important that all alarms lead to prompt investigation and remedy of the error. No alarm is insignificant. The most serious alarms are equipped with slow-down and/or shut-down functions. It is therefore important that all engine operation personnel are familiar with and well trained in the use and importance of the alarm system.

Subsuppliers and External Equipment

Check the special instructions concerning subsupplier delivery and external equipment for specific warnings!

Safety Notes



This warning is used when an operation, procedure, or use may cause personal injury or loss of life.



This warning is used when an operation, procedure, or use may cause a latently dangerous state of personal injury or loss of life.



This warning is used when an operation, procedure, or use may cause damage to or destruction of equipment and a injury.



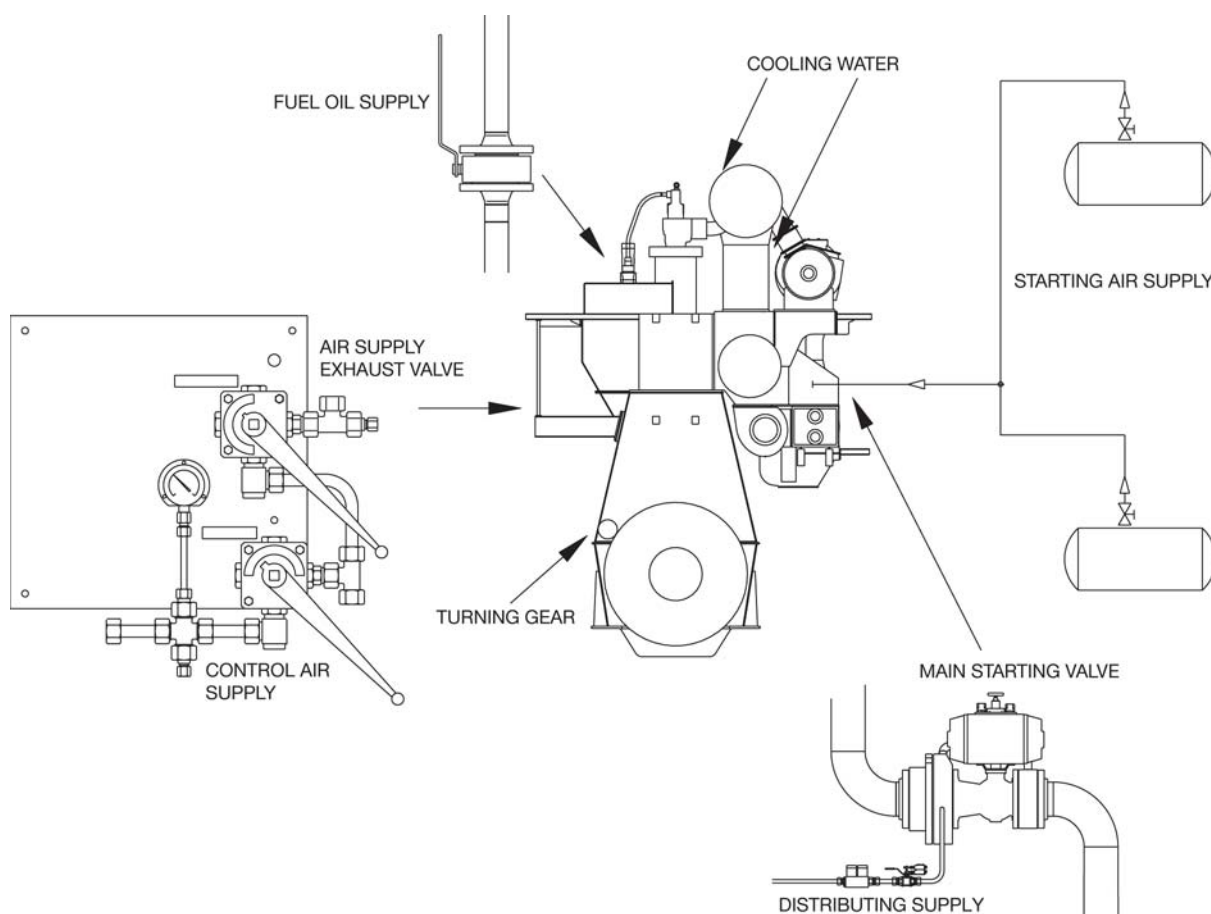
This warning is used when an operation, procedure, or use may cause damage to or destruction of equipment.

Safety Precautions at Maintenance

Before carrying out maintenance work, stop and block the engine according to the safety precautions given on the specific work card.

Other safety precautions than listed below may apply.

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off safety air supply - Not ME Engines
☐	Shut off control air supply
☐	Shut off air supply to exhaust valve - Only with stopped lub. oil pumps
☐	Engage turning gear
☐	Shut off cooling water
☐	Shut off fuel oil
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply
☐	Shut off and block the auxiliary blowers



The drawing gives the approximate location of the valves concerned.

0545-0100-0008C02

Data Sheet Signs

Data sheets may include warning signs for special dangers that could arise in connection with the maintenance procedures.

Warning signs		Mandatory action signs	
General warning sign		General mandatory action sign	
Explosive material		Wear ear protection	
Drop (fall)		Wear eye protection	
Slippery surface		Wear safety footwear	
Electricity		Wear protective gloves	
Overhead load		Wear face shield	
Hot surface		Wear head protection	
Crushing		Wear mask	
Overhead obstacle		Wear respiratory protection	
Flammable		Wear safety harness	
Crushing of hands		Disconnect before carrying out maintenance	
Pressurised cylinder		Wear antistatic footwear	

Warning signs		Mandatory action signs	
Pressurised device		Use gas detector	
Falling objects			



In case of malfunctioning hydraulic jacks or hoses

- Always keep clear of area above the pressurised hydraulic jack during use.
Broken studs or malfunctioning jack can eject !
- Bursting hydraulic hose can eject oil into the skin!
Always inspect the hose assembly before use.
Defective or damaged hose assemblies **must** be replaced and discarded !



Keep the work area clear



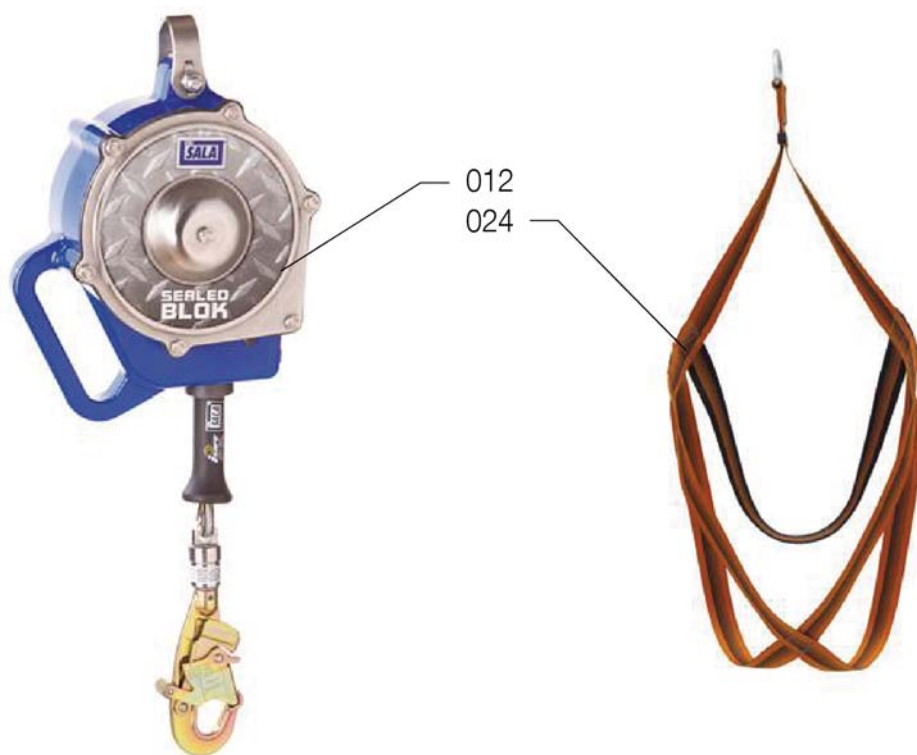
- Whipping hose ends poses a risk !
Verify correct engagement of couplings before applying hydraulic pressure
- Leaking hydraulic oil can pose a risk in case of skin contact.
Always use goggles and oil resistant gloves when working with hydraulic oil.



First Aid

If a fluid injection occurs, it must always be treated as a medical emergency!

For operation of hydraulic tools,
see description 7645-0100 and work card 7665-0101.



Safety Equipment

Plate
0570-0100-0002

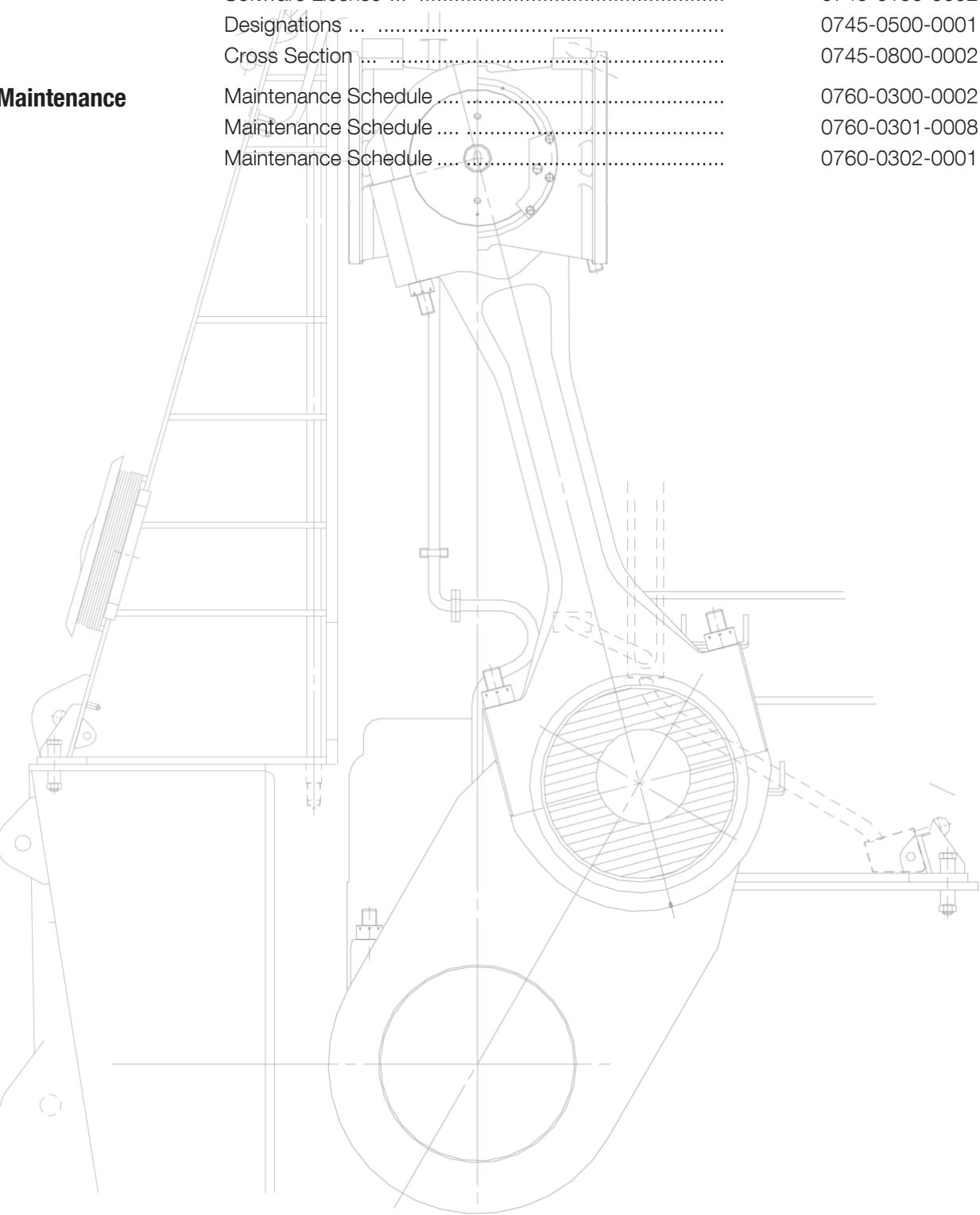
Item No.	Qty	Item Designation
012	-	Fall arrest block
024	-	Rescue harness



Preface Chapter
Description

Maintenance

General Description	0740-0100-0002
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Maintenance Schedule	0760-0301-0008
Maintenance Schedule	0760-0302-0001



General Description

This chapter of the instruction book is intended to provide the user with information regarding the software license which applies to this instruction book. In addition, various naming conventions (designations) used in the instruction book are explained.

1 The fuel optimised engine

The ever valid requirement of ship operators is to obtain the lowest total operational costs, and especially the lowest possible specific fuel oil consumption at any load, and under the prevailing operating conditions. Two of the most important factors in adjusting the engine to match the prevailing conditions is to control the fuel injection and exhaust valve activation.

A system with electronically controlled hydraulic activation provides the required flexibility, and such systems form the core of the engine control system.

In the chapter prefaces you can read more about the specific content of each chapter, for instance

See preface 4240-0100 - Fuel System

See preface 4540-0100 - Hydraulics

See preface 6640-0100 - Operation

2 ME Concept

The ME engine concept consists of a hydraulic-mechanical system for activation of the fuel oil injection and the exhaust valves. The actuators are electronically controlled by a number of control units forming the complete engine control system.

MAN Diesel & Turbo has specifically developed both the hardware and the software in-house, in order to obtain an integrated solution for the engine control system.

The fuel oil pressure booster consists of a simple plunger powered by a hydraulic piston activated by oil pressure. The oil pressure is controlled by an electronically controlled proportional valve.

The exhaust valve is opened hydraulically by means of a two-stage exhaust valve actuator activated by the control oil from an electronically controlled proportional valve. The exhaust valves are closed by the 'air spring'.

In the hydraulic system, the system lubricating oil is used as the medium. It is filtered and pressurised by a hydraulic power supply unit mounted on the engine or placed in the engine room.

The starting valves are opened pneumatically by electronically controlled 'On/Off' valves, which make it possible to dispense with the mechanically activated starting air distributor.

By electronic control of the above valves according to the measured instantaneous crankshaft position, the engine control system fully controls the combustion process.

System flexibility is obtained by means of different 'engine running modes', which are selected either automatically, depending on the operating conditions, or manually by the operator to meet specific goals. The basic running mode is 'fuel economy mode' to comply with IMO NO_x emission limitation.

3 Abbreviations

On the abbreviation list below there may be abbreviations which are not used in your system.

Abbreviation	Description
ACU	Auxiliary control unit
ACOS	Automated controlled oil switch
ALS	Alpha cylinder lubrication system
BN	Base number
BOG	Boil off gas
CCU	Cylinder control unit
CNG	Compressed natural gas
CoCoS EDS	Computer controlled surveillance, engine diagnostics system
CPC	Cylinder compression pressure
CWCU	Cooling water control unit
dB(A)	Decibel
DFO	Diesel fuel oil
ECS	Engine control system
ECU	Engine control unit
EGB	Exhaust gas by-pass
EICU	Engine interface control unit
ELFI	Electronic fuel injection
ELGI	Electronic gas injection valve
ELVA	Electronic valve actuation
ELWI	Electronic window valve
ESC	Engine side console
ETU	Exhaust (valve) timing unit
FGIV	Fuel gas injection valve
FGVT	Fuel gas valve train
FGS	Fuel gas supply
FGSS	Fuel gas supply system
FIVA	Fuel injection valve actuator
FO	Fuel oil
FOPB	Fuel oil pressure booster
FQA	Fuel quality adjustment
FRF	Feed rate factor
GACU	Gas auxiliary control unit, <i>same as SACU</i>
GCSU	Gas cylinder safety unit, <i>same as SCSU</i>
GCU	Gas combustion unit
GPCU	Gas plant control unit, <i>same as SPCU</i>
GPSU	Gas plant safety unit, <i>same as SPSU</i>
GRS	Grove recessed surface
GVT	Gas valve train, <i>same as FGVT</i>

Abbreviation	Description
GVU	Gas valve unit, <i>same as FGVT</i>
GW	Glycol / water
HC	Hydro carbon
HCB	Hydraulic control block
HCU	Hydraulic cylinder unit
HFO	Heavy fuel oil
HMI	Human machine interface
HPS	Hydraulic power supply
INJ	Injection
LCV	Lower calorific value
LDCL	Temperature load dependent cylinder liner cooling water system
LEL	Lower explosion limit
LNG	Liquified natural gas
LOP	Local operating panel
LPG	Liquified propane gas
LPS	Low pressure supply
MCR	Maximum continuous rating
MDO	Marine diesel oil
M/E	Main engine
MGV	Master gas valve
MOP	Main operating panel
MPC	Multi purpose controller
N ₂	Nitrogen
NC	Normally closed
NO	Normally opened
O ₂	Oxygen
PMI	Pressure measuring instrument
PSV	Pressure safety valve
PTO	Power take out
RCS	Remote control system
SACU	Second fuel auxiliary control unit
SAV	Starting air valve
SCSU	Second fuel cylinder safety unit
SCU	Scavenge control unit
SDF	Specified dual fuel operation
SL	Service letter
SPCU	Second fuel plant control unit
SPSU	Second fuel plant safety unit

General Description

Description
0745-0100-0001

Abbreviation	Description
VT	Variable turbocharger
VTI	Variable turbocharger inlet
WHR	Waste heat recovery



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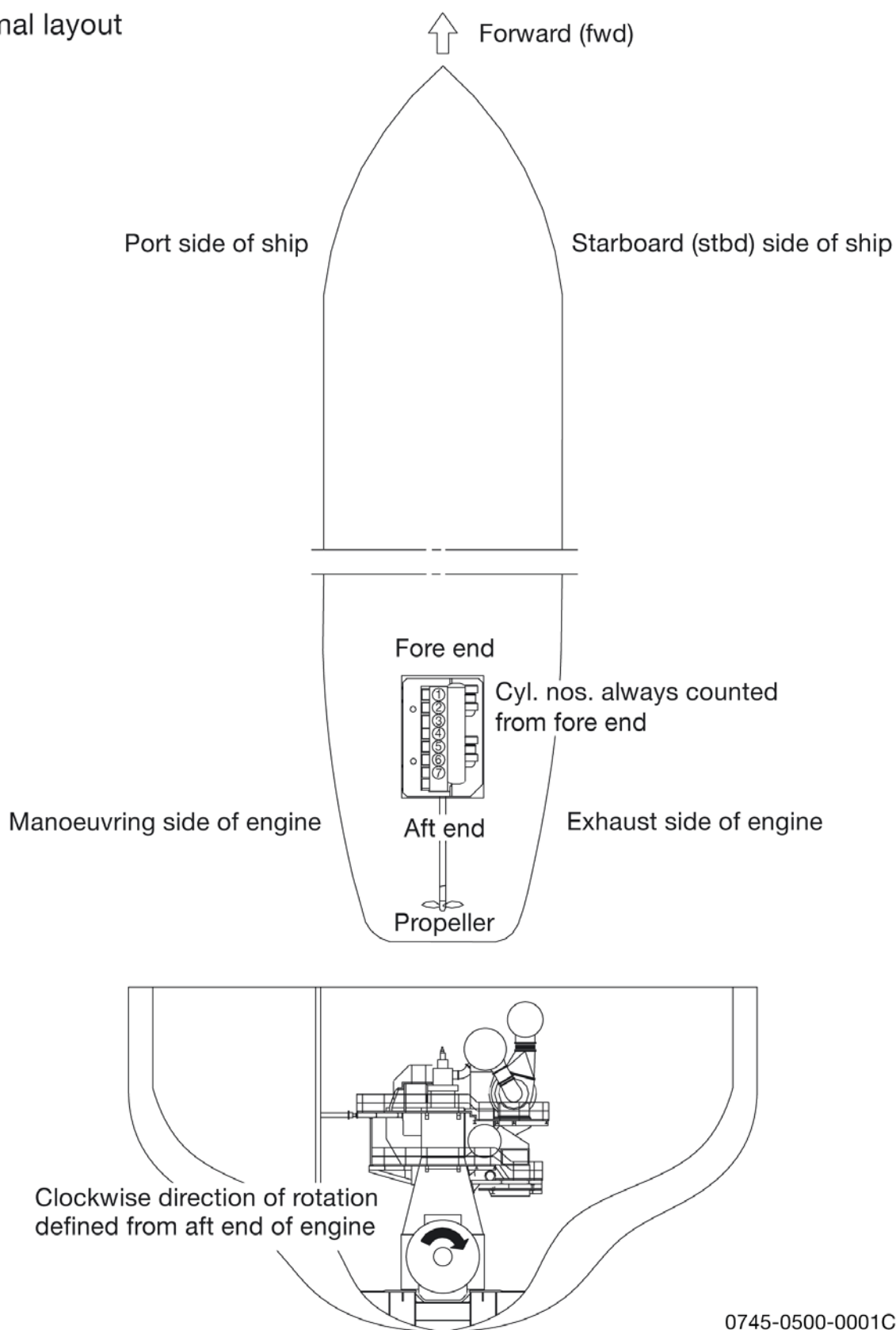
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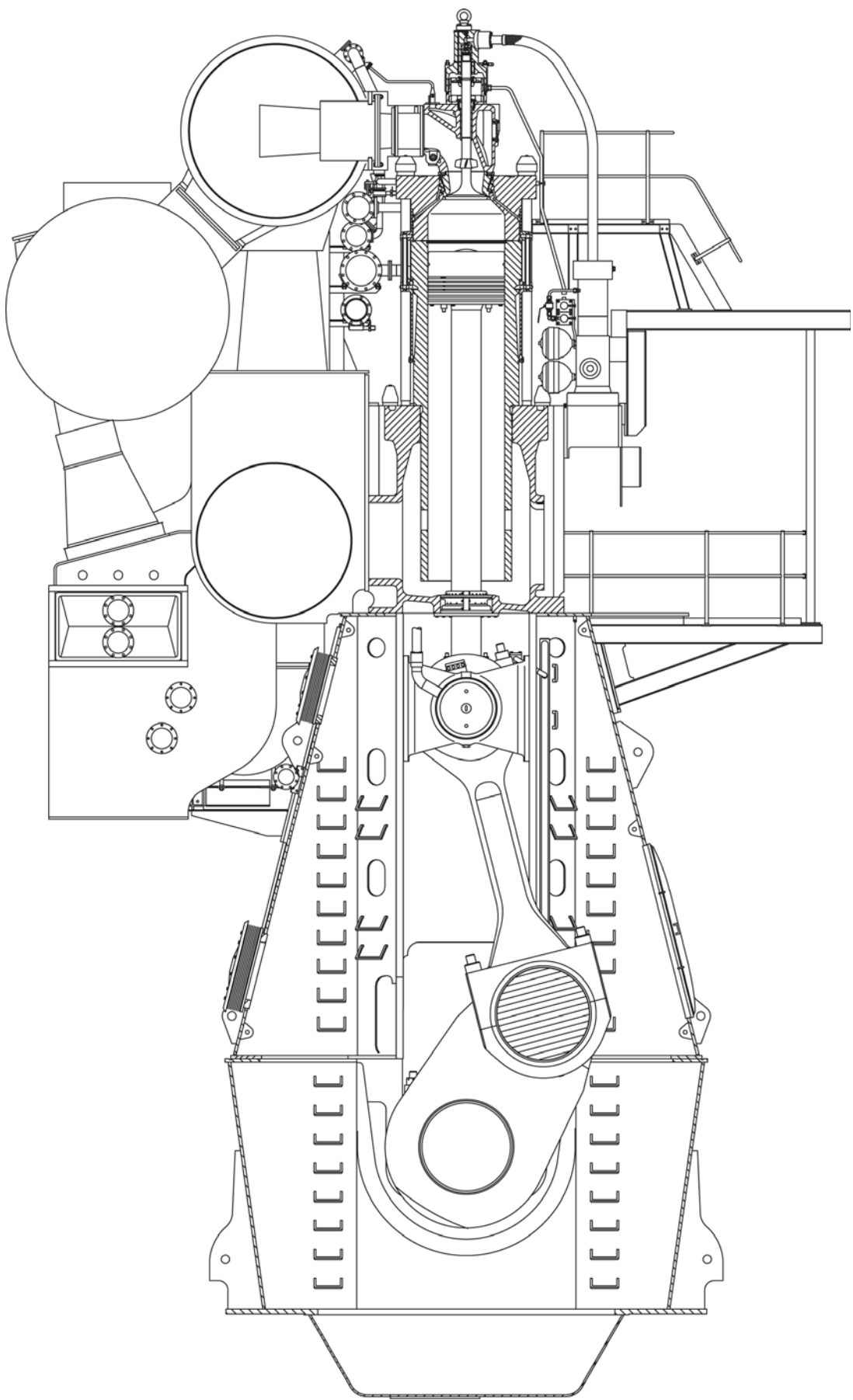
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Normal layout



Cross Section

Description
0745-0800-0002



General

The Checking and Maintenance Schedules indicate the intervals at which it is deemed appropriate to inspect the individual components of the engine and to carry out overhauls, if necessary, based on the engine condition or a criterion of time.

NOTICE

The Checking and Maintenance Schedules are intended for use with multiple engine types. Therefore the Checking and Maintenance Schedules may include components which are not installed on a specific plant/vessel. In such cases the »extra« components shown in the schedules are to be ignored.

The stated **Regular checks** or **Service interval** are intended primarily as a guide, as differences in the actual service conditions, the quality of the fuel oil or lubricating oil, the treatment of cooling water, etc., will decisively influence the actual service results, and thus the intervals between necessary overhauling.

Design modifications may necessitate a revision of the instructions, in which case the revised instructions and changed overhauling intervals, if any, will apply and supersede those originally issued (*see e.g. our Service Letters*).

In addition to the checking and overhauling intervals stated in this schedule, please note that the periodical survey requirements of the classification society may require additional checks, and reference is made to be carried out. For further information reference is made to the classification society.

The Checking and Maintenance Schedules consist of two sets of work procedures:

Duties During Operation

Minor work and inspection procedures which are carried out on a regular basis during the normal operation of the engine. Note that operation also includes the situation where the engine is routinely stopped, e.g. during stay in port.

Most duties during operation, with the exception of port inspection, can be carried out without entering into or dismantling the engine. Typically no tools or just basic hand tools are required for the procedures.

Major Overhaul

Major work and overhaul procedures which are carried out after a fixed number of running hours, except for situations where observations require a procedure to be carried out before the fixed number of running hours is reached.

Most major overhaul procedures require the engine to be shut down, as entering into the engine or dismantling engine components is involved.

Additionally, most major overhaul procedures require the supplies of fuel oil, lubricating oil, compressed air and/or cooling water to be shut off. Typically specialised tools in addition to hand tools and lifting equipment are required for the procedures.

The procedures are divided into five categories:

Time-based condition checking procedures are marked with a **C**, under the heading **Regular checks** or **Service interval**, deal with the service condition of a number of engine components, and form the basis for estimating whether further overhauling is necessary. In a number of cases the condition checking procedures refer to the **operation chapter** of the instruction book, in which more detailed descriptions and working procedures can be found.

Condition-based overhauling procedures are marked with an **O** under the heading **Regular checks** or **Service interval** under the heading "Refer to" (column P), a reference to additional information is stated.

This procedure number normally refers to one of the above condition checking procedures which form the basis of the overhaul. For this reason, the intervals stated are for guidance only.

Time-based overhauling procedures, also marked with an **O**, under the headings **Regular checks** or **Service interval** or **Based on observations**, are the procedures where an actual basis for estimation is lacking. It is recommended, therefore, to carry out these procedures at the overhauling intervals stated as a basis.

The letters **O** or **C** in **Based on observations** (column B), indicate that special service conditions may make checking or overhauling necessary beyond the actual standard schedules indicated.

Initial checking procedures (Major Overhaul only) marked with a **C**, under the heading **Check new/overhauled parts at 500, 1000 and 1500 hours** (column H), deal with initial checks that must be carried out on a new engine, or when parts have been replaced.

After the three initial checks have been completed, checks need only be carried out as per heading **Regular checks** or **Service interval**.

When using **electronic maintenance planning systems**, special attention should be paid to all initial checking procedures, as handling of such procedures often can not be done automatically. Instead, such procedures must be handled manually.

Initial adjustment procedures (Major Overhaul only), marked with an **A**, under the heading **Check new/overhauled parts at 500, 1000 and 1500 hours** (column H), deal with initial adjustment that must be carried out on a new engine, or when parts have been replaced.

After the three initial adjustments have been completed, adjustments need only be carried out as per headings **Regular checks** or **Service interval**.

When using **electronic maintenance planning systems**, special attention should be paid to all initial adjustment procedures, as handling of such procedures often can not be done automatically. Instead such procedures must be handled manually.

NOTICE

Special attention should be paid to the chain tightener, which must be adjusted three times (at 500, 1000 and 1500 hours of operation) on a new engine, or when chains or chain wheels have been replaced.

V : See description A : Adjustment to be carried out H : Check new/overhauled parts at 500, 1000 and 1500 hours			M : See maker's instruction O : Overhaul to be carried out C : Check the condition			R : Parts to be replaced B : Based on observations P : refer to									
No.	Procedure	H	Service interval (x1000 hours of operation)										B	P	
			1	2	4	6	8	12	16	24	32				
10	Structural Parts														
1065-0101	Crankcase Relief Valve					C						O	M		
1065-0201	Holding Down and End Chock Bolts	C				C									
1065-0301	Stay Bolts	C									C				
1065-0401	Crankcase Oil Outlet										C, R	R			
1065-0501	Top Bracings	C				C						O			
	Crankcase					C ¹									
	Counter Weights										C, O ⁵	C, O ⁵			
14	Driving Gear														
1465-0101	Reciprocating Parts	C										C, O			
1465-0201	Crosshead	C									O ^{2,3}	C, O	V ⁴		
1465-0301	Connecting Rod											O			
1465-0401	Chains	C				C						R	V		
1465-0501	Chain Tightener	C, A				C, A						A			
	Chain wheel, spray nozzles and guide bars	C				C						R			
Comments :															
1 : Check for loose nuts and bearing material fragments.															
2 : Overhaul may be omitted if Bearing Wear Monitoring equipment is installed.															
3 : Overhaul at 32,000 hours OR when the piston has been dismantled three times.															
4 : See description 2545-0100 and service letter regarding bearing wear monitoring.															
5 : Check and re-tighten, if installed.															

V : See description A : Adjustment to be carried out H : Check new/overhauled parts at 500, 1000 and 1500 hours			M : See maker's instruction O : Overhaul to be carried out C : Check the condition										R : Parts to be replaced B : Based on observations P : refer to			
No.	Procedure	H	Service interval (x1000 hours of operation)										B	P		
			1	2	4	6	8	12	16	24	32					
18	Vibration Control															
1865-0101	Axial Vibration Damper					C							O			
1865-0201	Moment Compensator	C		C									C, A			
1865-0301	Torsional Vibration Damper	C				C								M		
22	Cylinder Unit															
2265-0101	Exhaust Valve High-Pressure Pipe												O			
2265-0201	Exhaust Valve				C ¹						C, O	O				
2265-0301	Cylinder Cover				C ¹						C ²	O				
	Indicator Cock											O				
2265-0401	Piston									C, O						
2265-0501	Piston Rod Stuffing Box									C, O		O				
2265-0601	Cylinder Liner									C, O		O, R				
25	Bearings															
2565-0201	Crosshead Bearing	C ³				C ³						O ^{4, 5}	C, O	V		
2565-0301	Crankpin Bearing	C ³				C ³						O ^{4, 5}	C, O	V		
2565-0401	Main Bearing	C ³				C ³							C, O			
2565-0501	Journal Bearing	C ³				C ³							C, O			
2565-0601	Thrust Bearing	C											C, O			
2565-0701	Guide Bearing	C											C, O			
Comments :																
1 : Initial check only																
2 : Check whenever exhaust valve is removed																
3 : Bearings should only be opened if bearing material fragments fall out or top clearance is outside allowable limits.																
4 : Overhaul may be omitted if Bearing Wear Monitoring equipment is installed.																
5 : Overhaul at 32,000 hours OR when the piston has been dismantled three times.																

V : See description A : Adjustment to be carried out H : Check new/overhauled parts at 500, 1000 and 1500 hours			M : See maker's instruction O : Overhaul to be carried out C : Check the condition			R : Parts to be replaced B : Based on observations P : refer to									
No.	Procedure	H	Service interval (x1000 hours of operation)										B	P	
			1	2	4	6	8	12	16	24	32				
30	Lubricating Oil System														
3065-0601	Cylinder Lubricator										C, O	A	V, M		
	Cylinder Lubricator Level Sensor			C								O	V, M		
3065-0651	Cylinder Lubrication Non-Return Valve											O			
	System Lubricating Oil Bottom Tank										O¹				
34	Compressed Air System														
3465-0201	Starting Air Valve							C, O							
42	Fuel System														
4265-0101	Fuel Oil High-Pressure Pipe											O			
4265-0201	Fuel Valve						C, O								
	Fuel Nozzle						C		R			R			
4265-0301	Fuel Valve Spindle Guide						C		R						
4265-0401	Fuel Valve Non-Return Valve						O								
4265-0501	Fuel Oil Pressure Booster										O	O			
4265-0601	Fuel Oil Pressure Booster Top Cover											O			
4265-0701	Fuel Oil Pressure Booster Suction Valve						C, O					O			
4265-1301	Fuel System Shock Absorber						C, O					O			
Comments :															
1 : Empty and clean tank.															

V : See description A : Adjustment to be carried out H : Check new/overhauled parts at 500, 1000 and 1500 hours			M : See maker's instruction O : Overhaul to be carried out C : Check the condition			R : Parts to be replaced B : Based on observations P : refer to									
No.	Procedure	H	Service interval (x1000 hours of operation)												
			1	2	4	6	8	12	16	24	32	B	P		
45	Hydraulics														
4565-0101	Exhaust Valve Actuator											O			
	Valve Actuator Safety Valve							C, A							
4565-0201	Hydraulic Oil Pump											C		R	M
4565-0301	Hydraulic System											C		O	
4565-0401	Hydraulic Cylinder Unit													C, O	
4565-0501	Accumulator			C								O		A, O	
4565-0551	Control Valves											C		R	M
4565-0601	Hydraulic Power Supply Unit													O	
4565-1001	Hydraulic System Leakage Test					C								O	V
	Hydraulic Oil Fine Filter												C	O	M
	Hydraulic High-Pressure Hose													R ¹	M
	Rubber Compensator Before Hydraulic Pump											R ¹		R ¹	M
4565-1201	Hydraulic Power Supply Gear Box	C						C						R	V
Comments :															
1 : 32,000 hours or max. 5 years (Including shelf-life).															

V : See description A : Adjustment to be carried out H : Check new/overhauled parts at 500, 1000 and 1500 hours		M : See maker's instruction O : Overhaul to be carried out C : Check the condition		R : Parts to be replaced B : Based on observations P : refer to									
No.	Procedure	H	1	2	4	6	8	12	16	24	32	B	P
47	Electronics												
4765-0101	Pressure Sensors					C						R, A	V, M
4765-0151	Pressure Controllers					C						R, A	V, M
4765-0201	Temperature Sensors					C						R, A	V, M
4765-0251	Temperature Controller					C						R, A	V, M
4765-0301	Level Sensors					C						R, A	V, M
4765-0401	Proximity Sensors					C						R, A	V, M
4765-0601	Displacement Sensors					C						R, A	V, M
4765-1001	Cable Connections	C					C					O	V
4765-1201	Flow Sensors					C						R, O	V, M
4765-1901	Multi-Purpose Controller					C						R	V ¹
	Electronic Boxes					C						O	V
	Thrust Bearing Alarm System						C					O	
	Turning Gear Switch						C					A	M
Comments :													
1 : See Description 6645-0200.													

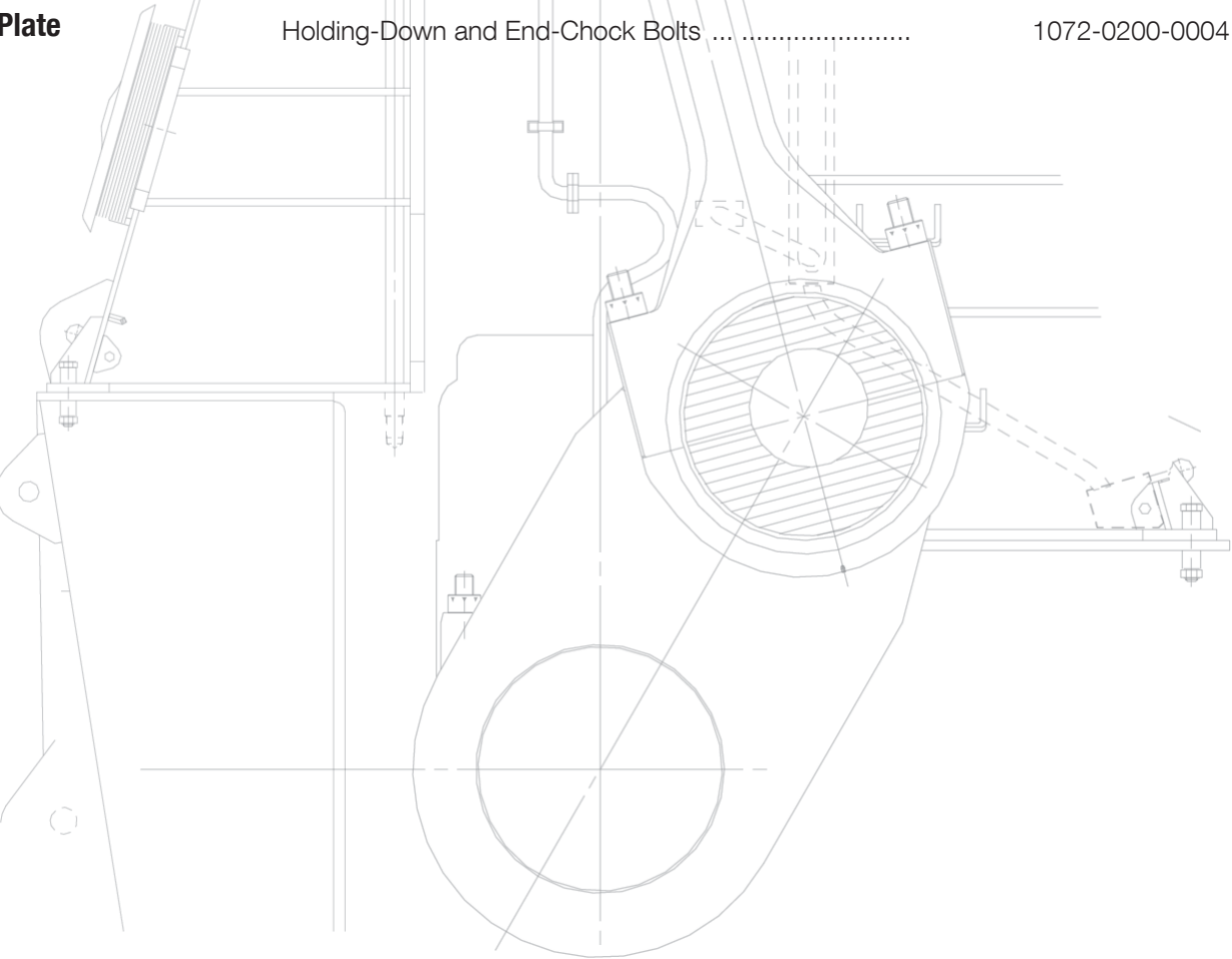
V : See description A : Adjustment to be carried out H : Check new/overhauled parts at 500, 1000 and 1500 hours		H	M : See maker's instruction O : Overhaul to be carried out C : Check the condition								R : Parts to be replaced B : Based on observations P : refer to				
No.	Procedure		Service interval (x1000 hours of operation)								16	24	32	B	P
54	Exhaust Gas and Scavenge Air System														
5465-0101	Air Cooler Element													C, O	V
5465-0201	Water Mist Catcher													C, O	
5465-0301	Axiliary Blower Non-Return Valve													O	
5465-0401	Scavenge Air Cooler Non-Return Valve													O	
5465-0501	Auxiliary Blower													C, O	
5465-0601	Scavenge Air Receiver Safety Valve							C						O	
5465-0701	Turbocharger							C						C, O	V, M
5465-0801	Gas By-Pass Valve							C						O	
5465-0901	Exhaust Receiver							C ¹						O	
56	Emission Control														
5665-0201	EGR Water Mist Catcher							C						C, O	
5665-0301	EGR Cooler							C						C, O	
5665-0401	EGR Scrubber							C						C, O	
5665-0501	EGR Blower							C		O ²			O ³	C, O	M
5665-1001	EGR Valves							C						C, O	
5665-1501	EGR Measuring System							C						C, O	
	EGR Drainer							C						C, O	M
	EGR Pipes							C						C, O	
	EGR Mixing Chamber							C						C, O	
	EGR Blower Suction Chamber							C						C, O	
Comments :															
1 : Check protective grid before turbocharger(s).															
2 : Small overhaul (↗service 1↘) as per maker's instructions. NOTE : 12.000 running hours of engine, NOT running hours of EGR blower.															
3 : Large overhaul (↗service 2↘) as per maker's instructions. NOTE : 32.000 running hours of EGR blower, NOT running hours of engine.															

V : See description A : Adjustment to be carried out H : Check new/overhauled parts at 500, 1000 and 1500 hours			M : See maker's instruction O : Overhaul to be carried out C : Check the condition			R : Parts to be replaced B : Based on observations P : refer to									
No.	Procedure	H	Service interval (x1000 hours of operation)										B	P	
			1	2	4	6	8	12	16	24	32				
66	Operation														
6665-0101	Exhaust Valve Special Running											O			
70	Control System														
7065-1101	Angle Encoder				C							C, A	V, M		
7065-1201	Tacho Sensor				C							C, A	V, M		
7065-1501	MPC Unit				C										
76	Tools														
7665-0101	Hydraulic Tools					C						O	M		
7665-0201	Standard Tightening Torques														
7665-0301	Torque Spanner														
7665-0401	Tighening Gauge														
7665-0501	Screws and Nuts														
7665-0601	Working Platforms														
7665-0701	Hydraulic Nut														
7665-0801	Hydraulic Ring														
7665-0901	Lubricating Procedure														
Comments :															

A : Adjustment to be carried out O : Overhaul to be carried out V : See Descriptions		M : See maker's instruction B : Based on observations C : Check the condition		R : Parts to be replaced W : Wash or clean P : Refer to			
		Regular Checks					
No.	Procedure	Daily	Weekly	Monthly	Annually	B	P
10	Structural Parts						
	No duties during operation						
14	Driving Gear						
	No duties during operation						
18	Vibration Control						
1865-0101	Axial Vibration Damper, Electronic Monitor	C					
22	Cylinder Unit						
2265-0401	Piston			C ¹		O	
2265-0601	Cylinder Liner			C ¹		O, R	
25	Bearings						
	No duties during operation						
30	Lubricating Oil System						
3065-0601	Cylinder Lubricator	C ⁵					
	Turbocharger lubricating oil water content		C ²				
	System lubricating oil water content		C				
	Lubricating oil filters, Δp	C				W, R ⁴	
	Oil flow sight glasses	C					
34	Compressed Air System						
	Compressed air tanks	C ³					
	Main starting valve, pilot valves air filters				W, R ⁴		
42	Fuel System						
	Fuel oil water content		C				
	Fuel oil filters, Δp	C				W, R ⁴	
	Fuel oil tanks	C ³					
45	Hydraulics						
	Hydraulic oil filters, Δp		C			W, R ⁴	
	Hydraulic oil water content		C ⁶				
Comments : 1 : Inspection through scavenge ports. 2 : Only if separate turbocharger oil system. 3 : Drain water from tanks. 4 : Clean or replace filters as necessary. 5 : Check indicator lamp / Flow indicator. 6 : Only if separate hydraulic oil system.							

A : Adjustment to be carried out O : Overhaul to be carried out V : See Descriptions		M : See maker's instruction B : Based on observations C : Check the condition		R : Parts to be replaced W: Wash or clean P : Refer to			
		Regular Checks					
No.	Procedure	Daily	Weekly	Monthly	Annually	B	P
47	Electronics						
	Local Operating Panel, lamp test		C				
54	Exhaust Gas and Scavenge Air System						
5465-0101	Air Cooler Element, Δp and Δt	C				W	
5465-0201	Water Mist Catcher, Δp	C				W	
5465-0301	Auxiliary Blower Non-Return Valve			C ¹		O	
5465-0401	Scavenge Air Cooler Non-Return Valve			C ¹		O	
5465-0701	Turbocharger	W ²	W ²				V ⁸ , M
	Turbocharger air inlet filter, Δp	C				W, R ³	
	Scavenge air space			C ¹		W	V
56	Emission Control						
5665-0151	Exhaust Gas Recirculation System						
	O ₂ Sensors	C				O	M
	Pre-scrubber / Main Scrubber	C ⁶					
	Water Treatment System	C	C ⁹			O	V, M
	EGR Pipe Dirt Trap		C				
	Exhaust gas from smoke stack	C					V
	EGR Blowers	C				O	V, M
66	Operation						
	Fuel pump index / VIT index	C ⁵				A	V
	Exhaust Gas temperatures	C				A	V
	Cooling water quality			C		A	V, M
	Performance Observations			C ⁷			V
70	Control System						
	No duties during operation						
76	Tools						
7665-0101	Hydraulic tools	C ⁴				O, R	
	Wire ropes and straps	C ⁴				R	
Comments :							
1 : Check at every port inspection.				8 : See drawings 5455-0110 and 5455-0115.			
2 : Dry cleaning daily. Water washing weekly.				9 : PH probes and turbidity probes only.			
3 : Clean or replace filters as necessary.							
4 : Inspect before every use. Replace if damaged.							
5 : MC / MC-C engines only.							
6 : Visual inspection for leaks.							
7 : Bi-weekly							

Preface Chapter	Structural Parts	1040-0100-0002
Work Card	Crankcase Relief Valve, Data	1065-0100-0001
	Crankcase Relief Valve	1065-0101-0002
	Holding-Down Bolts, Data	1065-0200-0001
	Holding-Down Bolts	1065-0201-0002
	Stay Bolts, Data	1065-0300-0014
	Stay Bolts	1065-0301-0006
	Crankcase Oil Outlet, Data	1065-0400-0001
	Crankcase Oil Outlet	1065-0401-0001
Tool Plate	Hydraulic Tools for Holding-Down Bolts	1070-0220-0015
	Hydraulic Tools for Large Parts	1070-0300-0022
	Crankshaft, Pin Gauge	1070-1020-0001
	Crankshaft, Tools	1070-1030-0009
	Thrust Shaft, Tools	1070-1040-0009
	Turning Gear, Tools	1070-1100-0002
Plate	Holding-Down and End-Chock Bolts	1072-0200-0004



General

Engine Seating

Section: 10XX-01YY

Regarding the engine seating for the specific engine, see the suppliers special instructions.

Holding-down bolts

Section: 10XX-02YY

The bedplate is secured to the bottom of the ship with holding-down bolts.

Stay bolts

Section: 10XX-03YY

The bedplate, frame box and the cylinder frame are tightened together with stay bolts to form one unit.

Bedplate

Section: 10XX-04YY

The bedplate is made in one section. The bedplate consists of two welded, longitudinal girders and a number of cross girders which support the main bearings. Each main bearing has one main bearing cap which is secured by studs and nuts, designed for tightening with hydraulic tools.

See description 2545-0100 and/or chapter 25, "Bearings".

The bedplate is equipped with an axial vibration damper.

For the design and functioning of the axial vibration damper, see chapter 18, "Vibration Control".

Frame box

Section: 10XX-06YY

A frame box is bolted to the top of the bedplate. The frame box is made in one piece. Together, the bedplate and the frame box constitute the crankcase of the engine.

The frame box is made with steel plate doors for access to the crossheads and to the main and crankpin bearings.

For each cylinder, the frame box is equipped with a slotted pipe for collecting piston cooling oil. A piston cooling oil outlet pipe is mounted on the crosshead, and this outlet pipe is able to travel up and down in the slotted pipe in the frame box. From the slotted pipe the cooling oil is, through an outlet pipe, led to the oil tray of the bedplate.

Equipment for local checking of the cooling oil temperature and flow, and for temperature and flow alarms, is installed in the outlet pipe.

See description 7045-0100.

Relief Valves

On the exhaust side of the engine a number of spring loaded relief valves are mounted, which will opens in the event of excessive pressure in the crankcase/chain casing, for instance as a result of the ignition of oil mist.



WARNING

Fire hazard

Keep the areas around the relief valves free of oil, grease, etc. to prevent the risk of fire caused by hot air/gas emitted in case the relief valves open.

Regarding how to:

- avoid evaporation of the lubricating oil in the crankcase,
- detect oil mist in the crankcase using an 'Oil Mist Detector',
see description 6645-0300.



WARNING

Personal injury

Do not stand near crankcase doors or relief valves – or in corridors near doors to the engine room casing in the event of an alarm for:

- a) oil mist
- b) high lube oil temperature
- c) no piston cooling oil flow, or
- d) scavenge box fire

Alarms b, c and d should be considered as pre-warnings of a possible increasing oil mist level.

See our Service Letter SL97-348/ERO and description 0545-0100.

NOTICE

Replace relief valves

If there has been a crankcase explosion, the complete flame arrester of the relief valves must be replaced.

Cylinder Frame

Section: 10XX-07YY

The cylinder frame is designed with an integrated camshaft housing (ME-B only). The cylinder section is tightened together with the engine frame box and the bed-plate with stay bolts. Alternatively, it is a complete welded assembly integrating the scavenge air receiver into the cylinder frame.

Bores and openings

Central bores at the top of the cylinder frame enclose the cylinder liners. Central bores in the bottom of the cylinder frame enclose the piston rod stuffing boxes. On the exhaust side of the cylinder frame there are openings which connect the scavenge air space around the cylinder liner with the longitudinal scavenge air receiver of the engine. There are also inlet pipes for cooling and lubricating oil. The cylinder frame is provided with cleaning and inspection covers giving access to the scavenge air spaces.

Cylinder cover studs

Studs for fastening the cylinder cover are mounted in the cylinder frame.

Crankshaft

The crankshaft is either of the semi-built type, where the parts are shrunk together.

The main bearings are lubricated via a main lubricating oil pipe that branches off to the individual bearings, whereas oil for lubricating the crankpin bearings is supplied from the crossheads through bores in the connecting rods.

The crankshaft is provided with a chain wheel for the camshaft drive (ME-B only), turning wheel etc. Furthermore, a tuning wheel, a torsional vibration damper and a

Turning Gear

chain wheel drive for 2nd order moment compensators are installed, if necessary according to vibration calculations.

See chapter 18, "Vibration Control".

Marine engines (except geared plants):

At the aftmost end of the engine, a thrust bearing is mounted.

See chapter 25, "Bearings".

Stationary engines and geared marine plants:

The crankshaft is provided with a collar for the guide bearing. The purpose of the guide bearing is to keep the crankshaft in its proper position in the axial direction.

The turning gear is fastened to the engine bedplate and is driven by an electric motor.

Via a worm gear and a following planetary gearing, the motor drives a horizontal shaft equipped with a gear wheel, which can be axially displaced manually to engage with the turning wheel of the engine.

This displacement is performed with a large vertical lever placed on the protecting shield of the gear wheel. A small vertical lever, placed on the end cover of the protecting shield of the turning gear, locks the position of the large lever in, respectively, engaged and disengaged position between the gear wheel and turning wheel.

Locking is performed by engagement of a tap of the small lever into two notches of the large vertical lever.

When the large lever is in its most forward position, the turning gear is not engaged with the turning wheel.

Engagement of the gear wheel with the turning wheel is achieved by moving the large lever to its most aftward position. In this position, an interlock valve inserted in the starting air system of the engine is actuated by the large lever. This interlock prevents starting air from being supplied to the engine as long as the turning gear is in the engaged position.

Through an inspection groove at the top of the protecting shield, it must always be ensured that the gear wheel is in correct position according to the planned operation of the turning gear.

Always ensure that any of the two positions of the large lever (engagement/disengagement of the turning wheel) is locked by the small lever.

See description 6645-0120.



Dismantling of working parts:

During any dismantling of working parts of the engine, the turning gear must be in the engaged position in order to prevent outside forces from turning the engine, thus causing injuries to personnel or damage to the machinery.

See work cards, data.

**WARNING****Pressure testing of starting valves:**

The turning gear must be in the disengaged position during pressure testing of starting valves, as a leaky valve may cause the engine to rotate, and damage the turning gear.

See description 6645-0170.

Safety**Precautions**

*For detailed sketch
see 0545-0100*

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Engage turning gear
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

Data

Ref.	Description	Value	Unit
-	Table is empty on purpose. No Data needed.	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

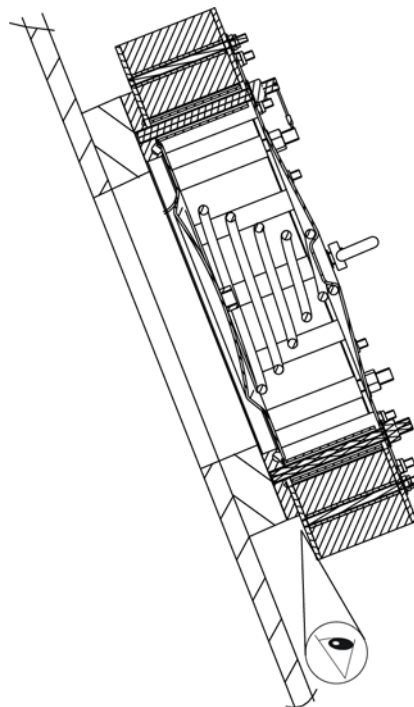
Tools

Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.

1. Leaks during running During running of the engine, check if there are any leaks.

If a leak occurs, replace the O-ring inside the relief valve.

See separate instructions from the valve manufacturer.



1065-0101-0002C01

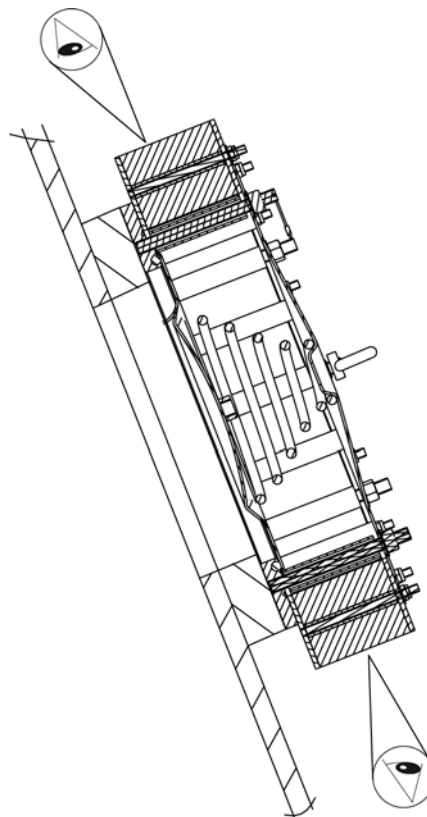
Relief Valve • Checking

2. Checking the plates If work involving risks of mechanical damage to the flame arrester has been carried out, a visual inspection of the flame arrester should always be performed before starting the engine.

Check on the whole circumference that all the plates in the flame arrester are evenly distributed and that no local openings exist.

If one or more plates in the flame arrester are damaged, the relief valve must be disassembled and the flame arrester replaced.

See separate instructions from the valve manufacturer.



1065-0101-0002C02

NOTICE

The complete flame arrester has to be replaced after a crankcase explosion.

Work Card
1065-0101-0002

Safety Precautions

For detailed sketch
see 0545-0100

○	Stop the Engine
---	-----------------



Data

Ref.	Description	Value	Unit
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1070-0200	-	Hydraulic Tools for End-Chock Bolts
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	047	Hose with unions, 1500 mm

NOTICE

The hydraulic jack used for tightening the holding-down bolts is marked with:

For: Holding-down bolts

The larger jack used for tightening the end-chock bolts is marked with:

For: End-chock bolts

Hydraulic tightening of holding-down bolts and end-chock bolts is carried out as detailed.
See work card 7665-0101.

The normal tightening pressure is indicated *in data* and is also stamped on the tightening tool.

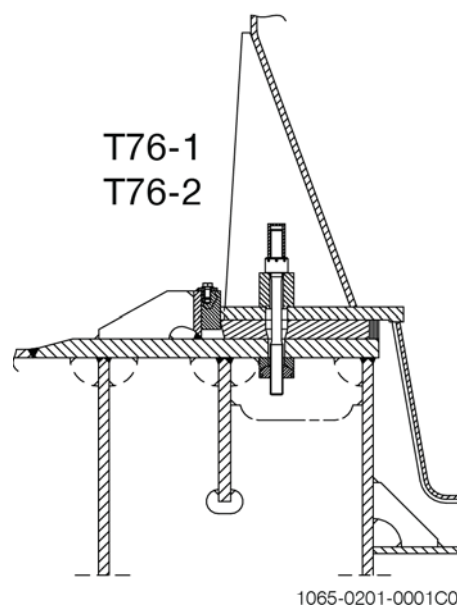
1. Checking the bolt tightening

The holding-down bolts and end-chock bolts must be checked for correct tightness at the intervals indicated *in data*.

For this purpose, raise the pressure on the hydraulic tool slowly while constantly attempting to loosen the nut with the tommy bar. The oil pressure indicated on the pressure gauge when the nut comes loose (**loosening pressure**) is to be noted down in the checking tables, see pages 4 and 5, following which the bolts are tightened to the normal **tightening pressure**.

The condition of the bolted joints, and thus the general condition of the foundation, can be effectively checked by comparing the tables from successive bolt checks.

If the **loosening pressure** is below 80 per cent of the **tightening pressure**, the relative chocks must always be checked for possible defects. If the chocks are in position and in order, the bolts should be taken out for inspection of threads and contact faces.



2. Checking of epoxy supporting chocks

If a number of measuring pins have been welded to the tank top, the heights of the epoxy supporting chocks are to be checked immediately after finishing the checking of the loosening pressures of the holding-down bolts and the retightening of these.

The distance between the measuring pins and the bedplate is to be measured with a blade gauge and noted down. Any possible settling of the chocks during the intervals between measurements can thereby be followed.

3. Side-chocks and side-chock liners

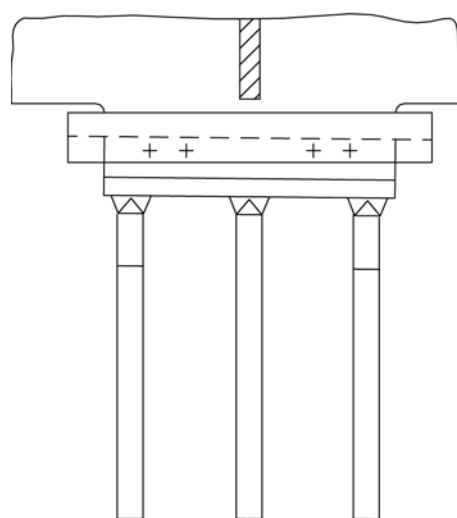
Mounting the liners with a 50 - 80 percent contact area on both sides of the liners, then knock the liners a further 3 to 4 mm inwards.

The liners located in way of each main bearing on either side of the engine must be mounted and knocked into position simultaneously.

The first time the ship is sailing in a fully-loaded condition after the engine has been operating for 1,000 hours, all side chocks should be checked to see whether the liners can be knocked further inward.

The fit of the side chock liners should be checked with a feeler gauge each time the loosening pressure of the holding down bolts is checked, and thus at the same time intervals.

The feeler gauge is applied at the 7 points indicated in the table *on page 5*, and the measurements found are to be entered in the relevant table. These results are used to determine whether refitting or, possibly, replacement of the liners is necessary.



1065-0201-0001C03

If the measurements at 3 points or more have increased 5/100 mm or more from the initial results, we recommend that the following procedure is followed:

1. Loosen the hexagon screws.
2. Try to knock the liner further inward.
3. Measure again at the 7 points indicated in the table.

If this procedure does not improve the situation, the liner must be removed, and it must be checked that the actual contact area is between 50 and 80 per cent of the possible contact surface areas on both sides of the liner.

The liners are secured in their correct position by means of hexagon socket set screws with cup point.

Holding-down bolts

Engine frame No.	Bolt No.	Port side			Cylinder No.	Starboard side			Bolt No.	Engine frame No.
		pressure	% dev.	remarks		pressure	% dev.	remarks		
1	1				1				1	1
	2								2	
	3								3	
	4								4	
2	1				2				1	2
	2								2	
	3								3	
	4								4	
3	1				3				1	3
	2								2	
	3								3	
	4								4	
4	1								1	4
	2								2	
	3								3	
	4								4	
5	1								1	5
	2								2	
	3								3	
	4								4	
6	1								1	6
	2								2	
	3								3	
	4								4	
7	1								1	7
	2								2	
	3								3	
	4								4	
8	1								1	8
	2								2	
	3								3	
	4								4	
9	1								1	9
	2								2	
	3								3	
	4								4	
10	1								1	10
	2								2	
	3								3	
	4								4	
11	1								1	11
	2								2	
	3								3	
	4								4	
12	1								1	12
	2								2	
	3								3	
	4								4	
13	1								1	13
	2								2	
	3								3	
	4								4	
14	1								1	14
	2								2	
	3								3	
	4								4	
	1								1	

1065-0201-0001C04

Side-chocks and end-chock bolts

Port side								Starboard side									
Chock No.	Point							Cylinder No.	Point							Chock No.	
	A	B	c	d	e	f	g		A	B	c	d	e	f	g		
1								1 2 3								1	
2									2								2
3									3								3
4																	4
5																	5
6																	6
7																	7
8																	8
9																	9
10																	10
11																	11
12																	12
13																	13
14																	14

FORE

FORE

Port side					Starboard side								
Ch No.	Bolt No.	Pressure (kp/cm ²) bar	Deviation %	Point					Deviation %	Pressure (kp/cm ²) bar	Bolt No.	Ch No.	
				a	b	c	d	e					a
E	1											1	E
	2											2	

No. 2

No. 2

AFT

1065-0201-0001C05

Holding-Down and End-Chock Bolts • Checking

Work Card
1065-0201-0002

Safety Precautions

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply

Data

Ref.	Description	Value	Unit
T10-07	Check measurement	155±3	mm
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1070-0300	019	Hydraulic jack, Complete
1070-0300	020	Support for hydraulic jack
1070-0300	032	Support for hydraulic jack
1070-0300	044	Tommy bar
1070-0300	103	Stud setter
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	118	3-way distributor block, complete
7670-0410	054	Feeler gauge set

**WARNING**

This job requires a minimum of two persons, long sleeves and heat resistant gloves.

1. Inspection

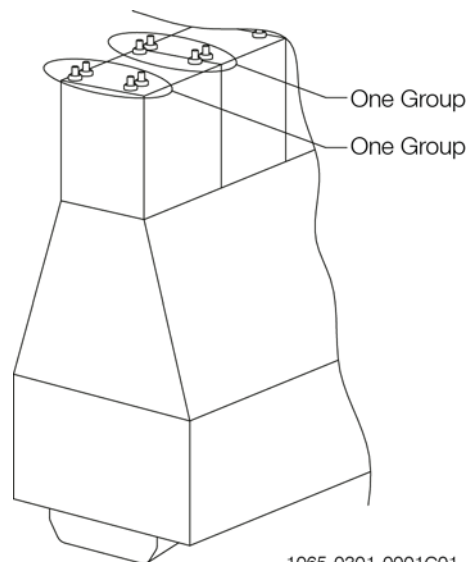
This check can be performed during several periods of stopped engine, but must be performed on complete twin stay bolt groups at a time, thereby ensuring uniform tension in the affected bearings.

NOTICE

The first time this check is performed it has to be completed in one operation.

The following checks have to be completed within a 500-hour period.

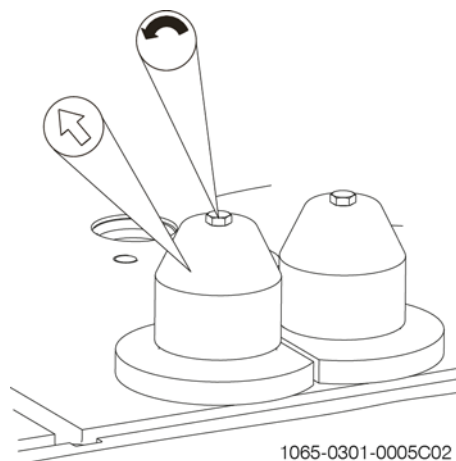
The engine must be at normal operational temperature (approx. 50° C) when the retightening is carried out.



1065-0301-0001C01

2. Protective caps

Before retightening the stay bolts, remove the protective caps.



1065-0301-0005C02

3. Loose stay bolts

Check for loose stay bolt nuts with the tommy bar.

If a loose nut is found, unscrew the nut until a gap occurs between cylinder frame and nut.

Loosen and unscrew the nut on the opposite stay bolt.

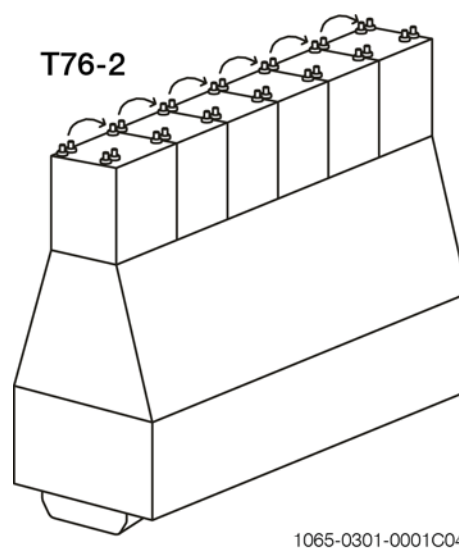
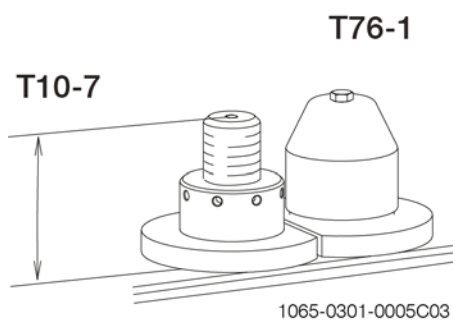
Check for the correct mounting of the stay bolt by comparing with the check measurement.

See data.

If the check measurement is not reached, indicating that the stay bolt is not screwed down properly in the thread of the bedplate, apply a screw and a counter nut in the thread in the top of the stay bolt, and turn the stay bolt until the check measurement data is met.

4. Retighten

Retighten the stay bolts in pairs (athwartships), working from fore to aft of the engine.



5. Mounting of hydraulic tools

Clean the contact faces and mount the hydraulic tools on a pair of stay bolts positioned opposite each other.

NOTICE

On some engines pipes mounted above the stay bolts may interfere with the mounting of the hydraulic tools on the stay bolts. In this case remove the pipes which prevent the mounting of the hydraulic tools on the stay bolts.

If hydraulic pipes need to be removed first depressurise the hydraulic system.

See work card 4565-0501.

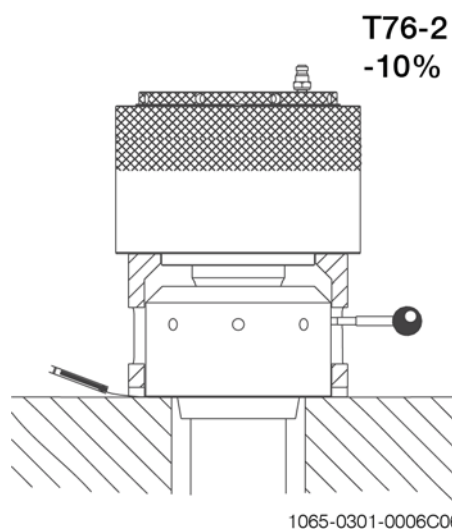
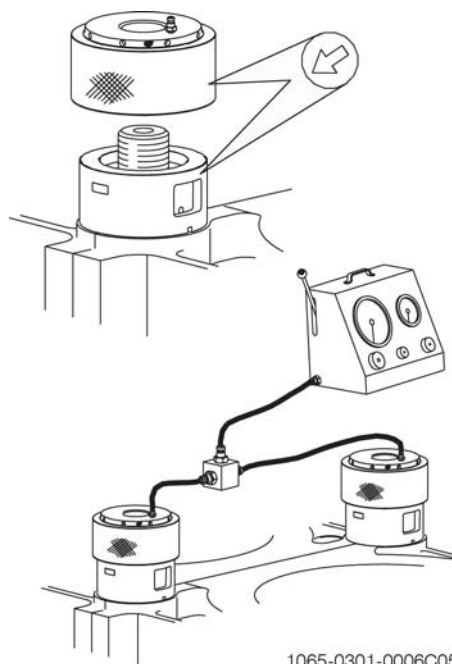
Connect the high-pressure pump by means of the high-pressure hoses, so that the two stay bolts are tightened in one operation.

For use of hydraulic tools, see work card 7665-0101.

6. Clearance

Maintain the mounting pressure, and retighten the stay bolt nuts with a tommy bar.

Before relieving the system of pressure, check with a feeler gauge that the nuts bear against their contact faces.

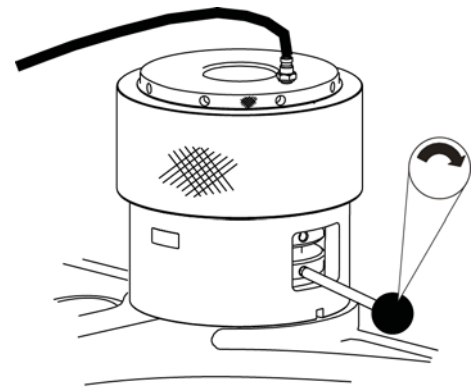


7. Rechecking

When all stay bolts have been retightened, reconnect the hydraulic tools to the pair of stay bolts first tightened. Tighten to 10% below the mounting pressure and check whether the nut is loose.

If the nut is not loose: Tighten the stay bolts concerned to the mounting pressure.

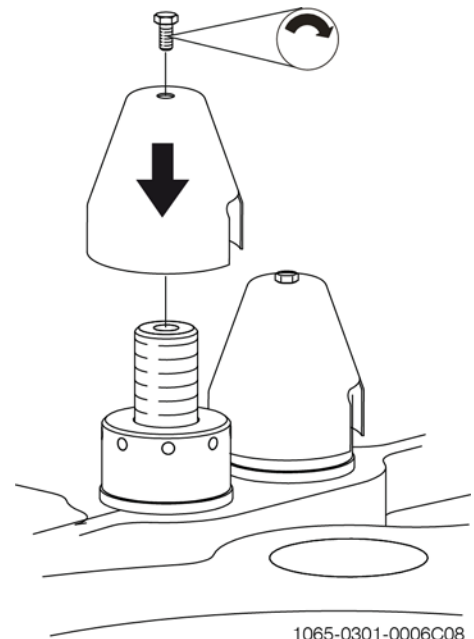
If the nut is loose: Tighten **all** stay bolts once again to the mounting pressure.



1065-0301-0006C07

8. Protective caps

After completing the retightening procedure, mount the protective caps.



1065-0301-0006C08

Safety**Precautions**

For detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Engage turning gear
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T10-10	Metal bellow, up to	15	Kg

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.

Crankcase Oil Outlets

The crankcase oil outlets guide the lubricating oil from the crankcase to the lubricating oil bottom tank. The sealing of the crankcase oil outlets must be checked at regular intervals, for example during dockings. The crankcase oil outlets may be equipped with either rubber diaphragm sealing or metal bellow sealing.

**WARNING**

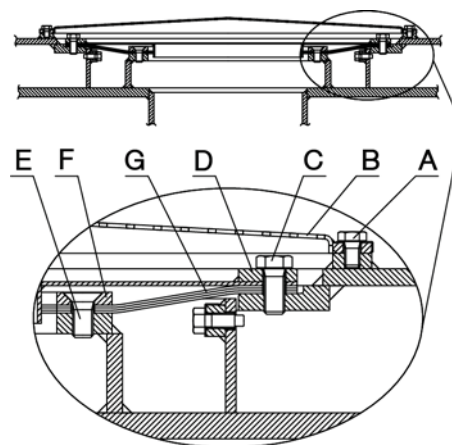
Observe safety precautions when working in the crankcase.
See description 0545.0100.

NOTICE

If the water content of the main engine lube oil is rising, this may indicate that the crankcase oil outlet sealings are fractured.

1. Rubber diaphragm dismantling

To access the rubber diaphragm sealing remove:
Screws A
Grating B
Screws C
Cover plate D
Screws E
Steel ring F.

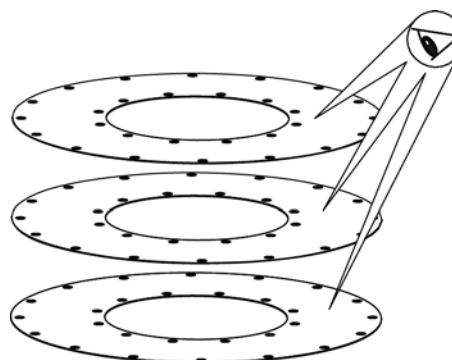


1065-0401-0001C01

2. Rubber diaphragm replacement

Lift away the rubber sealing diaphragms G and examine each diaphragm closely.

In case of any rips or tears in the diaphragms, they must be replaced.



1065-0401-0001C02

NOTICE

It is strongly recommended always to replace the diaphragms during inspection.

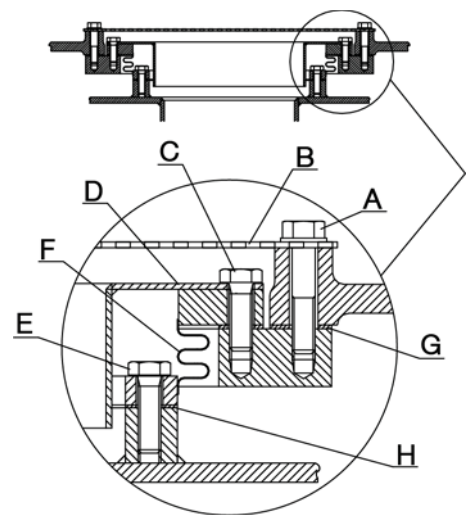
If unavailable, new diaphragms may be made from three layers of 2 mm thick oil and temperature resistant rubber.

3. Rubber diaphragm mounting
- Mount:
 Rubber sealing diaphragms G
 Steel ring F
 Screws E
 Cover plate D
 Screws C
 Grating B
 Screws A.

NOTICE

Remember to mount new locking plates at screws A.

4. Metal bellow dismantling
- Remove all screws A and grating B.
- Remount four of the screws A at diametrically opposite positions.
- Remove:
 Screws C
 Cover plate D
 Screws E.



1065-0401-0001C04

5. Metal bellow replacement
- Lift away metal bellow sealing F and examine it closely.
- If any cracks or punctures are found in the metal bellow sealing, it must be replaced.

NOTICE

It is recommended to always replace the metal bellow sealing during inspection.

6. Metal bellow mounting

Replace gaskets G and H.

Mount metal bellow sealing F.

Mount:

Screws E

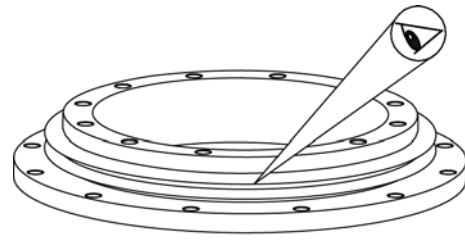
Cover plate D

Screws C

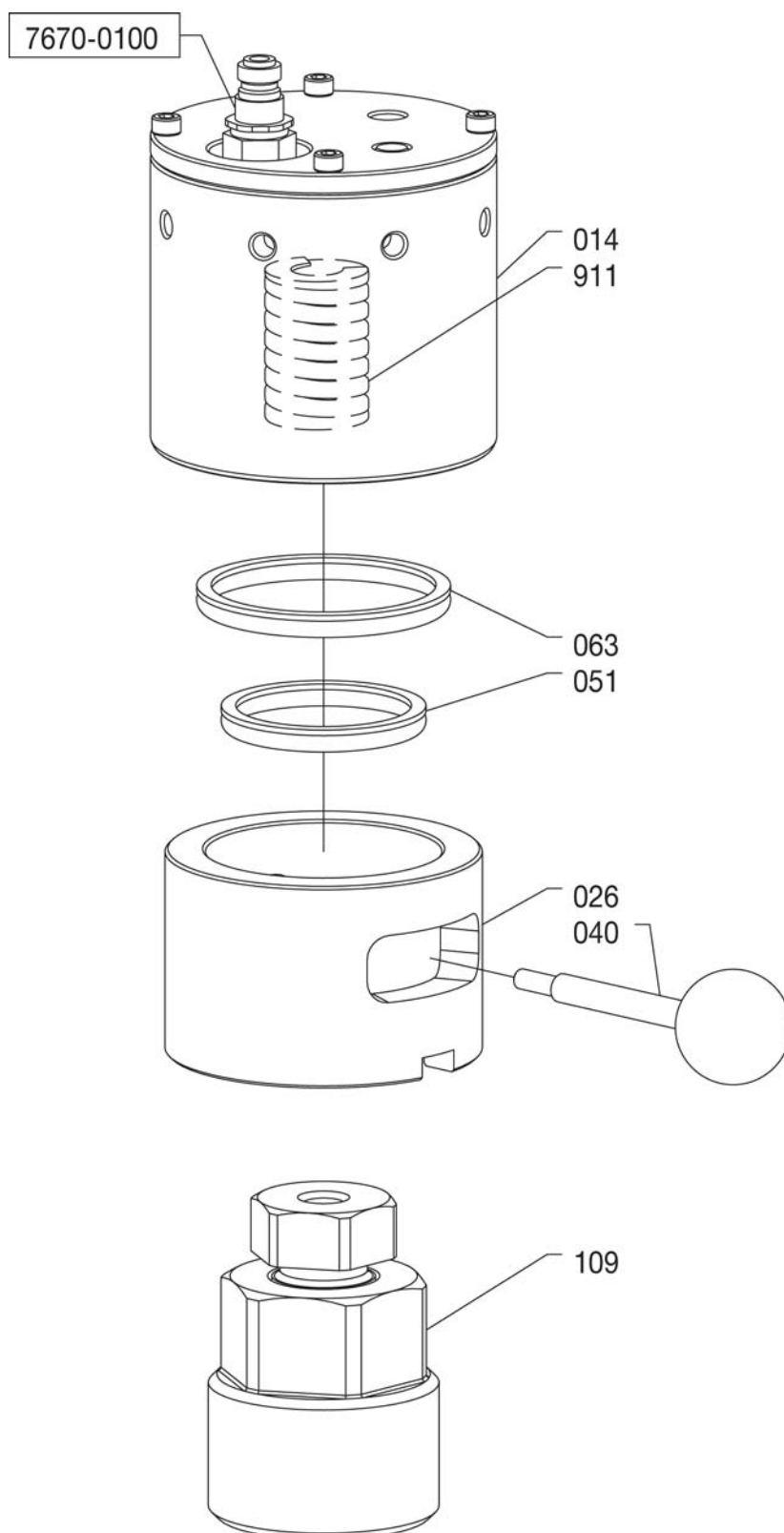
Remove the four screws A

Mount grating B

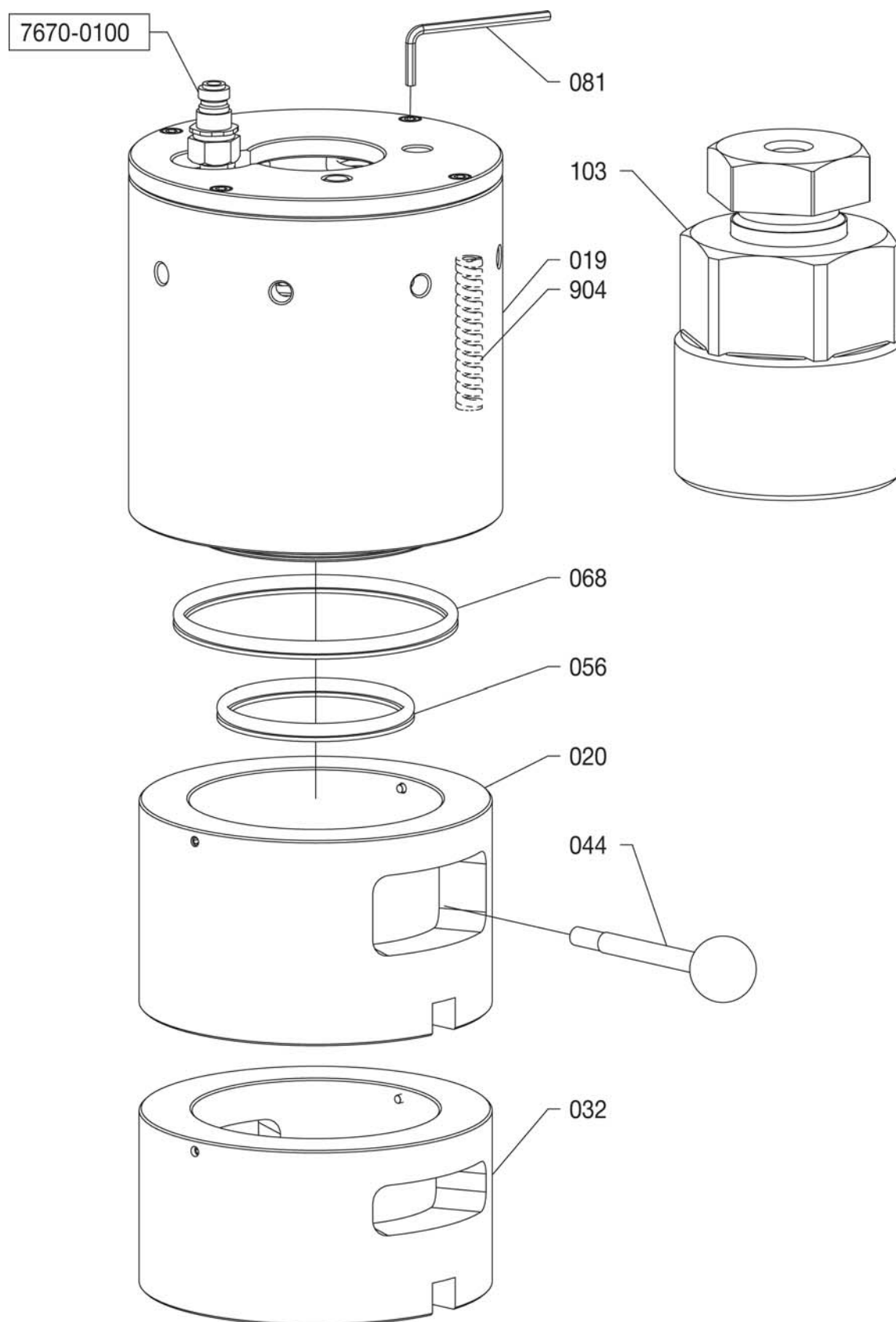
Mount all screws A.



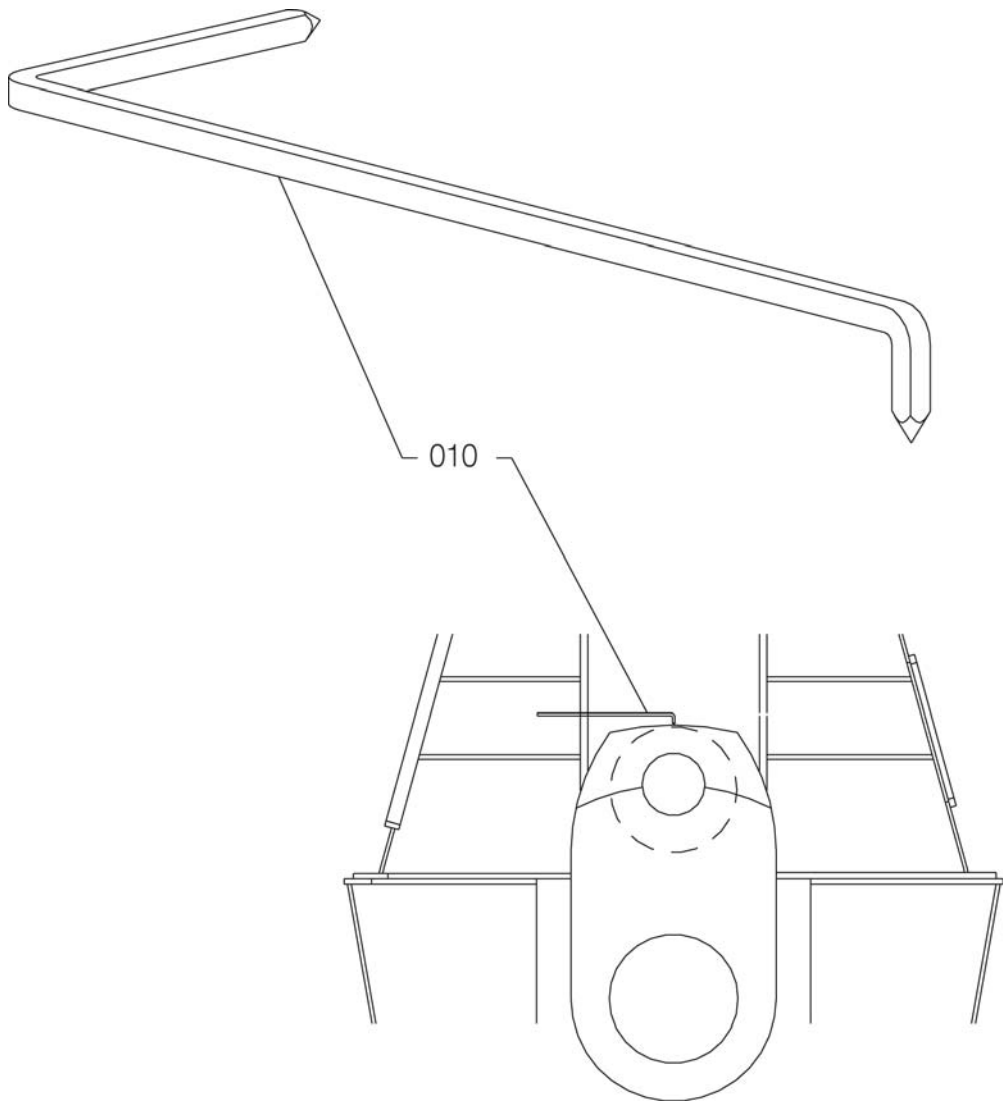
1065-0401-0001C07



Item No.	Qty	Item Designation
014	-	Hydraulic jack, complete
026	-	Support for hydraulic jack
040	-	Ball handle
051	-	Sealing ring with back-up
063	-	Sealing ring with back-up
109	-	Stud setter
911	-	Spring

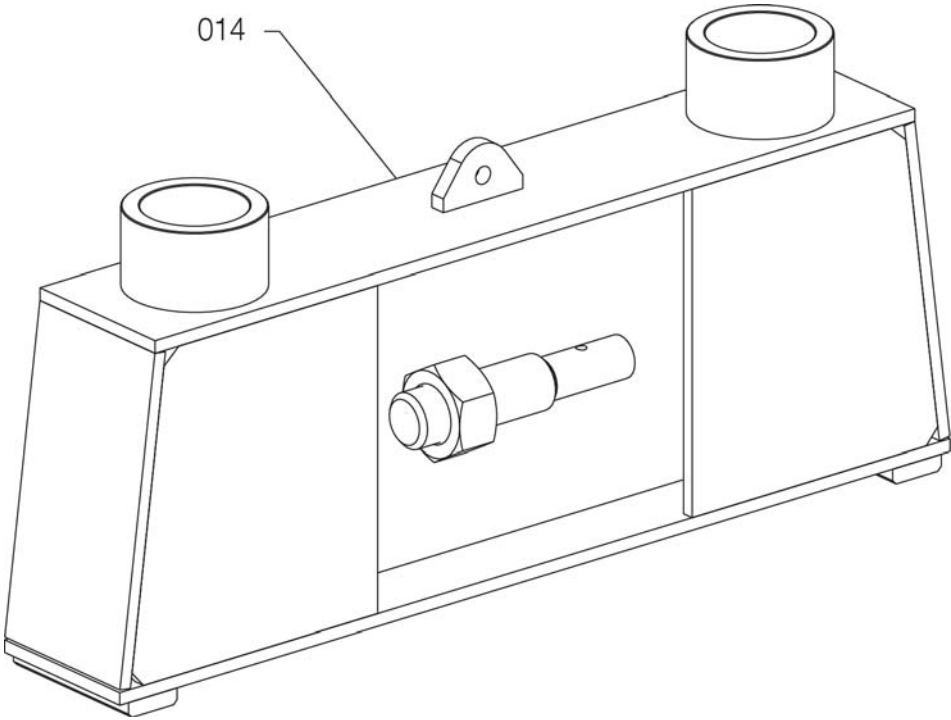


Item No.	Qty	Item Designation
019	-	Hydraulic jack, complete
020	-	Support for hydraulic jack
032	-	Support for hydraulic jack
044	-	Ball handle
056	-	Sealing and back-up ring
068	-	Sealing and back-up ring
081	-	Hex key
103	-	Stud setter
904	-	Spring



Crankshaft Pin Gauge

Plate
1070-1020-0001

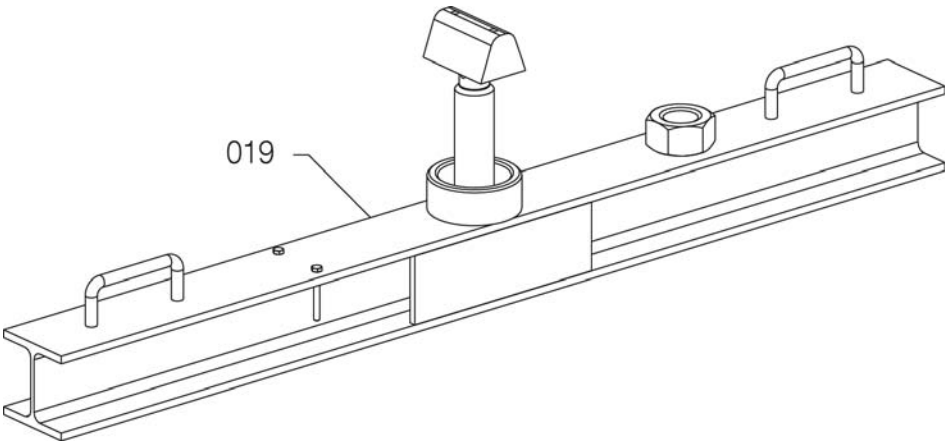


Crankshaft Tools

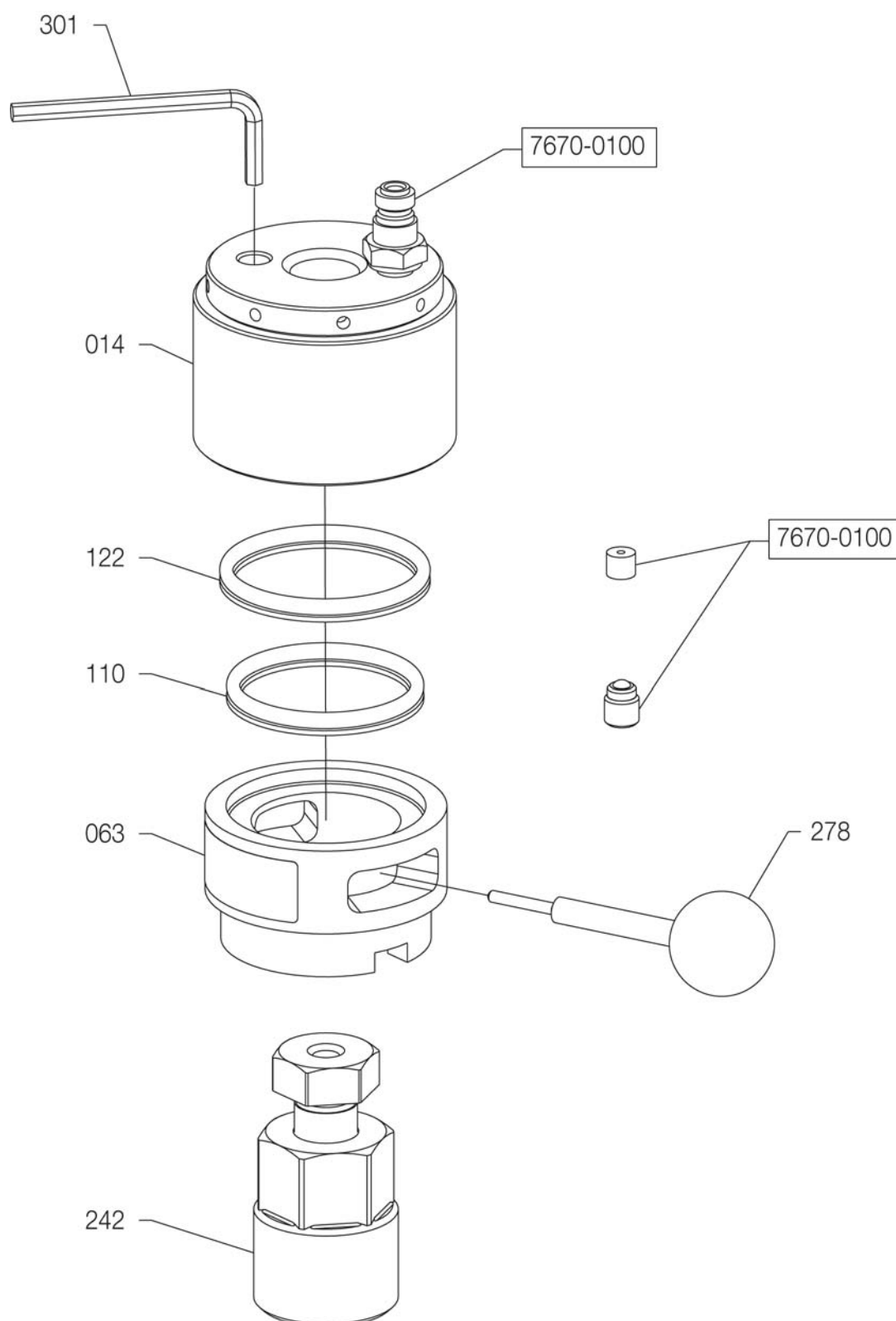
Plate

1070-1030-0009

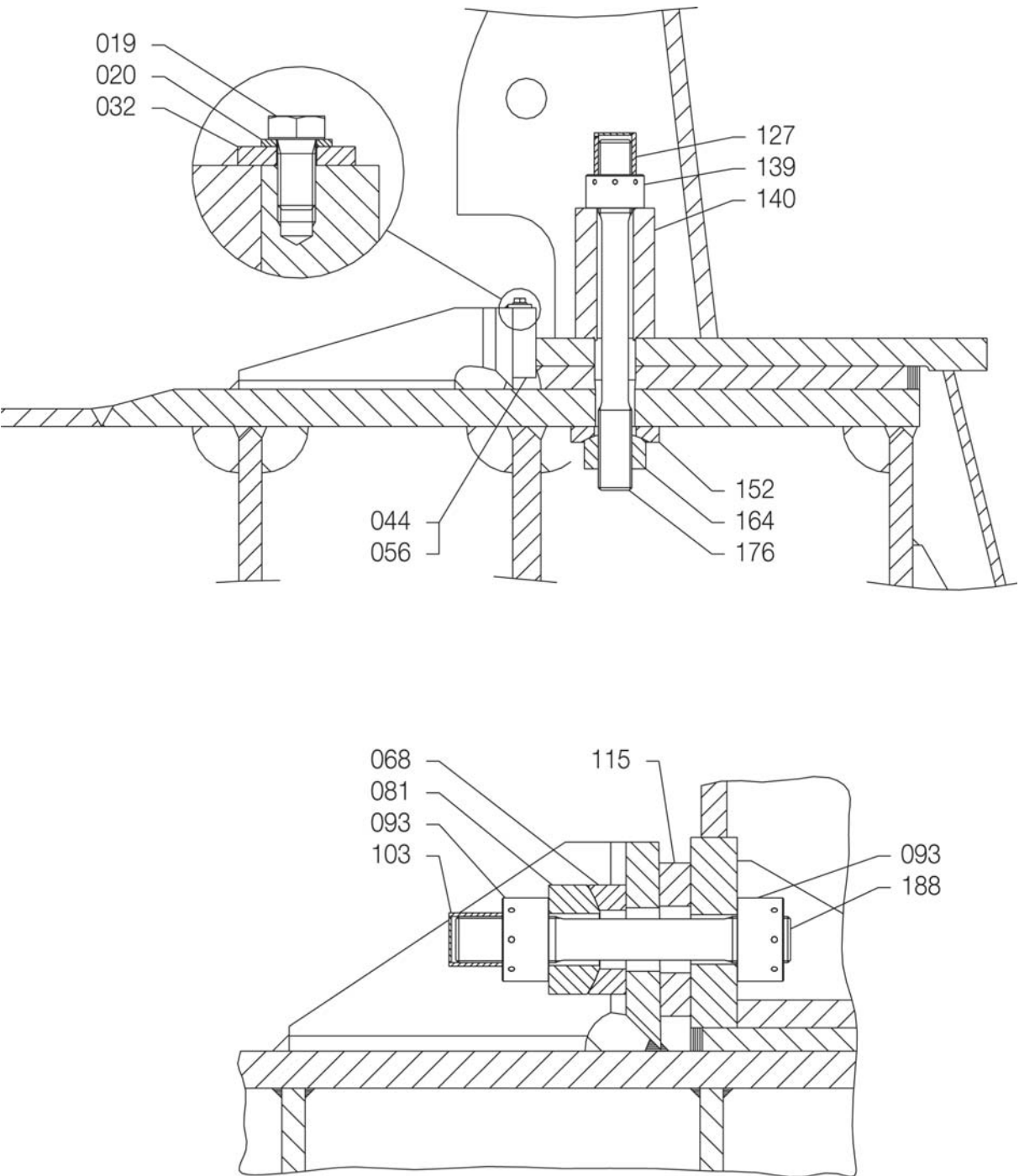
[illegible]



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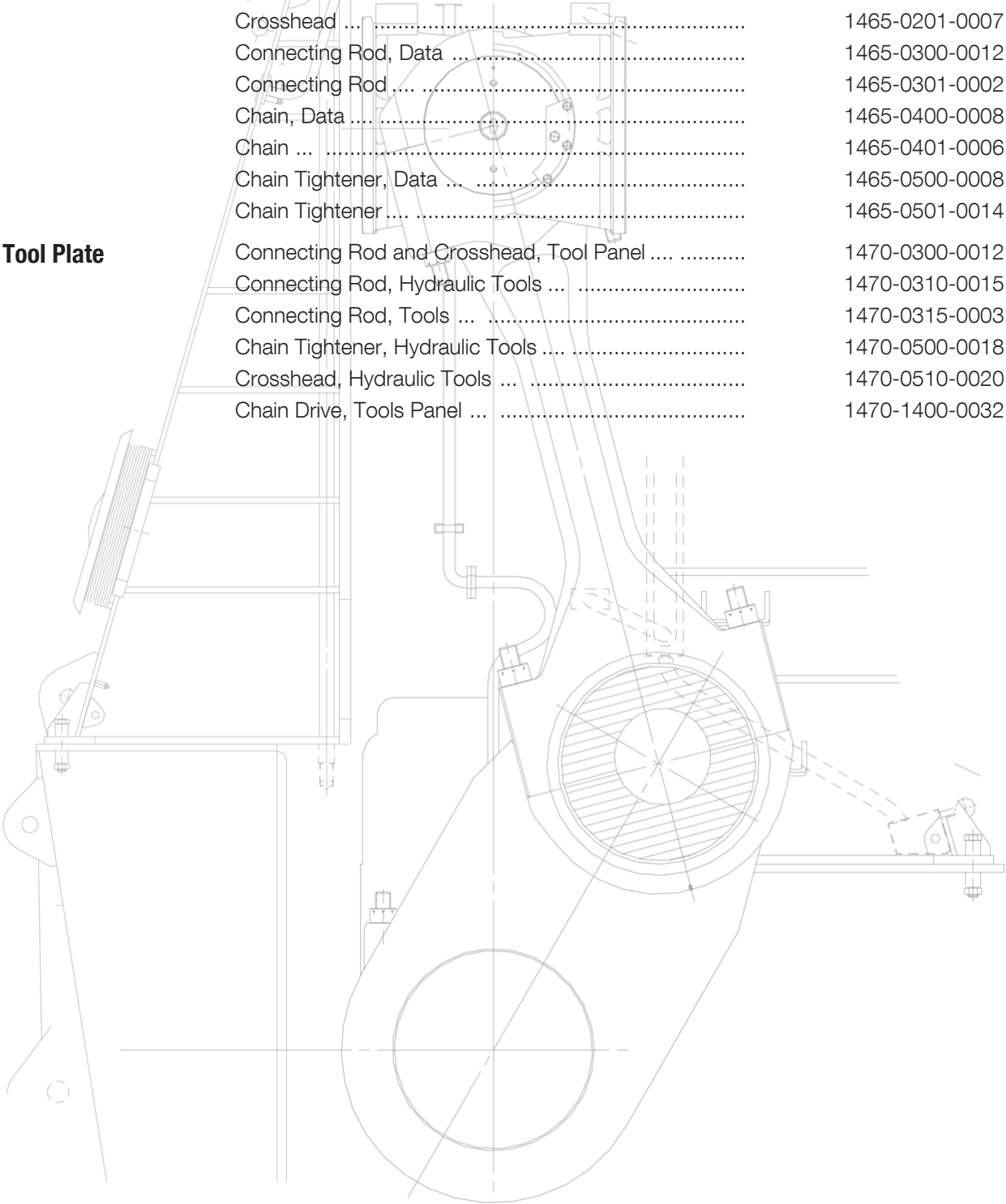
Item No.	Qty	Item Designation
014	-	Hydraulic jack, complete
063	-	Support for hydraulic jack
110	-	Sealing and back-up ring
122	-	Sealing and back-up ring
242	-	Stud setter
278	-	Tommy bar
301	-	Hex key



Preface Chapter
Work Card

Tool Plate

Driving Gear	1440-0100-0002
Reciprocating Parts, Data	1465-0100-0014
Reciprocating Parts	1465-0101-0004
Crosshead, Data	1465-0200-0012
Crosshead	1465-0201-0007
Connecting Rod, Data	1465-0300-0012
Connecting Rod	1465-0301-0002
Chain, Data	1465-0400-0008
Chain	1465-0401-0006
Chain Tightener, Data	1465-0500-0008
Chain Tightener	1465-0501-0014
Connecting Rod and Crosshead, Tool Panel	1470-0300-0012
Connecting Rod, Hydraulic Tools	1470-0310-0015
Connecting Rod, Tools	1470-0315-0003
Chain Tightener, Hydraulic Tools	1470-0500-0018
Crosshead, Hydraulic Tools	1470-0510-0020
Chain Drive, Tools Panel	1470-1400-0032



General Crosshead

Section: 14XX-02YY

The crosshead is provided with two guide shoes fitted on the crosshead ends.

The centre part of the crosshead is designed as a bearing journal which is housed in the crosshead bearing.

The crosshead bearing cap is provided with a cut-out, enabling the piston rod to be assembled with the crosshead journal. *See also description 2545-0100 and Chapter 25, "Bearings".*

Piston rod foot

The piston rod foot is fastened to the crosshead. To match different engine layouts, a shim of predetermined thickness is inserted between the piston rod and the crosshead.

Lubrication

The crosshead is provided with bores for distributing the oil supplied through the telescopic pipe, partly as cooling oil for the piston, partly as lubricating oil for the crosshead bearing and guide shoes and – through a bore in the connecting rod – for lubricating the crankpin bearing.

The piston cooling oil outlet is led through a control device for each cylinder for the purpose of checking the temperature and flow before the oil is passed on to the lube oil tank.

Guide shoes

The sliding faces of the guide shoes are lined with cast-on bearing metal.

The guide shoes are guided by crosshead guides in the engine framebox and properly secured against displacement by guide strips fastened to the guide shoes.

On some engines, the guide shoes are provided with counterweights.

Tightening

The crosshead bearing is held together by studs and nuts. The nuts are tightened with hydraulic tools.

The crankpin bearing is fitted with steel shells lined with bearing metal and assembled in the same way as the crosshead bearing.

Chain Drive

Section: 14XX-04YY

The chain drive consists of one or more roller chains running on chain wheels fitted on the crankshaft and the camshaft. The chain is kept tightened by a chain tightener placed in the chain casing between the crankshaft and the camshaft.

The long free lengths of the chain are guided by rubber-clad guide bars. Lubricating oil is supplied through spray pipes fitted at the guide bars and chain wheels.

Safety Precautions

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Engage turning gear
○	Shut off cooling water
○	Stop lubricating oil supply
○	Shut down hydraulic power supply



Data

Ref.	Description	Value	Unit
-	Acceptance criteria with piston in centre (F-A direction)	-	-
T14-01	PF+PA, N max.	0.6	mm
T14-02	PF+PA, O max.	1.1	mm
T14-04	E+G, H+F, N max.	0.55	mm
T14-05	E+G, H+F, N min.	0.2	mm
T14-06	E+G, H+F, O max.	0.85	mm
T14-10	J+X1, L+Y1, K+X2, M+Y2, N max.	1.1	mm
T14-11	J+X1, L+Y1, K+X2, M+Y2, N min.	0.5	mm
T14-12	J+X1, L+Y1, K+X2, M+Y2, O max.	1.3	mm
T14-16	ZF/ZA N min.	6	mm
T14-17	ZF/ZA O min.	5	mm
T14-18	TF + TA O max.	0.8	mm
T14-22	Crankshaft position (after BDC)	60	°
T14-23	Piston inclination R1-R2, O max.	0.40	mm
T14-120	TF + TA N max.	0.7	mm
T14-121	TF + TA N min.	0.3	mm
--	N: New and cold engine with staybolts tightened (less than 100 running hours)	-	-
--	O: Engine in service	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
7670-0410	054	Feeler gauge set
7670-0410	078	Dial gauge and stand tool



WARNING

ALWAYS ensure that the turning gear is engaged during inspection.

- Block the starting air supply to the main starting valve.
- The turning gear must always be operated exclusively by the person(s) who enter(s) the crankcase.
- *See description 0545-0100.*

1. Trim the Ship

In order to achieve uniform measuring conditions on board, the ship's trim must be as close as possible to 0°.

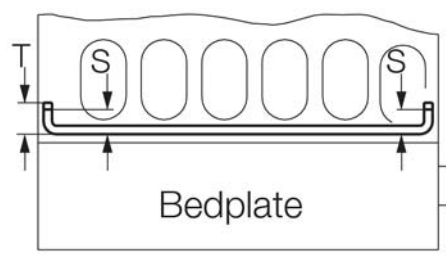
Mount a transparent plastic tube along the length of the bedplate.

Bend each end approx. 250 mm upwards at the frame box side.
See T.

Fill the tube with water (preferably coloured) until the water level is approx. 100 mm from the end of the tube.

Trim the ship until the difference between the water level S fore and aft is less than 1.5 mm per 1000 mm.

Measurements are to be taken with a ruler.



1465-0101-0004C01

2. The piston and the cylinder liner

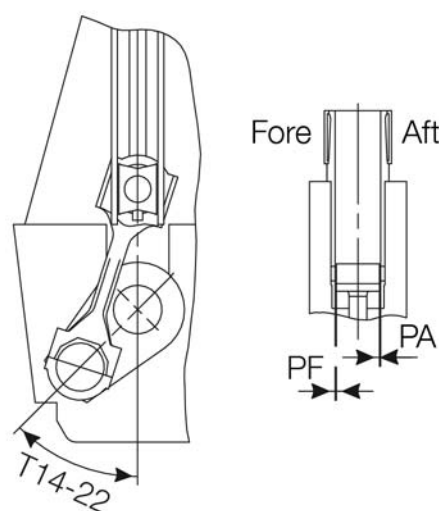
Turn the crankshaft in ASTERN direction to T14-22 (see data) degrees after BDC (the guide shoe must rest against the crosshead guide).

NOTICE

Piston centering is only to be checked in case of repair or replacement.

Check the centering of the piston in the cylinder liner by measuring the clearance (use a long feeler gauge from the scavenge air space) between the piston skirt and the cylinder liner in the fore and aft positions (PF-PA).

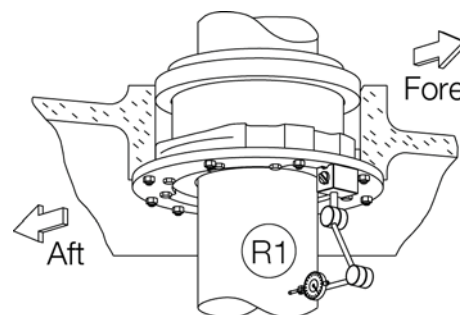
Make sure that the piston is clear of the cylinder liner in the fore and aft directions.



1465-0101-0004C02

3. Mount a dial gauge Mount a dial gauge in the bottom of the flange below the stuffing box to the front of the piston rod with the tip of the dial gauge against the piston rod.

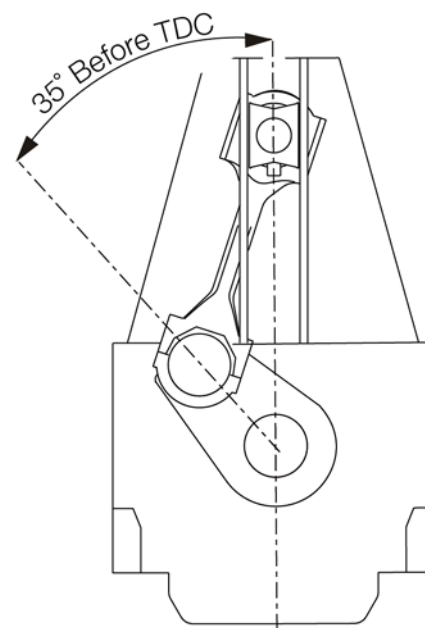
Note the reading of the dial gauge R1.



T14-23

1465-0101-0005C03

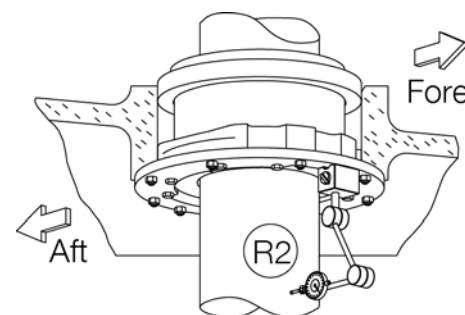
4. Turn the crankshaft Turn the crankshaft in ASTERN direction to 35° before TDC.



1465-0101-0004C04

5. Piston inclination Note down the reading of the dial gauge R2.

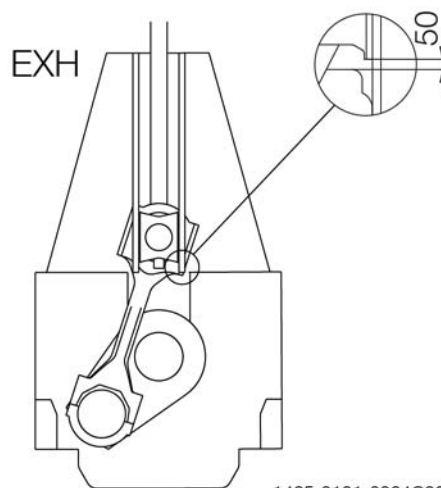
Calculate the piston inclination R1-R2.



T14-23

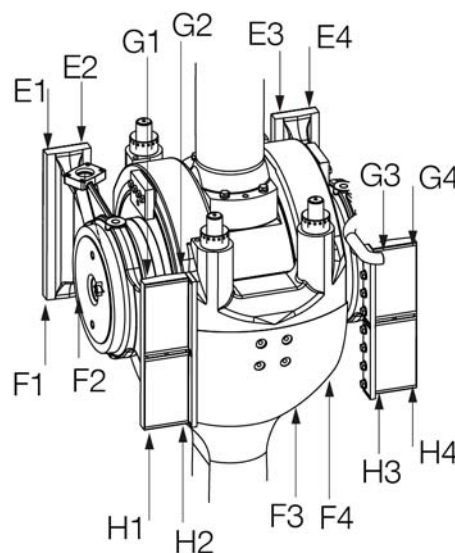
1465-0101-0005C05

6. Turn the crankshaft Turn the engine astern until the guide shoe is 50 mm from the bottom edge of the guide plan (approximately 45° after BDC — on some engine types this angle is larger).



1465-0101-0004C06

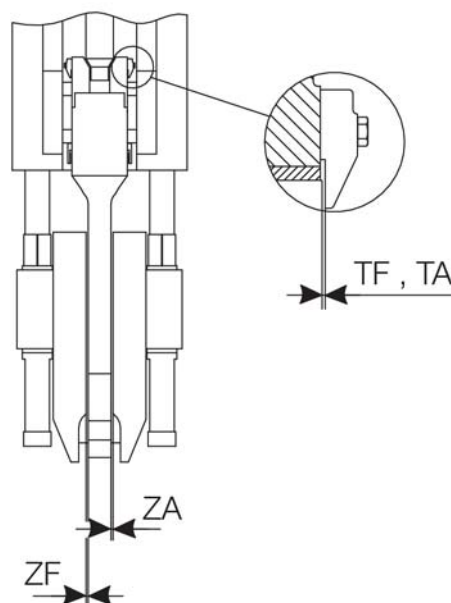
7. Measure the crosshead guides clearance Measure the clearance between the crosshead guides and the guide shoes (E1-4, F1-4, G1-4 and H1-4).



1465-0101-0004C07

8. Measure the clearance ZF/ZA

Measure the clearance between the crankthrow and the connecting rod (**ZF** and **ZA**). Measure the clearance between the thrust piece and the crosshead (**TF** and **TA**).



1465-0101-0004C08

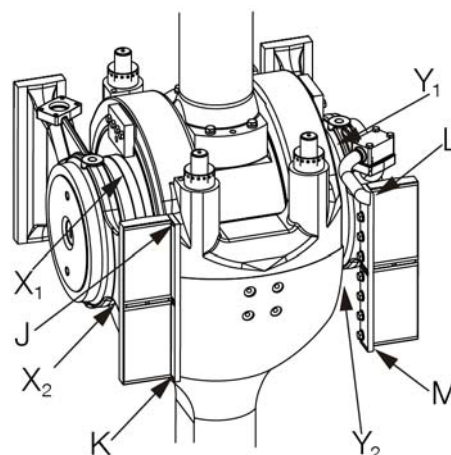
9. Measure the clearance

Measure the clearance between the guide strips and guide planes **J** & **L** (top).

Measure the clearance between the guide strips and guide planes **K** & **M** (bottom).

Measure the clearance between the guide shoe and crosshead **X1** & **Y1** (top).

Measure the clearance between the guide shoe and crosshead **X2** & **Y2** (bottom).



1465-0101-0004C09

The clearance, calculated as **J+X1**, **L+Y1**, **K+X2** and **M+Y2**, is adjusted by the insertion of shims so that it is symmetrical in relation to the clearance between the piston skirt and the cylinder liner.

Parallelism between the guide strip and guide plane is to be kept within a tolerance of 0.2 mm per 1000 mm.

10. Recommended

It is recommended to note down the measured results, so that possible later changes can be ascertained.

Unit mm	Cyl.	1	2	3	4
Piston/Liner	PF				
	PA				
Frame Box	E1				
	E2				
	E3				
	E4				
	F1				
	F2				
	F3				
	F4				
	G1				
	G2				
	G3				
	G4				
	H1				
	H2				
	H3				
	H4				
	J+X ₁				
	L+Y ₁				
	K+X ₂				
	M+Y ₂				
Crosshead Connecting Rod	TF				
	TA				
Crankthrow Connecting Rod	ZF				
	ZA				
Piston Inclination	R1-R2				

1465-0101-0004C10

Safety**Precautions**

For detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Engage turning gear
☐	Shut off cooling water
☐	Shut off fuel oil
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T14-24	Cooling oil outlet pipe, tightening torque	160	Nm
T14-30	Guide strip screws, tightening torque	330	Nm
T14-32	Crosshead/piston rod stud, screwing-in torque	350	Nm
T14-33	Telescopic pipe, tightening torque	160	Nm
T14-35	Thrust piece tightening torque	450	Nm
T14-42	Crosshead, complete	2800	kg
T14-43	Guide shoe	300	kg
T14-45	Cooling oil outlet pipe	15	kg
T14-46	Telescopic pipe	40	kg
T14-49	Crosshead, without guide shoes	2100	kg
T14-50	Stop bolt, tightening torque	1000	Nm
T14-53	Connecting rod, without bearing caps	2400	kg
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1470-0300	041	Wire guide
1470-0300	053	Lifting attachment for connecting rod

Plate	Item No.	Description
1470-0300	065	Lifting tools for crosshead
1470-0300	089	Retaining tool for telescope pipe
1470-0300	090	Bracket, support of crosshead
1470-0300	219	Torque wrench offset tool
1470-0310	-	Connecting rod, hydraulic tools
1470-0315	018	Lifting tool for crankpin shell
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	106	5-way distributor block, complete
7670-0200	-	Torque spanners
7670-0300	-	Lifting tools, etc

WARNING**ALWAYS ensure that the turning gear is engaged during inspection**

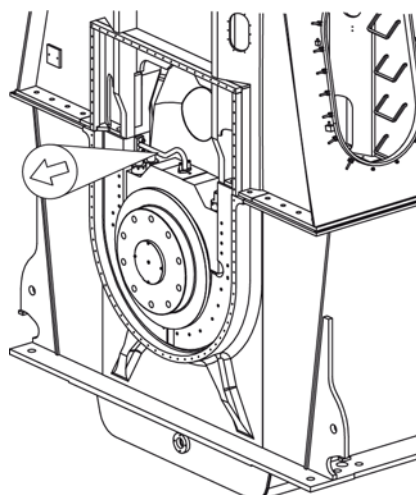
- Block the starting air supply to the main starting valve.
- The turning gear must always be operated exclusively by the person(s) who enter(s) the crankcase.
- *See description 0545-0100.*

NOTICE

Before dismantling the crosshead, dismantle the piston.
See work card 2265-0401.

1. Dismantling of oil pipes

Dismantle the main bearing lubricating oil pipes.



1465-0201-0002D02

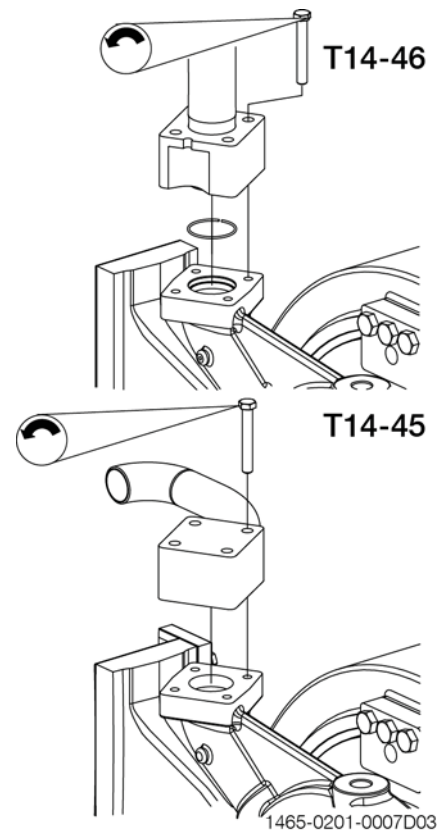
2. Dismantling of cooling oil pipes

Dismantle the cooling oil outlet pipe from the guide shoe.

Loosen and remove the screws which secure the telescopic pipe to the guide shoe.

In order to reach the bolt in the corner behind the telescopic pipe, use the offset tool along with a socket wrench.

Lift up and suspend the telescopic pipe by means of the tool.



3. Mounting of hydraulic tools

Turn the crankshaft to gain access to the nuts on the crosshead bearing studs.

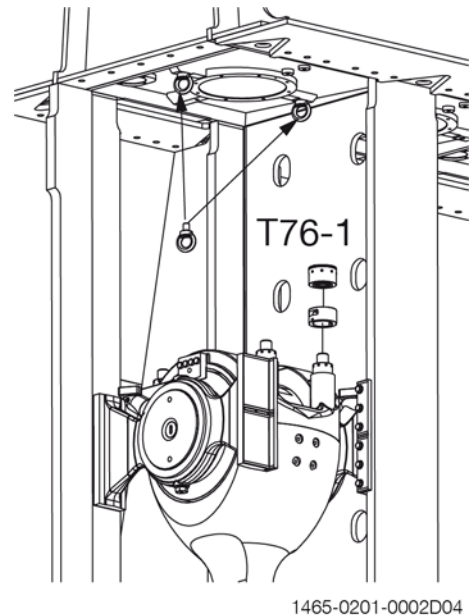
Mount two eyebolts in the top of the crankcase in the fore-and-aft direction.

Mount the spacer rings and the hydraulic jacks for loosening the nuts on the crosshead bearing studs.

Loosen all four crosshead bearing cap nuts simultaneously.

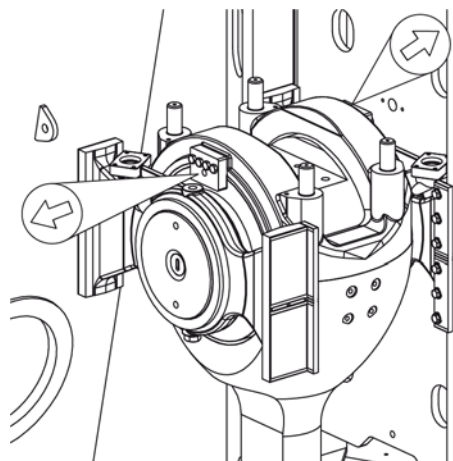
For operation of the hydraulic tools, *see work card 7665-0101*.

Remove the hydraulic jacks and unscrew the nuts.



4. Thrust piece
dismantling

Remove both thrust pieces on the
crosshead bearing cap.



1465-0201-0002D05

Crosshead • Dismantling

Work Card
1465-0201-0007

5. Mount tackles

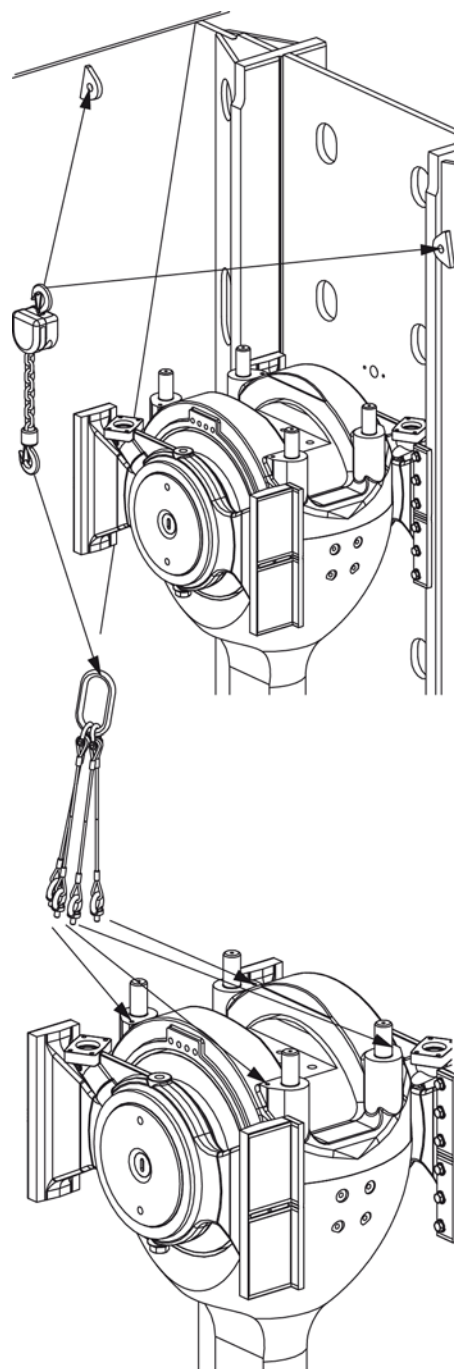
Suspend two tackles from the lifting brackets in the athwartships direction.

Fit the lifting tool on the top of the crosshead bearing cap.

**WARNING****Safe working load (SWL)**

Always use lifting gear with sufficient SWL.

See data.



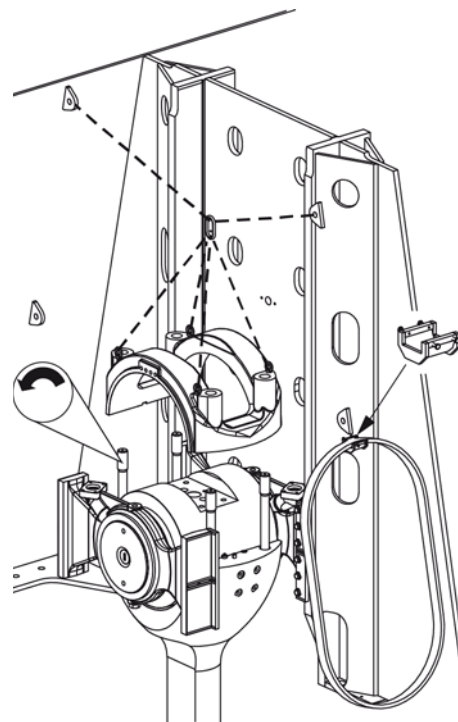
1465-0201-0002D06

6. Dismantling of bearing cap

Dismantle the bearing cap and lift it out of the engine.

Unscrew and remove the studs for the crosshead bearing.

Mount the wire guide in the doorway.



1465-0201-0002D07

7. Mounting of lifting tools

Mount the special lifting tool on the crosshead.

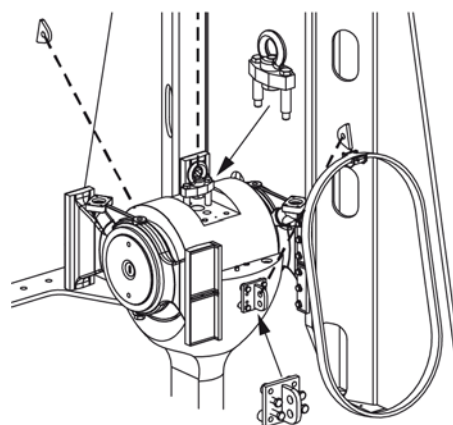
Mount the lifting attachments for fixing the connecting rod, on the head of the connecting rod.

Fasten tackles to the lifting brackets on the frame box wall and attach the tackle hooks to the lifting attachments. Haul the tackles tight.

Attach the flat-plaited wire strap to the engine room crane.

Hook the engine room crane on to the lifting tool on the crosshead, and lift the crosshead.

T14-42



1465-0201-0002D08

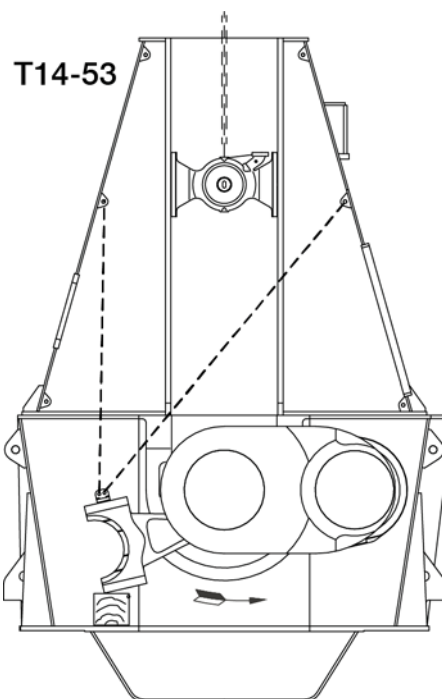
8. Lowering the connecting rod

Using the tackles, tilt the connecting rod towards the exhaust side, while turning the crankthrow towards the manoeuvring side.

Transfer the tackles from one lifting attachment to another as necessary.

When the crankthrow is 90° after BDC, stop turning.

By alternate use of the tackles, tilt the connecting rod until it rests against a couple of wooden planks in the bottom of the bedplate.



1465-0201-0007D09

9. Loosening the crosshead from the guide shoes

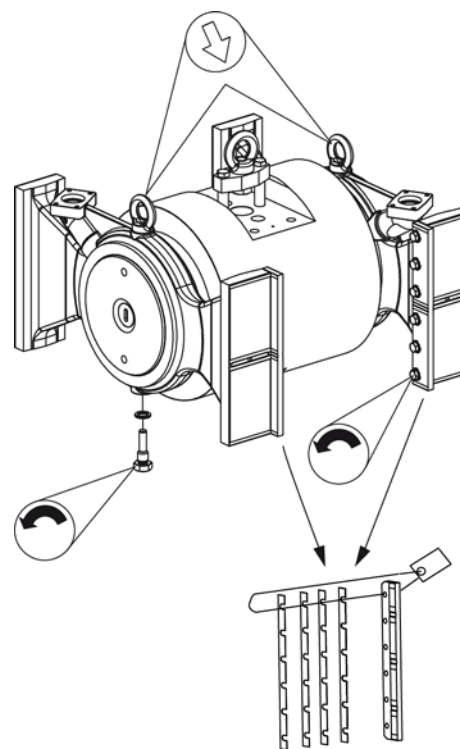
Lower the crosshead to a position just above the main bearing caps.

Remove the guide strips and both guide plates from the guide shoes.

NOTICE

It is recommended to tag the guide strips and shims to avoid mixing them.

Mount lifting eyebolts in both guide shoes.



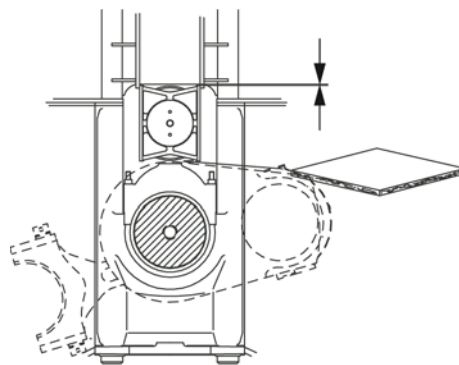
1465-0201-0002D10

10. Lowering the crosshead

Lower the crosshead so that the guide shoes are just below the cutout in the side walls of the frame box.

NOTICE

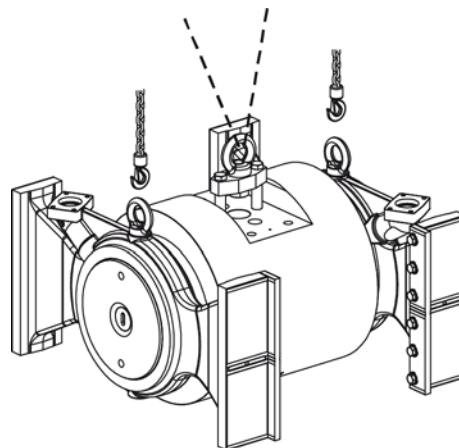
Make sure that the crosshead journal does not touch the crank.



1465-0201-0002D11

11. Securing the guide shoes

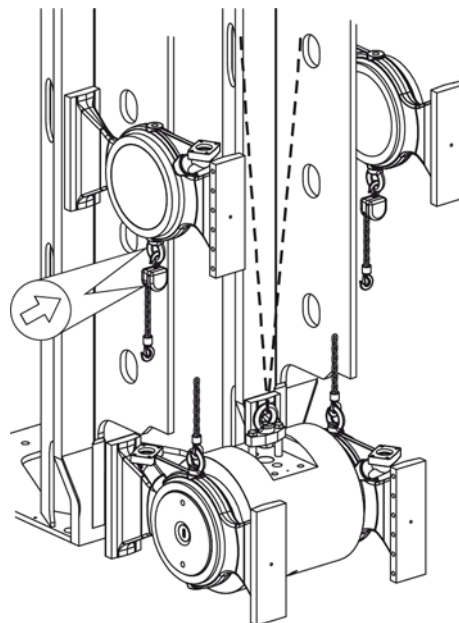
Hook the tackles on to the eyebolts in the guide shoes.



1465-0201-0002D12

12. Adjacent cylinder guide shoes

Mount two eyebolts in the holes for stop screws in the guide shoes in the adjacent cylinder units, and suspend two tackles from the eyebolts.



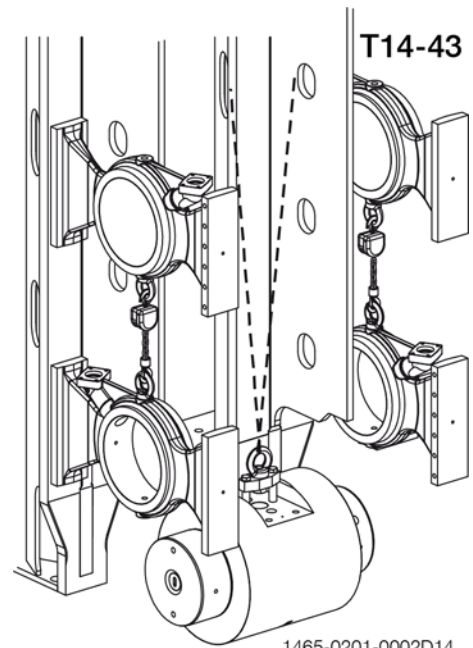
1465-0201-0002D13

13. Removing the guide shoes

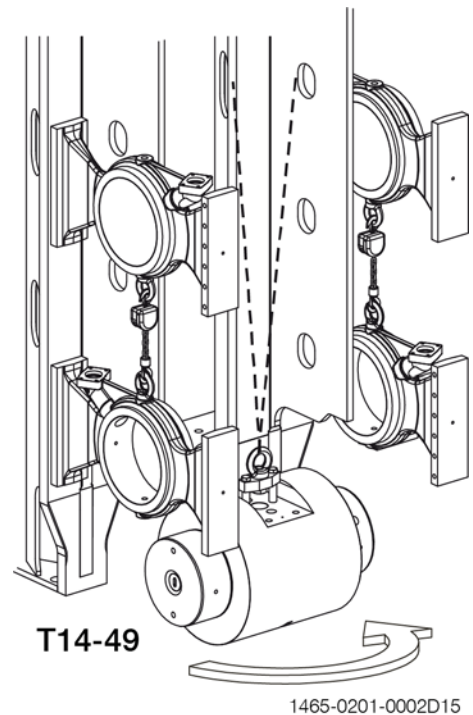
Haul tight the tackles for the guide shoes and, at the same time, pull the guide shoes sideways until they are free of the crosshead.

Take the guide shoes through the openings in the side walls by means of the tackles in the two adjacent cylinders.

Lift the guide shoes to provide space for turning the crosshead.

**14. Crosshead turning**

Turn the crosshead 90°.



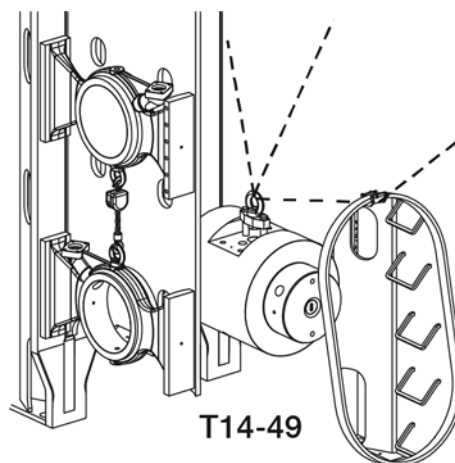
15. Crosshead removal Mount a tackle outside the engine and, by means of wire rope and tackle, remove the crosshead from the engine.

Land and protect the crosshead outside the engine.

If necessary, remove the guide shoes from the engine and tag them.

NOTICE

Take care that the crosshead does not bump into anything as this will damage the sliding surfaces of the crosshead.



1465-0201-0002D16

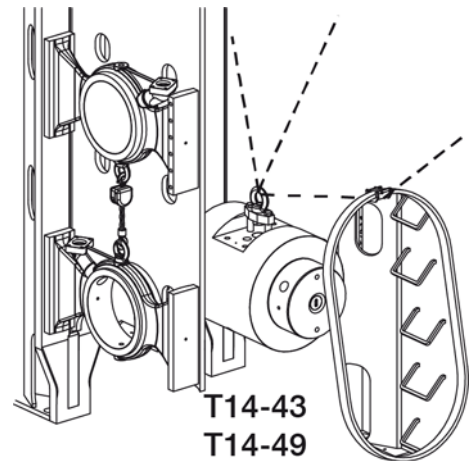
1. Lift the crosshead into the engine

Clean the crosshead and mount the lifting tool with shackle and wire ropes.

Mount the wire guide tool in the frame box door opening.

Suspend two tackles from the top of the frame box between the guides.

Suspend two tackles from the top lifting brackets in the frame box and use them in conjunction with a tackle mounted outside the engine to carefully lift the crosshead and ease it into the crankcase.



1465-0201-0002M01

2. Turn the crosshead into position

Turn the crosshead 90° to enable mounting of the guide shoes.

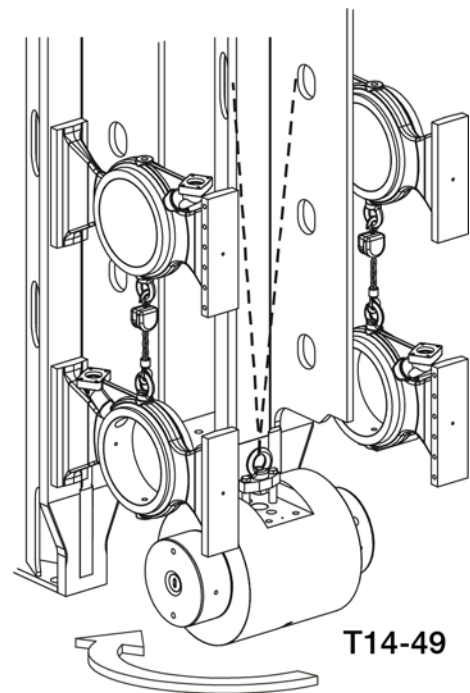
NOTICE

The ends of the crosshead are marked »Fore« and »Aft«.

The markings »Fore« and »Aft« on the crosshead may be reversed on engines with port side configuration.

The oil inlet hole in the crosshead (large diameter) must face towards the guide shoe where the telescopic pipe is mounted.

The oil outlet hole in the crosshead (small diameter) must face towards the guide shoe where the outlet pipe is mounted.



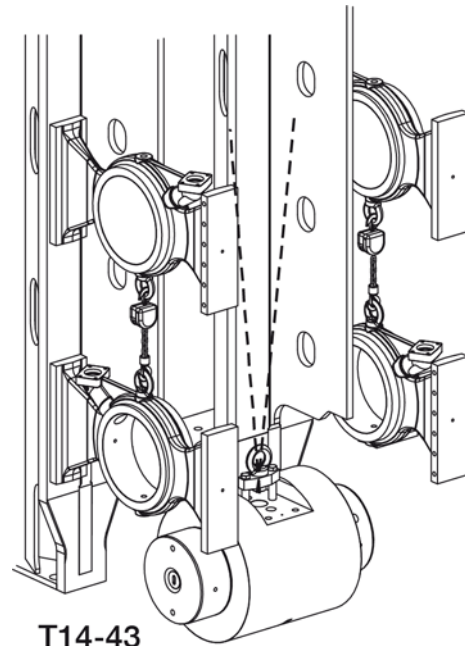
1465-0201-0002M02

NOTICE

When handling the crosshead, take great care that its surfaces are not scratched or damaged.

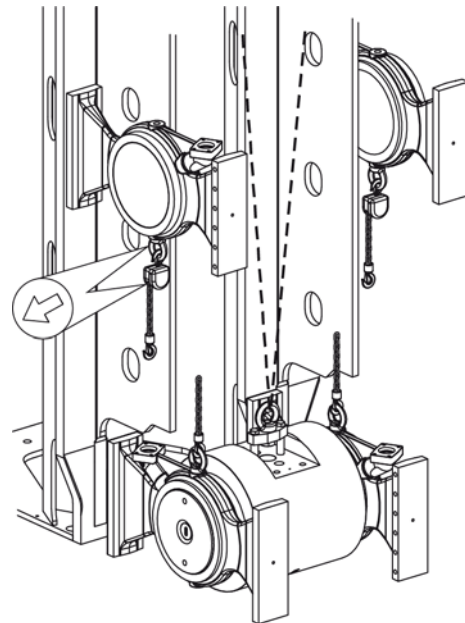
If necessary, protect the crosshead with a cloth.

3. Lower the guide shoes
Lower the guide shoes into position.



1465-0201-0002M03

4. Mount the guide shoes
Lubricate the sliding surfaces of the guide shoes and the crosshead with plenty of clean lubricating oil, and push the guide shoes into position through the openings in the side walls.



1465-0201-0002M04

5. Guide strips and shims

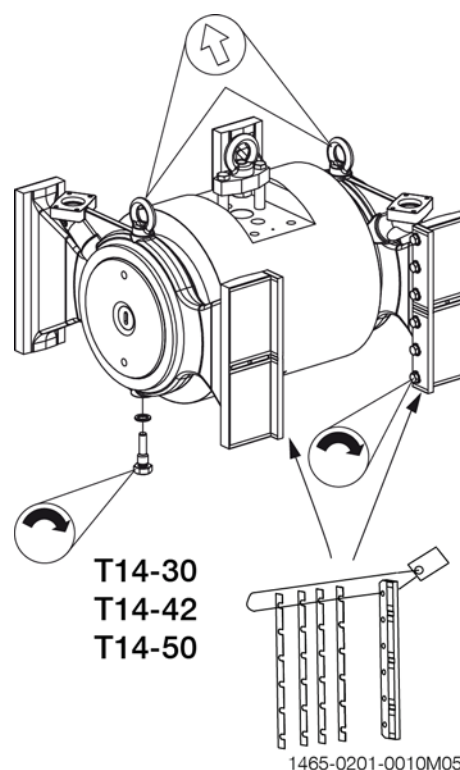
Use the tackles in the top of the frame box to lift the crosshead into a suitable position and mount the guide strips and shims on the sides of the guide shoes.
See data T14-30.

Mount and tighten the stop bolts into the bottom of the guide shoes.
See data T14-50, secure with 'Loctite 243' or similar.

Remove the tackles and the eyebolts from the guide shoes.

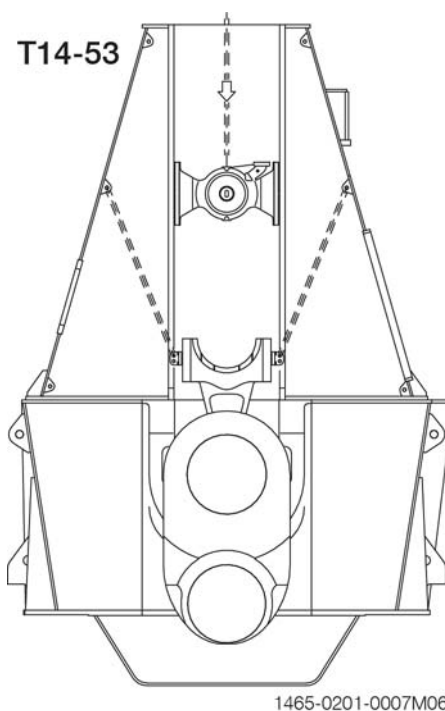
NOTICE

Some engines are provided with a special stop bolt arrangement, with a hexagon screw next to the stop bolt, requiring the use of locking wire.
In this case there is no need to use Loctite.



6. Connecting rod

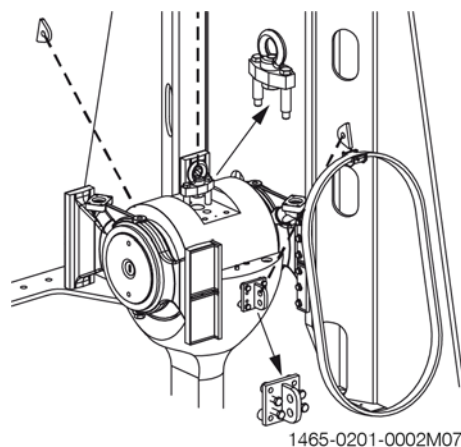
Using the tackles, lift the connecting rod to a vertical position while turning the crankthrow to BDC.



7. Land the crosshead When the connecting rod is in a vertical position, lower the crosshead and land it on the connecting rod.

Remove the lifting attachments from the connecting rod head.

Remove the lifting tool from the crosshead.



1465-0201-0002M07

8. Bearing cap mounting

Remount the studs for the crosshead bearing for tightening.

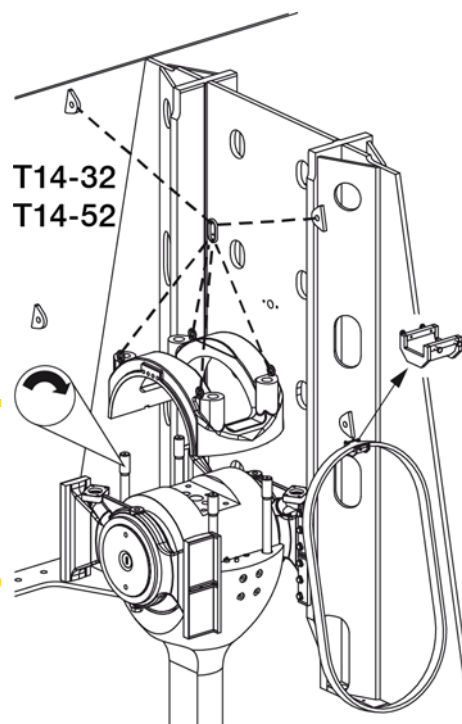
See data.

See work card 7665-0301.

Lift the crosshead bearing cap into the engine.

See work card 2565-0201.

Remove the wire guide from the doorway.



1465-0201-0008M08

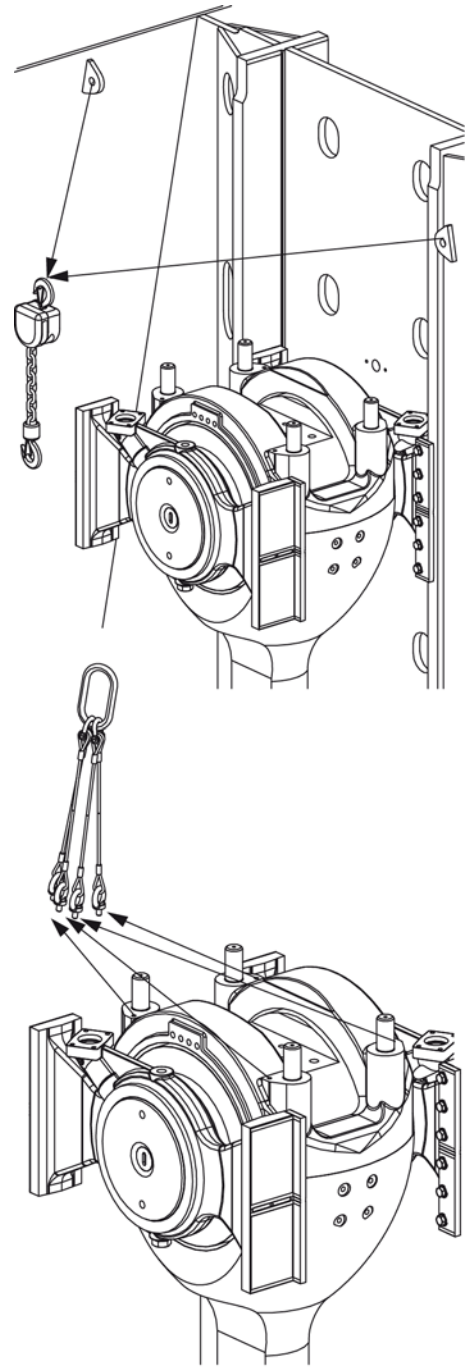
NOTICE

If one or more piston rod studs have been removed, then remount the studs.
See data.

9. Tools removal

Remove all tackles from the crankcase.

Remove the lifting tool from the crosshead bearing cap.



1465-0201-0002M09

10. Thrust piece mounting

Mount the thrust pieces on the bearing cap.

NOTICE

Make sure that there is clearance between the thrust piece and the crosshead, fore and aft, before any tightening of the thrust piece.

Tighten the bolts to the torque stated *in data*.

For correct tightening, see *work card 7665-0301*.

11. Hydraulic nuts

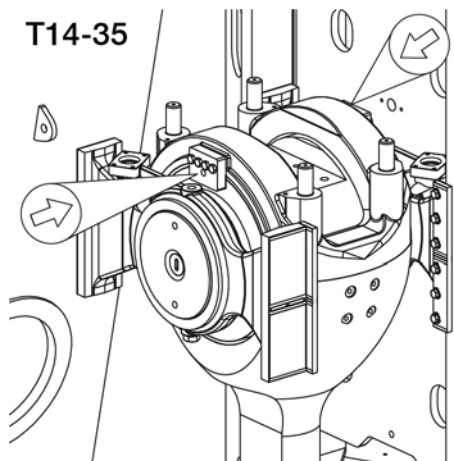
Mount the spacer rings and the hydraulic jacks for tightening the nuts on the crosshead bearing studs.

Tighten all four crosshead bearing cap nuts simultaneously.

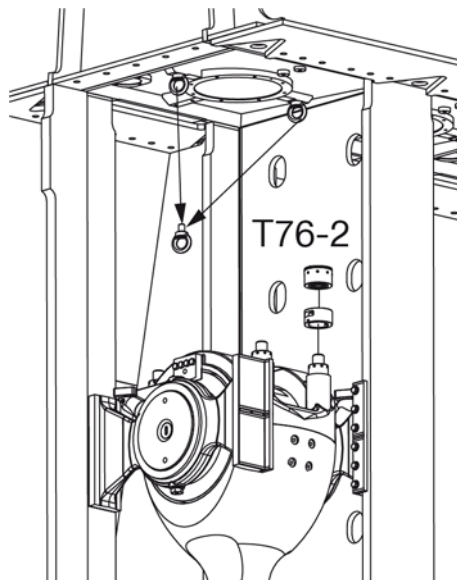
For operation of the hydraulic tools, see *work card 7665-0101*.

Remove the lifting eyebolts.

T14-35



1465-0201-0002M10



1465-0201-0002M11

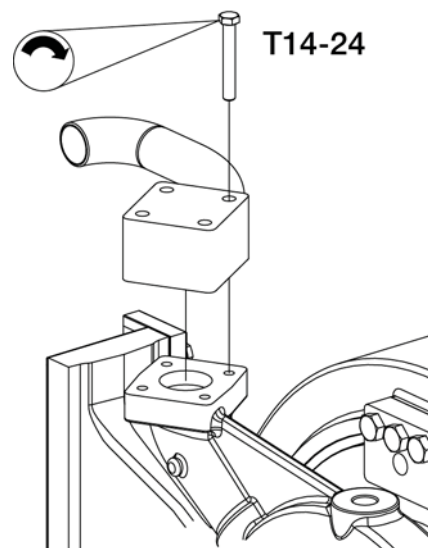
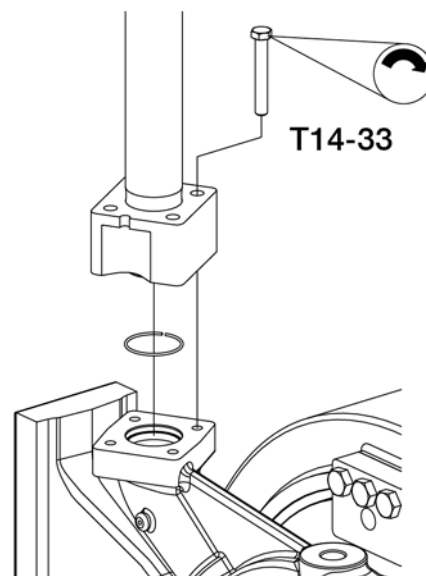
12. Telescopic pipe

Turn the crankshaft to TDC.

Land the telescopic pipe on the guide shoe.

For tightening the bolt in the corner behind the telescopic pipe, use the offset tool along with the torque wrench.

Mount the drain oil slotted pipe and the cooling oil outlet pipe on the guide shoe.



1465-0201-0007M12

13. Finally

Mount the lubricating oil pipes on the main bearing caps.

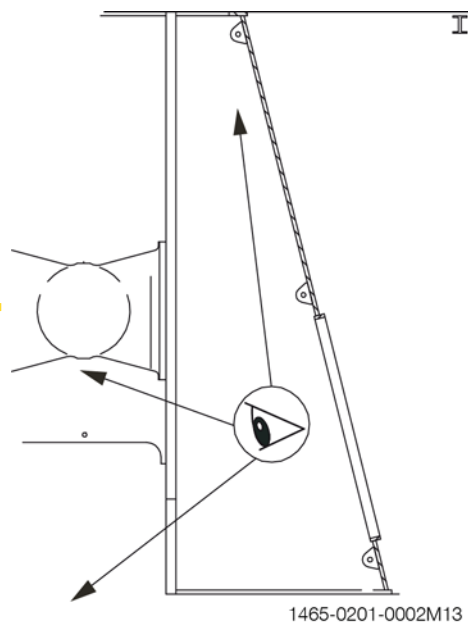
Mount the piston.
See work card 2265-0401.

Check that all tools have been removed from the crankcase.

NOTICE**Bearing wear monitoring**

The engine may be equipped with a bearing wear monitoring (BWM) system.

If the bracket for the BWM probe has been dismantled, re-mount the bracket and re-adjust the BWM system according to the BWM system manufacturer's instructions.



Safety**Precautions**

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T14-52	Connecting rod studs, screwing-in torque	680	Nm
T14-53	Connecting rod, without bearing caps	2400	kg
T14-54	Connecting rod complete	3200	kg
T14-55	Crosshead bearing stud	10	kg
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1470-0300	041	Wire guide
1470-0300	053	Lifting attachment for connecting rod
1470-0300	077	Chain for suspending piston
1470-0300	090	Bracket, support of crosshead
1470-0310	-	Connecting rod, hydraulic tools
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	106	5-way distributor block, complete
7670-0100	118	3-way distributor block, complete
7670-0200	-	Torque spanners
7670-0300	-	Lifting tools, etc

WARNING

ALWAYS ensure that the turning gear is engaged during inspection.

- Block the starting air supply to the main starting valve.
- The turning gear must always be operated exclusively by the person(s) who enters the crankcase.
- *See description 0545-0100.*

NOTICE

Before dismantling the connecting rod, suspend the piston rod and dismount the crosshead bearing cap.
See work card 2565-0201.

1. Tackles

Suspend two tackles from the two lifting brackets at the sides of the frame box.

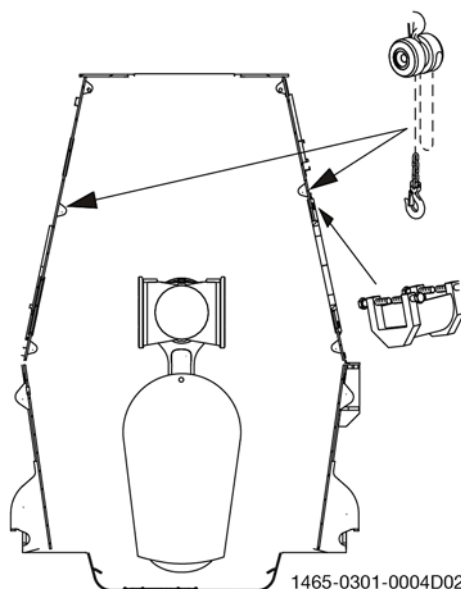
WARNING

Safe working load (SWL)

Always use lifting gear with sufficient SWL.

See data.

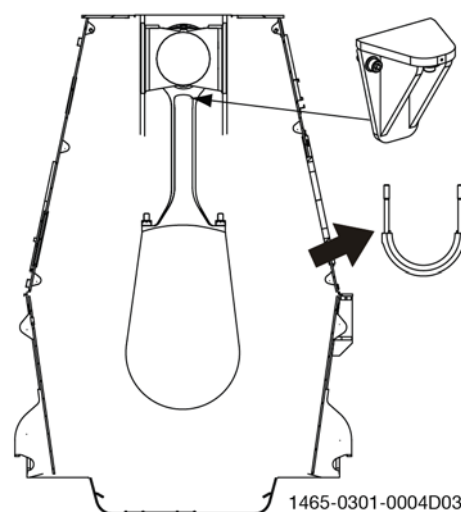
Mount the wire guide in the top of the crankcase doorway.



2. Turn the crank to TDC

Dismantle the crankpin bearing cap, and remove it from the engine.
See work card 2565-0301.

Mount the support brackets for guide shoes on the web plates.



3. Lifting attachments Mount the lifting attachments for fixing the connecting rod on the head of the connecting rod.

NOTICE

There are different lifting attachments for each end of the connecting rod.

Use the tackles fastened to lifting brackets **A** and **B** on the frame box wall, and attach the tackle hooks to the mentioned lifting attachments on the connecting rod.

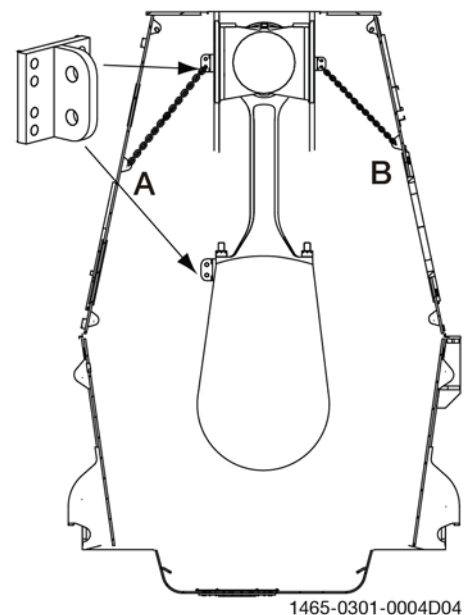
Haul the tackles tight.

Also mount a lifting attachment in the crankpin end of the connecting rod, on the exhaust side.

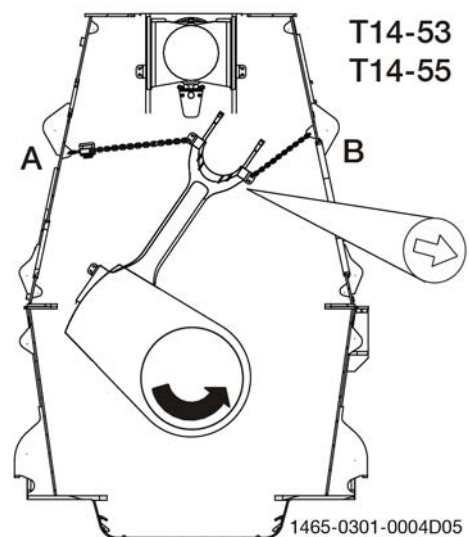
Carefully turn the crank down towards the exhaust side, until the crosshead guide shoes rest on the supports.

Adjust the support brackets to the guide shoes so that the weight of the crosshead is evenly distributed on the two supports.

4. Turn the crank BDC Turn the crankthrow towards BDC while “following” with the tackles, thus continuously supporting the connecting rod.



1465-0301-0004D04



1465-0301-0004D05

5. Turn the crank 90° Turn the crankthrow to 90° before BDC.

Remove the four studs from the connecting rod.

Shift the hook of the tackle attached to lifting bracket **B** from the lifting attachment on the lowermost side of the connecting rod to the lifting attachment on the uppermost side.

6. Tilt the connecting rod

By means of the tackle from lifting bracket **A**, tilt the connecting rod towards the manoeuvre side until the connecting rod is leaning out of the doorway.

Attach a tackle to lifting bracket **A** on the frame box wall and connect the tackle hook to the lifting attachment at the lower end of the connecting rod.

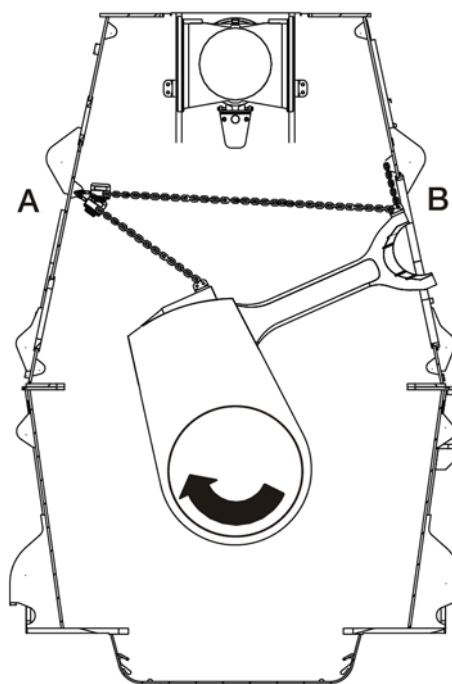
Turn the crank carefully upwards while "following" with the tackles, guiding the head of the connecting rod out of the doorway.



WARNING

Risk of breakage

Carefully observe the tension of the tackle chains while turning.



1465-0301-0004D07

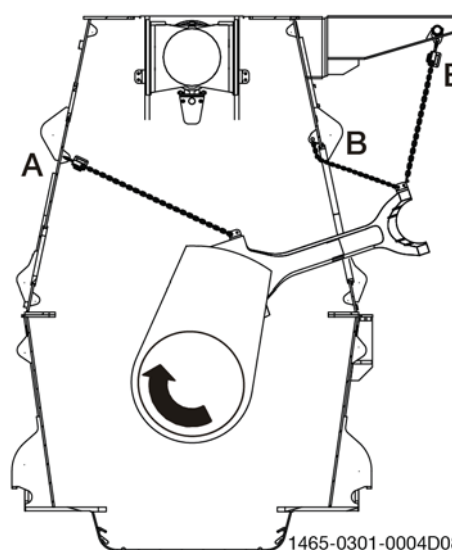
7. Attach a tackle

Attach a tackle to the gallery-mounted lifting bracket **E**, and hook on to the lifting attachment on the connecting rod.

NOTICE

In some cases, a travelling trolley is mounted on an H beam, under the gallery.

In this case, the travelling trolley may only be used for vertical lift. Any diagonal lift should be done by using tackles and fibre round slings around the H beam.



1465-0301-0004D08

Shift the tackles from one lifting bracket/attachment to the other, as required.

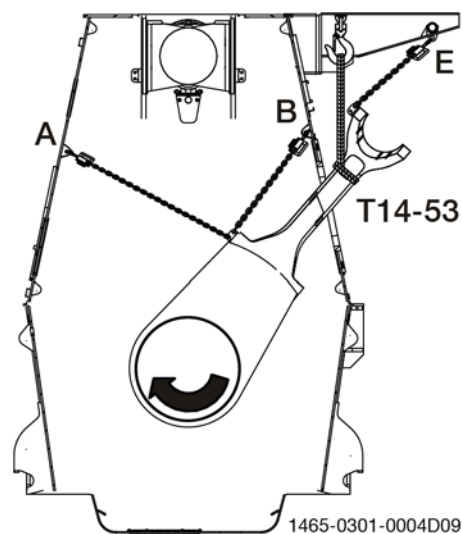
Remove the floor chequer plate for the pertaining cylinder.

8. Lifting the connecting rod out of the engine

Place a wire rope round the connecting rod, hook on the engine room crane and haul tight.

Continue turning upwards till about 30° after TDC, while “following” with the tackles and the engine room crane.

Lift the connecting rod out of the engine using the engine room crane and the tackles.

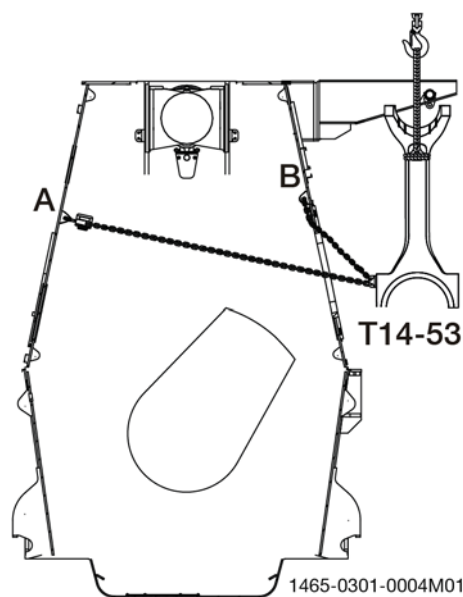


1. Apply oil to the bearing shell

Equip the connecting rod with the same lifting attachments as mentioned under dismantling.

Turn the crank to a position about 30° past TDC on the manoeuvre side.

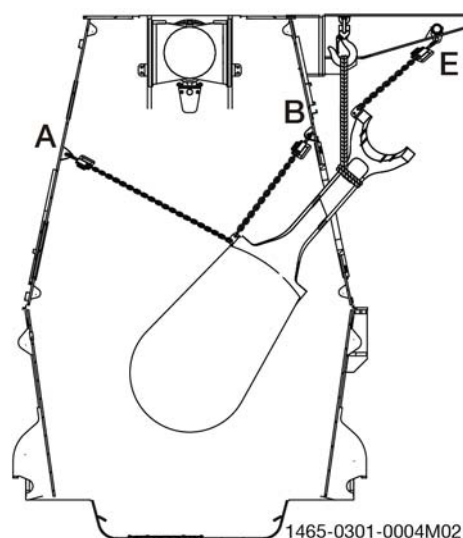
Apply clean lubricating oil to the crankpin bearing shell and journal.



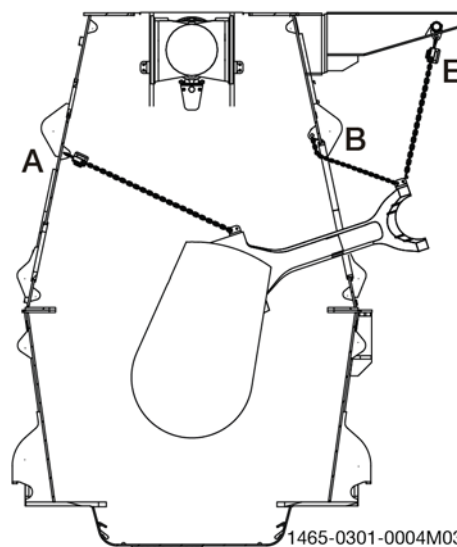
2. Moving the connecting rod into the crankcase

Lift the connecting rod carefully into the crankcase by alternate use of the engine room crane and the tackles attached to lifting brackets A and B.

Attach a tackle to bracket E and the upper end of the connecting rod.

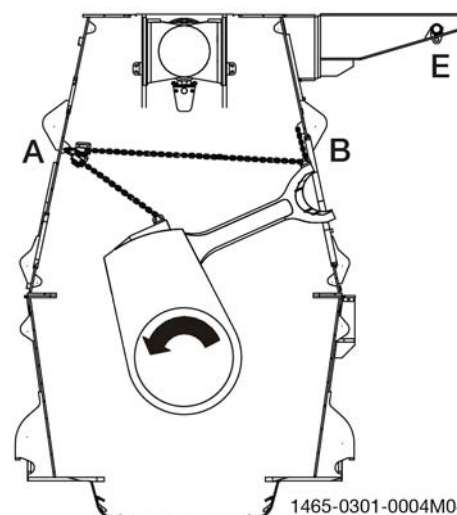


3. The connecting rod rests on the crankpin journal
- When the end of the connecting rod rests on the crankpin journal, shift tackle **B** from the lower end to the upper end of the connecting rod.



4. Engine room crane
- Turn the crankthrow towards BDC, past TDC, while 'following' with the tackles. Lower the engine room crane and remove the strap around the connecting rod.

When the uppermost lifting bracket on the connecting rod is just below lifting point **B**, remove the tackle from lifting point **E**, mount a tackle between lifting point **A** and the upper end of the connecting rod.

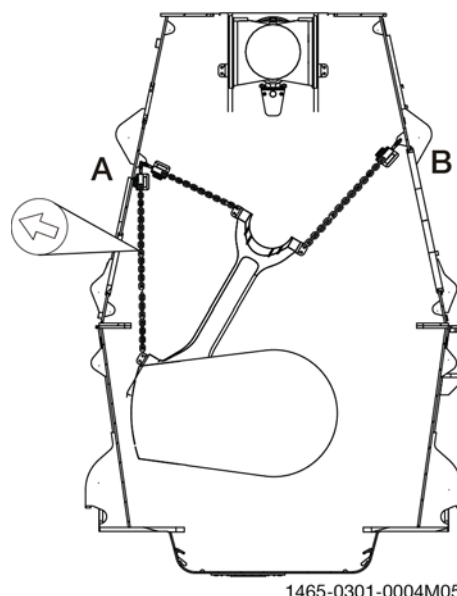


5. Lifting attachments
- Turn the crankthrow to 90° before BDC, and use the tackles to raise the connecting rod to an upright position.

Shift tackle **B** from the lifting attachment on one side to the other side of the connecting rod.

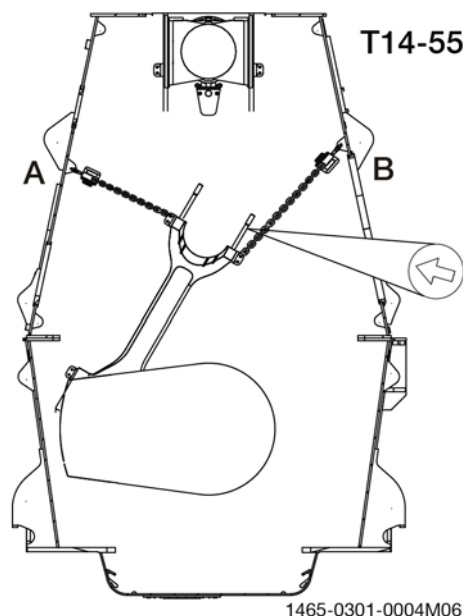
Remove tackle **A** from the lower end of the connecting rod.

Remove the lifting attachment at the lower end of the connecting rod.



6. **Connecting rod studs** Screw the studs into the connecting rod. Using the stud setter and a torque wrench, tighten the studs.

Lubricate the crosshead bearing shell and journal.

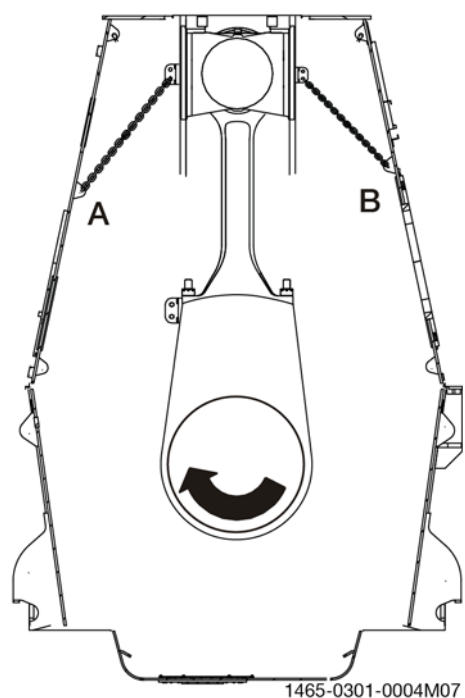


7. **Landing the crosshead on the connecting rod**

Turn the crankthrow towards TDC while 'following' with the tackles, carefully land the crosshead on the connecting rod.

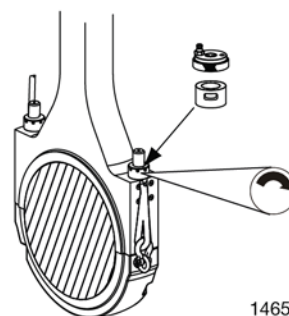
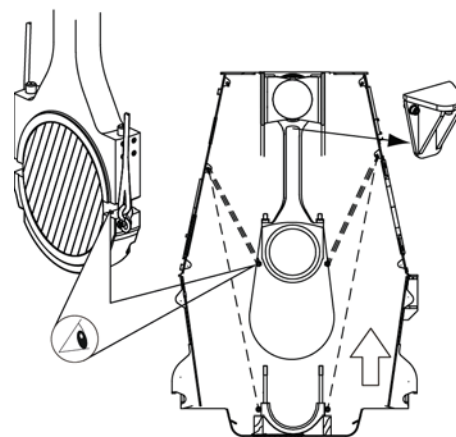
NOTICE

Take care that the studs do not damage the crosshead bearing journal.



8. The crankpin bearing cap
When the crank is in TDC, mount the crankpin bearing cap.
See work card 2565-0301.

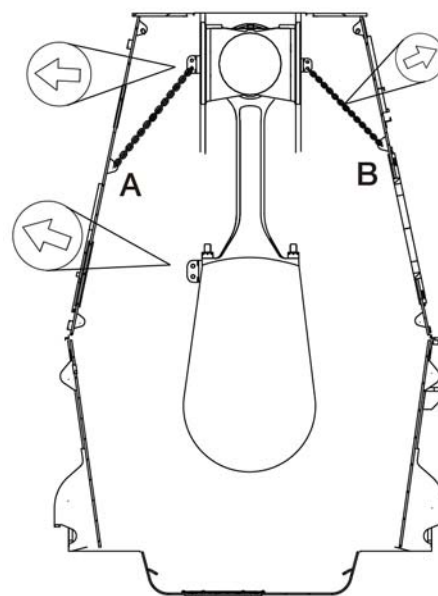
Remove the crosshead supports.



1465-0301-0004M08

9. Cross head bearing cap and piston rod
Mount the cross head bearing cap and the piston rod.
See work card 2565-0201.

10. Tackles and lifting attachments
Remove the tackles and lifting attachments.



1465-0301-0004M09

Safety Precautions

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Engage turning gear
○	Shut off cooling water
○	Stop lubricating oil supply
○	Shut down hydraulic power supply



Data

Ref.	Description	Value	Unit
T14-60	4.0" Chain- 2nd order moment compensators-Fore.		
T14-61	Teeth on chain wheel, max. wear	3.5	mm
T14-62	Original length (chain pitch x 10 links)	1016	mm
T14-63	10 links measurements + 1 of a tensioned chain = scrapping of chain	1026	mm
T14-60	4.5" Chain- 2nd order moment compensators-Aft.		
T14-61	Teeth on chain wheel, max. wear	4	mm
T14-62	Original length (chain pitch x 10 links)	1143	mm
T14-63	10 links measurements + 1% of a tensioned chain = scrapping of chain	1154.4	mm

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1470-1400	073	Chain assembling tool
1470-1400	085	Chain disassembling tool
7670-0300	-	Lifting tools, etc
1470-1400	050	Chain assembling tool
1470-1400	061	Chain disassembling tool
7670-0300	-	Lifting tools, etc

1. General inspection Make a general inspection for loose bolts and screws.
- Inspect lube oil pipes for damage, and check jet nozzles for possible stoppages or deformations.
- Examine the rubber track of the guide ways for cracks or other damage.
- Replace the guide way if bits have started to be “plucked out” of the rubber track.



Slippery surface
Use safety harness.

2. Wear check & measurements

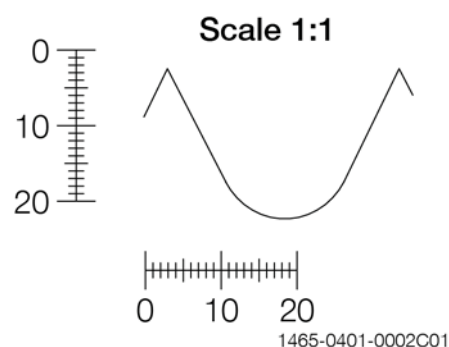
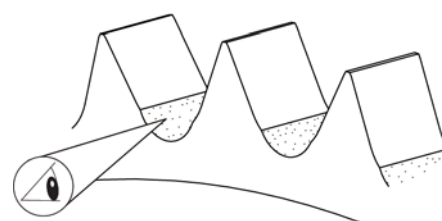
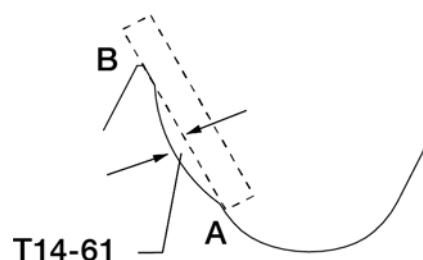
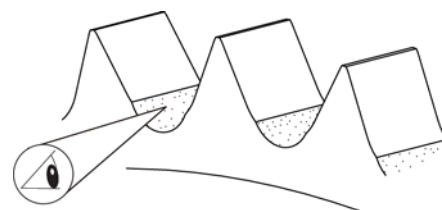
Check the teeth of the chain wheels. If abnormal wear is found, take a measurement.
See data.

Measurements are best taken by placing a short straight-edge over points **A** and **B** and then measuring the distance *T14-61*.

If abnormal wear is observed at the bottom of the teeth, make a drawing in scale 1:1 of the teeth and wear profile.

For assessing the measurement results, contact MAN Diesel & Turbo.

In most cases, scratches caused by the side plates of the chain will be found on the sides of the teeth. Such scratches can generally be considered normal.



3. Chain's marking

On engines with more than one chain, the chains for the camshaft drive are matched together to ensure an even load distribution.

To keep such matching chains in their pairs, the side plates of the outer link nearest to the assembled link have been marked with year, month, day and chain number.

Example:
No. 1 order,
120520 1A
120520 1B

(120520 2C, possible 3rd chain)

No. 2 order,
120520 2A
120520 2B

(120520 2C, possible 3rd chain)

On the same links there is an arrow (→) which indicates the mounting direction.

Check the chains for cracks on possibly defective rollers and side plates.

Check that the chain rollers can run freely and that the chain links can freely move on the pin and bushing (that they are not "seized" between the pin and the bushing).

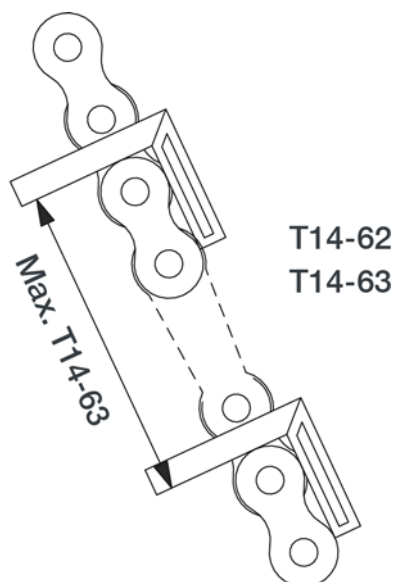
It is normal, however, that the rollers get light, circumferential scratches during the running-in period. These fine scratches are of no importance and need not be considered.

It is recommended that each single link is checked.

4. Compare the length of 10 chain links

Check chain wear by measuring the length of 10 chain links. Use two master squares and a steel measuring tape as shown on the sketch. Compare the result with the value given *in data*.

If necessary, adjust the chain tightener.
See work card 1465-0501.



1465-0401-0001C07

1. The chain

It may become necessary to disassemble the chain if, for instance, cracked rollers or seizures between pin and bushing have been discovered during the inspection.

NOTICE

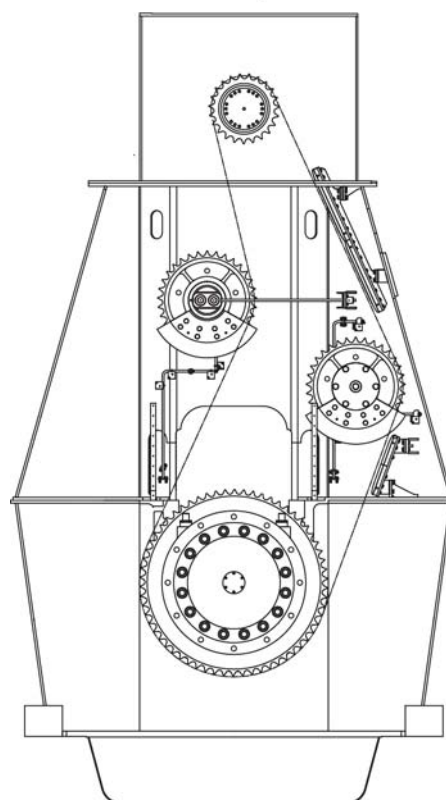
Every time a chain link is disassembled, a new link must always be mounted as the link pin press-fit is destroyed when breaking the chain.

When a new link is mounted in one chain, the corresponding link in the other chain must also be renewed.

2. Loosen the chain tightener

Remove the tension on the chain by loosening the chain tightener.
See work card 1465-0501.

Turn the engine until the slack part of the chain, with the chain link that is to be disassembled, is in a favourable position for the work. If the engine is equipped with balance weights, continue the turning until the balance weights are hanging vertically downwards, as shown in the sketch.

With compensator

1465-0401-0006D01

3. Mount a wire around the link rollers
the link rollers
- Mount a wire around the link rollers a short distance from the disassembly point, and tighten the wire lightly with a tackle.

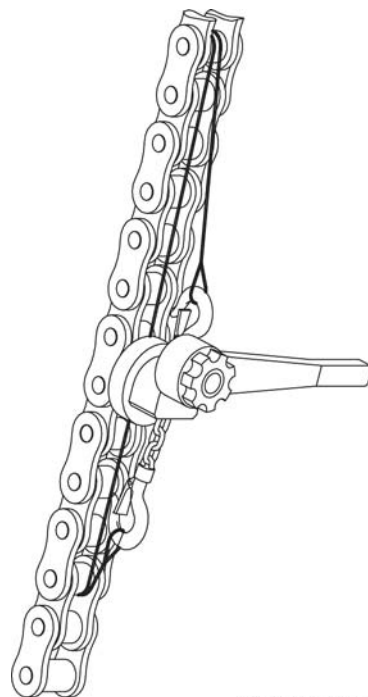
Protect the link rollers over which the wire is wrapped.

NOTICE

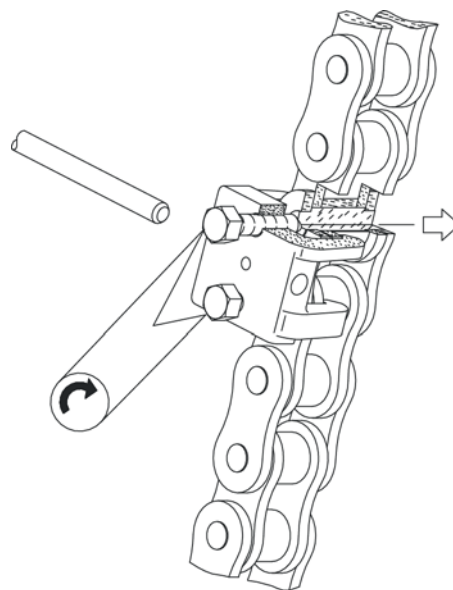
If the chain is to be completely removed, contact MAN Diesel & Turbo for further information.

The rivetting of the pins that are to be pressed out is to be chiselled or ground away.

4. Chain bursting tool
- Place the chain bursting tool over the outer chain link, and dismantle the link by alternately tightening the screws on the tool.



1465-0401-0001D02

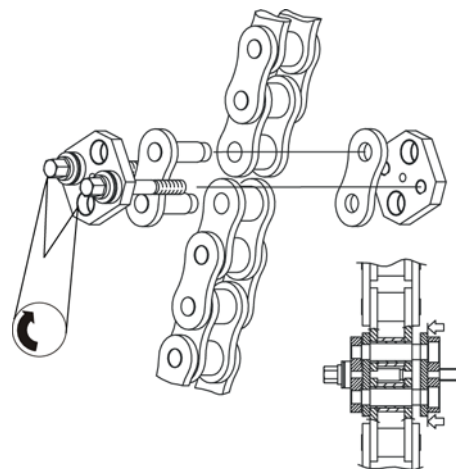


1465-0401-0001D03

Before assembling the inner and outer links, clean the pins and bushings.

1. **Compression tool** Combine the inner chain links with the outer chain link and mount the compression tool.

Force the loose side plate of the outer link into place by alternately tightening the screws on the compression tool.



1465-0401-0001M01

2. **Remove the tools** When the link has been assembled, remove the compression tool and lock the pin ends by rivetting.

Remove the tackle and wire and adjust the chain tension.

See work card 1465-0501.

Safety**Precautions**

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Engage turning gear
○	Shut off cooling water
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1070-0300	-	Hydraulic tools for large parts
1470-0500	-	Hydraulic tools - chain tightener
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	023	Hydraulic pump, hand operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	060	Hose with unions, 5000 mm
7670-0100	118	3-way distributor block, complete

WARNING

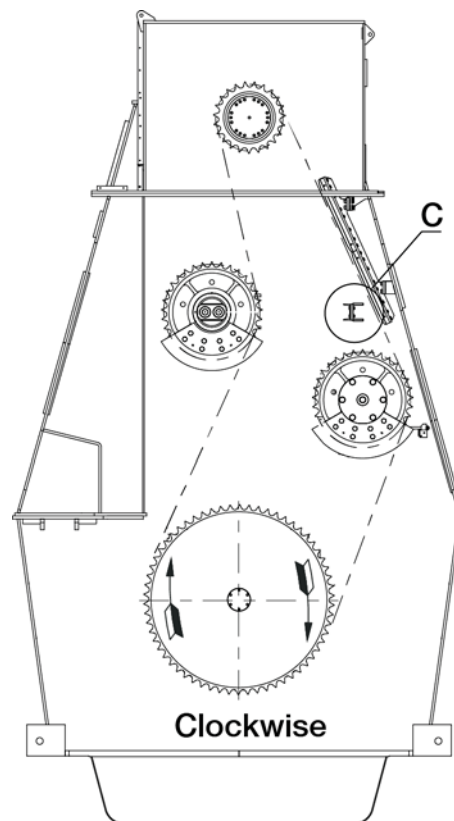
Slippery surface
Use safety harness.



1. Turn the engine

Turn the engine in the clockwise direction to get the slack part of the chain to the tightening wheel.

Continue turning until the flyweights are hanging almost vertically downwards.

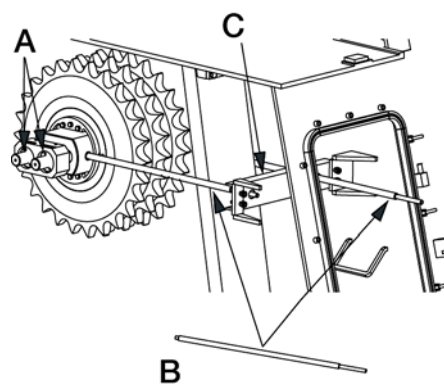


1465-0501-0010001

2. Tightening tool

Mount the tightening tool studs **B** in the threaded holes in the tightener wheel shaft.

This is done through the opening in the supports on the guide bar **C**.



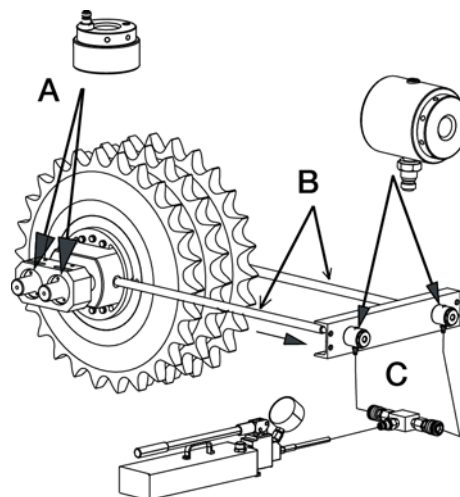
1465-0501-0010002

3. Hydraulic nuts A Loosen the hydraulic nuts **A** on the chain tightener wheel (one at a time).
See data T76-01.

For operation of the hydraulic tools, see work card 7665-0101.

4. Chain tightener tool Mount the chain tightener tool nuts and sleeves on the studs **C**, and tighten both by hand. After tightening by hand, use the hydraulic jacks simultaneously to the value stated.
See data T76-02.

Use the hand operated hydraulic pump for this operation.



1465-0501-0010003

5. Tighten nuts A Tighten one of the hydraulic nuts **A** to the value stated
See data T76-02.

Then tighten the other nut to the value stated
See data T76-02

Finally re-tighten the first hydraulic nut to the value stated.
See data T76-02.

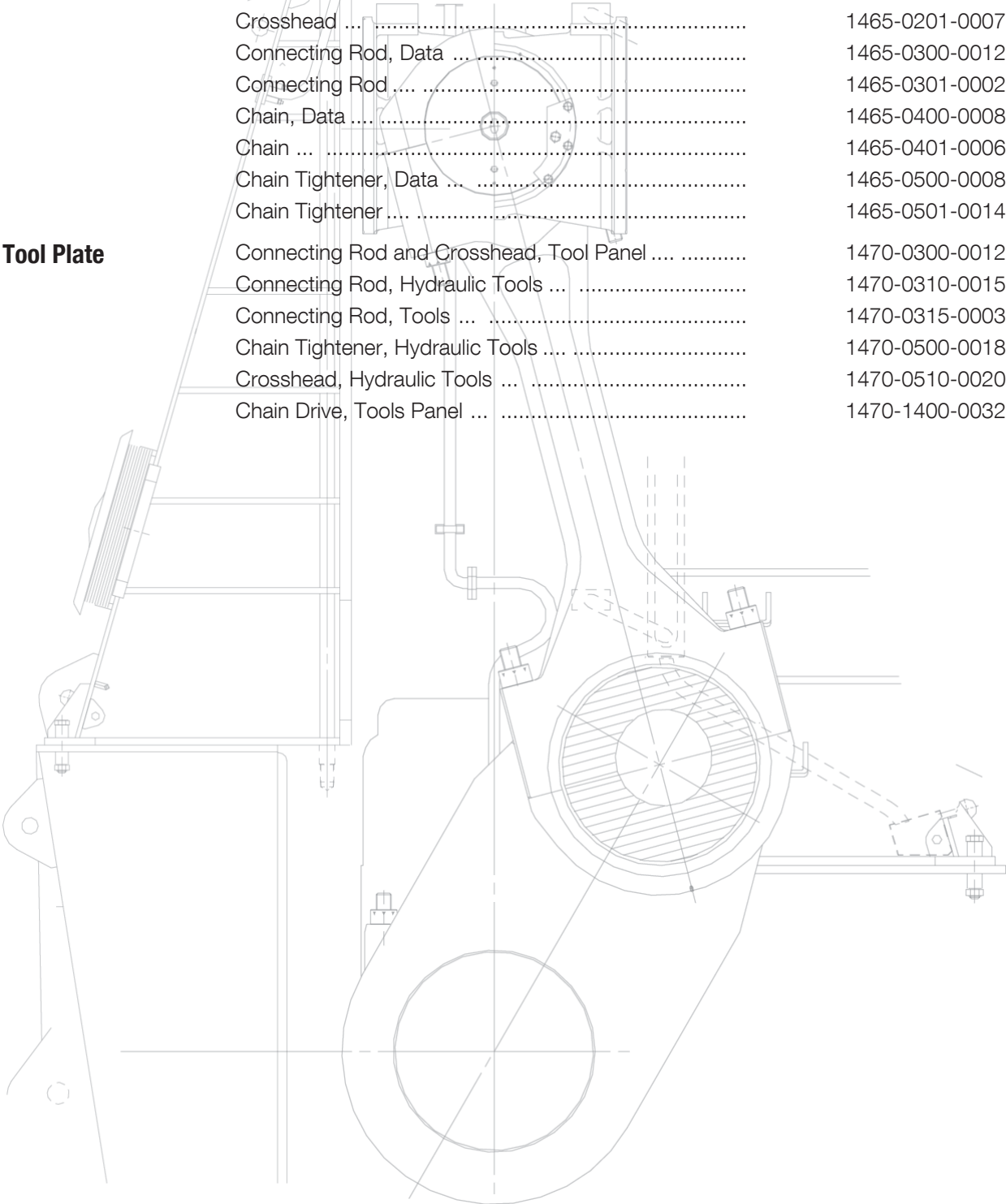
Use the hydraulic pump for this operation.

6. Loosen nuts C Loosen nuts **C** and remove chain tightener tools.

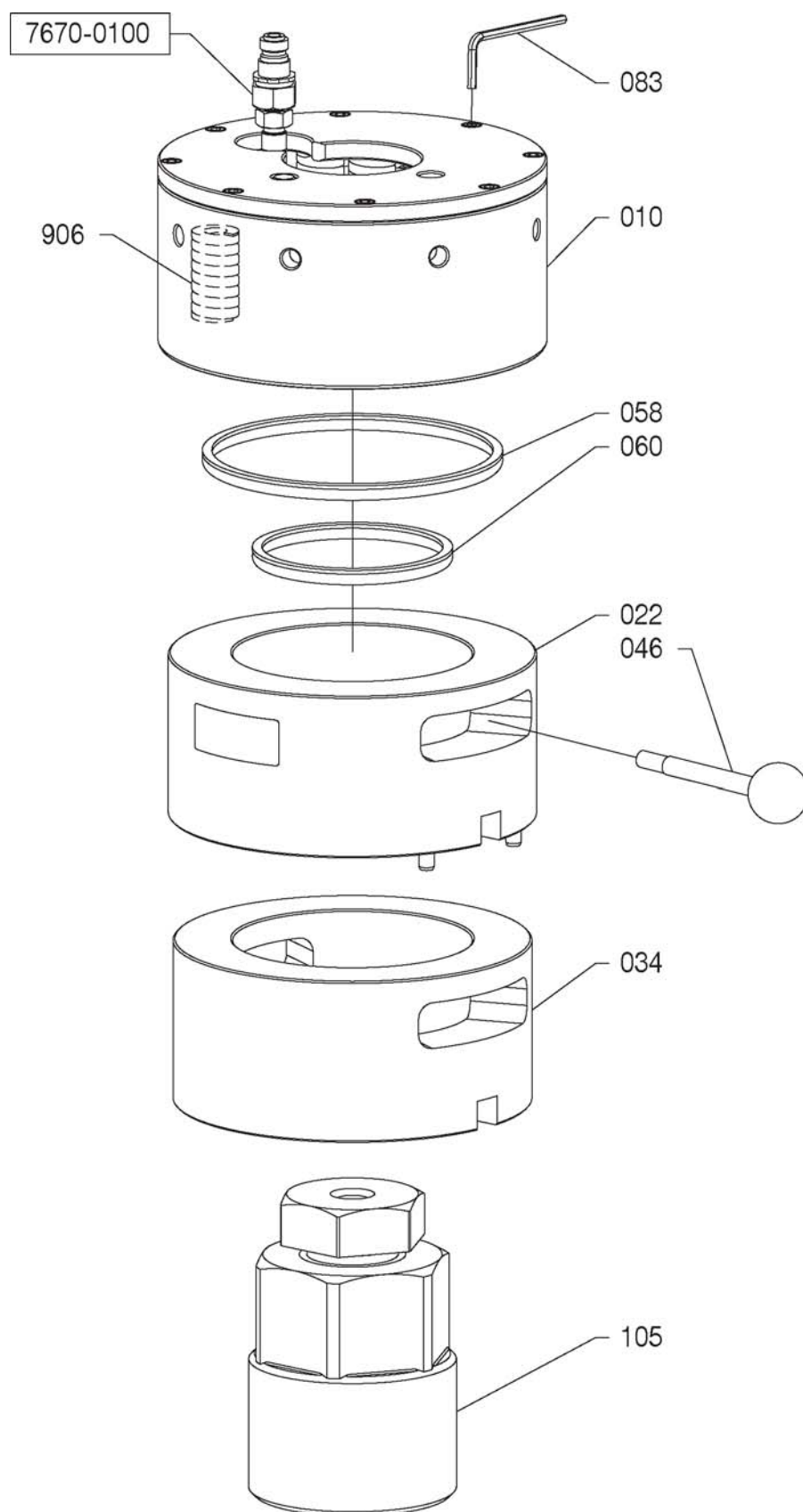
Preface Chapter
Work Card

Tool Plate

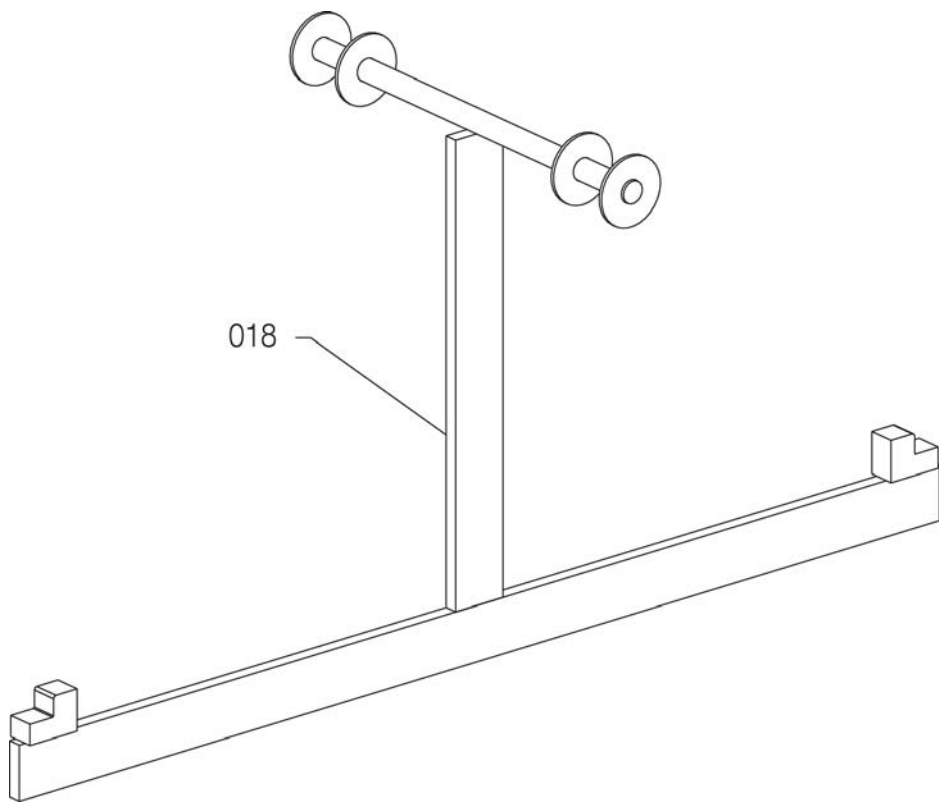
Driving Gear	1440-0100-0002
Reciprocating Parts, Data	1465-0100-0014
Reciprocating Parts	1465-0101-0004
Crosshead, Data	1465-0200-0012
Crosshead	1465-0201-0007
Connecting Rod, Data	1465-0300-0012
Connecting Rod	1465-0301-0002
Chain, Data	1465-0400-0008
Chain	1465-0401-0006
Chain Tightener, Data	1465-0500-0008
Chain Tightener	1465-0501-0014
Connecting Rod and Crosshead, Tool Panel	1470-0300-0012
Connecting Rod, Hydraulic Tools	1470-0310-0015
Connecting Rod, Tools	1470-0315-0003
Chain Tightener, Hydraulic Tools	1470-0500-0018
Crosshead, Hydraulic Tools	1470-0510-0020
Chain Drive, Tools Panel	1470-1400-0032



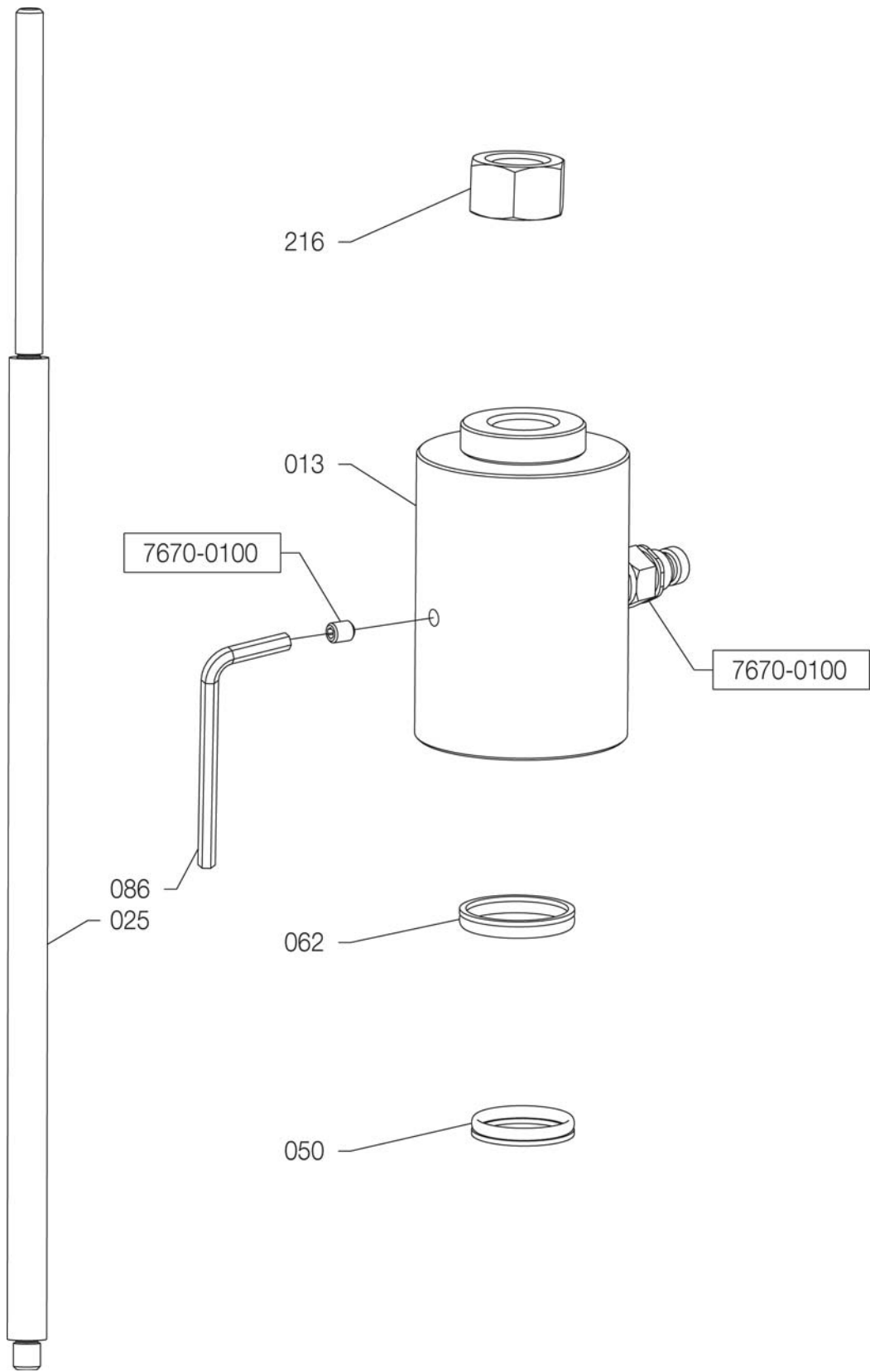
Item No.	Qty	Item Designation
016	-	Panel for tools ms904
028	-	Name plate
041	-	Wire guide
053	-	Lifting attachment for connecting rod
065	-	Lifting tool for crosshead
077	-	Chain for suspending piston
089	-	Retaining tool for telescope pipe
100	-	Bracket, support of crosshead
112	-	Rubber cover for croshead
124	-	Rubber cover for crosshead
219	-	Torque wrench offset tool
256	-	Lifting attachment for connecting rod
268	-	Eye bolt
281	-	Protective screw
293	-	Wire sling



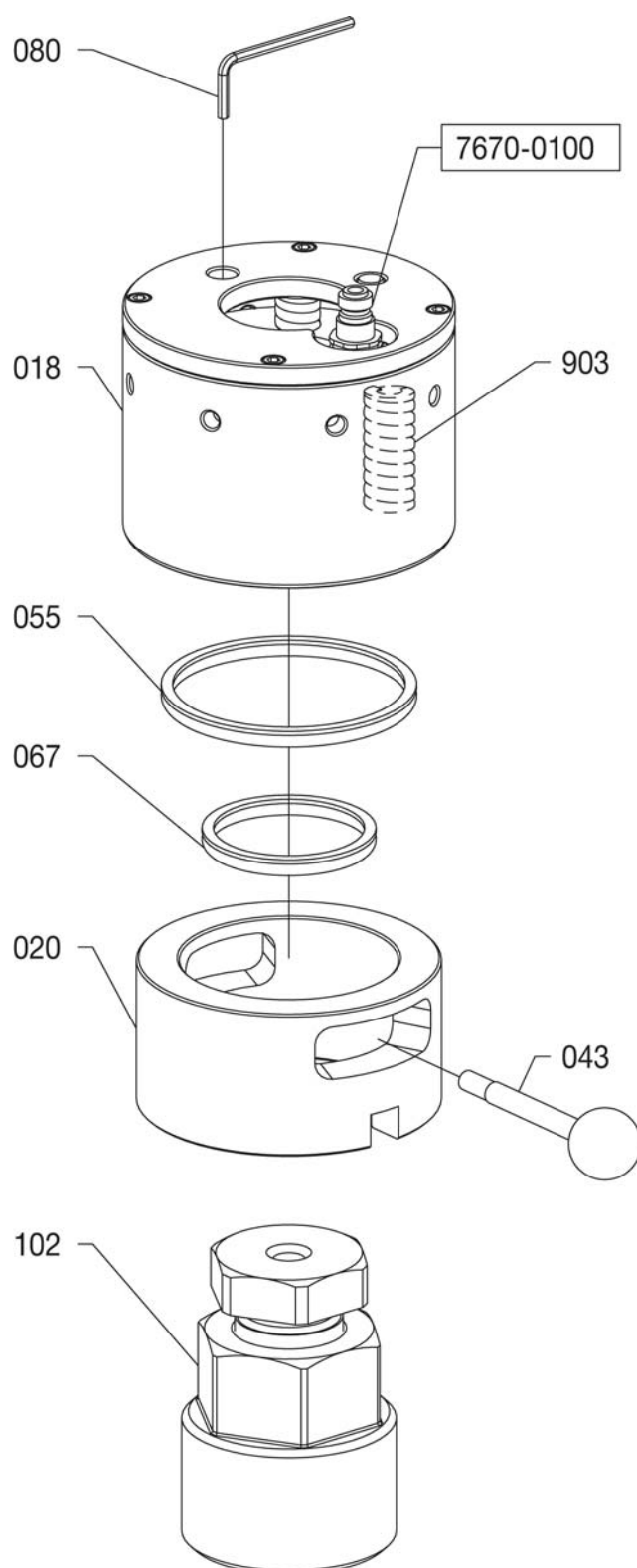
Item No.	Qty	Item Designation
010	-	Hydraulic jack, complete
022	-	Support for hydraulic jack
034	-	Support for hydraulic jack
046	-	Ball handle
058	-	Sealing ring with back-up
060	-	Sealing ring with back-up
083	-	Hex key
105	-	Stud setter
906	-	Spring



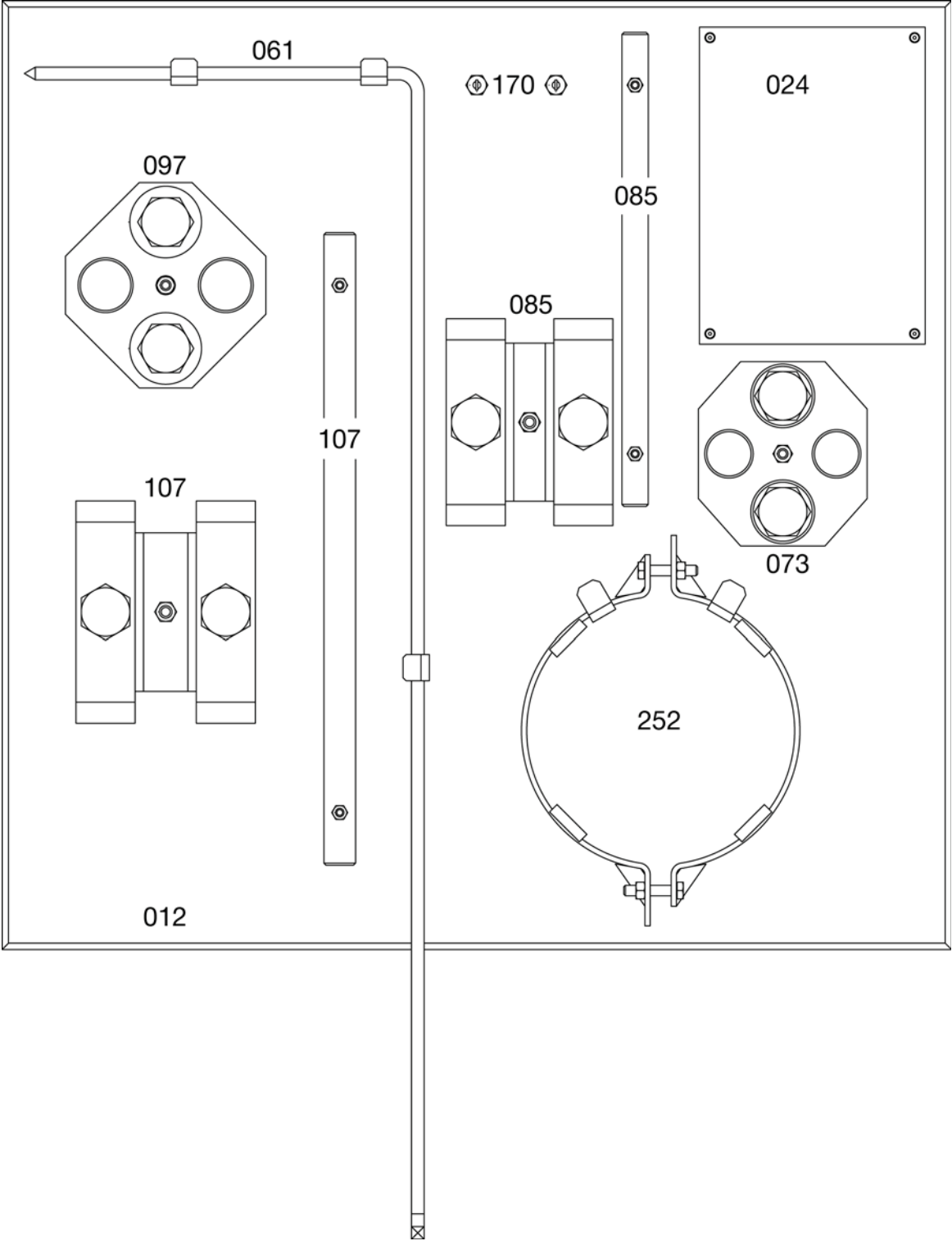
[illegible]



Item No.	Qty	Item Designation
013	-	Hydraulic jack, complete
025	-	Stud
050	-	Sealing ring with back-up
062	-	Sealing ring with back-up
086	-	Hex key
216	-	Nut



Item No.	Qty	Item Designation
018	-	Hydraulic jack, complete
020	-	Support for hydraulic jack
043	-	Ball handle
055	-	Sealing ring with back-up
067	-	Sealing ring with back-up
080	-	Hex key
102	-	Stud setter
903	-	Spring



Chain Drive Tools Panel

Plate
1470-1400-0032

Chain Drive Tools Panel

Plate

1470-1400-0032

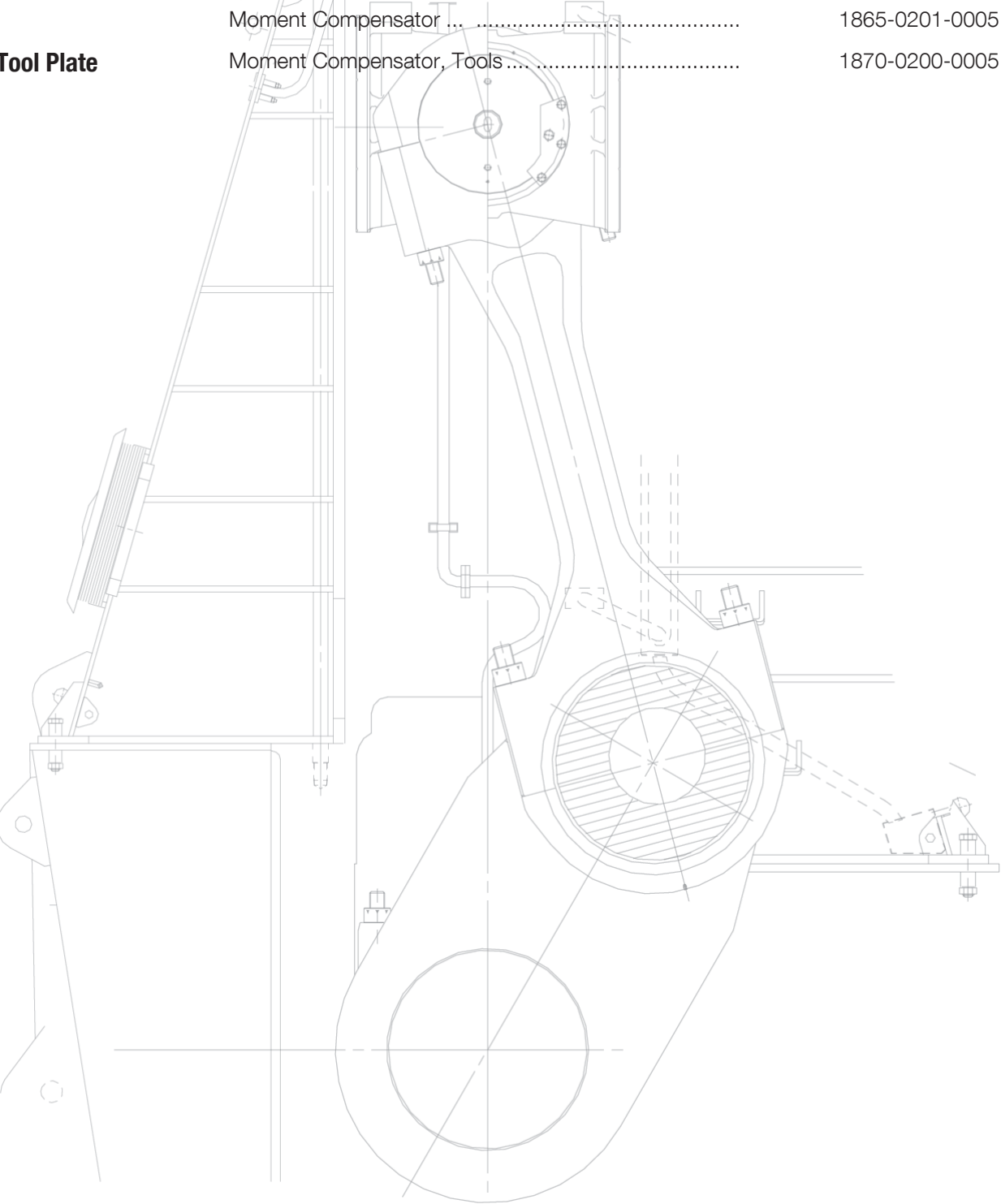
Item No.	Qty	Item Designation
012	-	Panel for tools
024	-	Name plate
061	-	Pin gauge for crankshaft
073	-	Chain assembling tool
085	-	Chain disassembling tool
097	-	Chain assembling tool
107	-	Chain disassembling tool
170	-	Stud
252	-	Lifting attachment

Preface Chapter

Work Card

Tool Plate

Vibration Control	1840-0100-0001
Axial Vibration Damper, Data	1865-0100-0016
Axial Vibration Damper	1865-0101-0009
Moment Compensator, Data	1865-0200-0004
Moment Compensator	1865-0201-0005
Moment Compensator, Tools	1870-0200-0005



General

Axial Vibration Damper

Section: 18XX-01YY

To counteract heavy axial vibrations, and any resultant adverse forces and vibrations, the crankshaft is provided with an axial vibration damper.

The damper consists of a 'piston' and a slit-type housing. The 'piston' is made as an integrated collar on one of the main bearing journals, and the housing is mounted on the pertaining main bearing support.

The axial movement is damped as a result of the 'restrictions' incorporated in the bores which interconnect the oil-filled chambers on the two sides of the 'piston'.

Lubricating oil is supplied to both sides of the 'piston' from the main system.

Moment Compensators

Section: 18XX-02YY

On the basis of calculations, the engine may be provided with fly weights to counteract engine forces and moments.



If the chain drives for the compensators have been dismantled, the flyweights must be positioned correctly in relation to the crankshaft. See Workcard 1865-0200.

Incorrectly fitted moment compensators may excite heavy vibrations.

1st order moment

Applicable on 4-cylinder engines. The moment compensator is arranged as adjustable flyweights on both ends of the crankshaft.

Alternatively, the 1st order moment compensator can be positioned in the main chain drive.

This moment compensator consists of a (new) chaintightener wheel with an incorporated flyweight and a flyweight rotating with the crank shaft.

Safety Precautions

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply



Data

Ref.	Description	Value	Unit
T18-02	Inner studs, screwing-in torque	410	Nm
T18-03	Nuts on inner studs, tightening torque	930	Nm
T18-04	Nuts on inner studs, tightening torque+angle	100+150	Nm+°
T18-06	Outer studs, screwing-in torque	410	Nm
T18-07	Horizontal screws, tightening torque	760	Nm
T18-08	Horizontal screws, tightening torque+angle	100+40	Nm+°
T18-09	Damper housing, upper part	650	kg
T18-10	Nuts on outer studs, tightening torque	930	Nm
T18-11	Nuts on outer studs, tightening torque+angle	100+150	Nm+°

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
7670-0300	-	Lifting tools, etc
7670-0200	-	Torque spanners

Checking the Effectiveness of the Axial Vibration Damper

For checking the effectiveness of the axial vibration damper, it is necessary to measure the longitudinal movements of the fore end of the crankshaft during running.

The measurement (or reading) should be taken at the same r/min as during the sea trials. (Preferably 90% and 100% of MCR.)

As different equipment can have been mounted on the specific engines, the checking procedure describes two different systems:

A: Electronic, with Axial Vibration Monitor

B: Mechanical

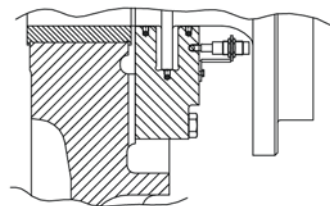
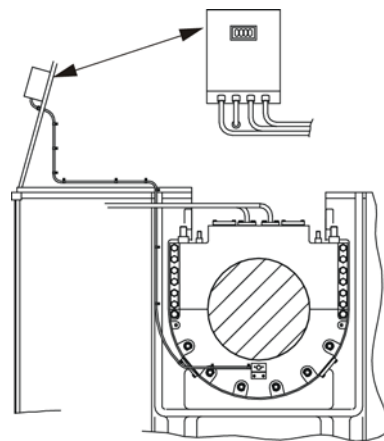
1. A: Electronic, with Axial Vibration Monitor

A proximeter probe is built onto the lower part of the damper housing. The probe is connected to a control unit which displays peak-to-peak movements and sends signals to the engine control system.

Concerning overhaul and setting of the electronic device, refer to makers instructions and guidance values.
See description 7045-0100.

The peak-to-peak values displayed in mm are to be compared with the original values obtained during sea trial and the given limits.
See description 7045-0100.

If the peak-to-peak value exceeds the *normal service value*, it is necessary to overhaul the axial vibration damper.
See overhaul procedure.

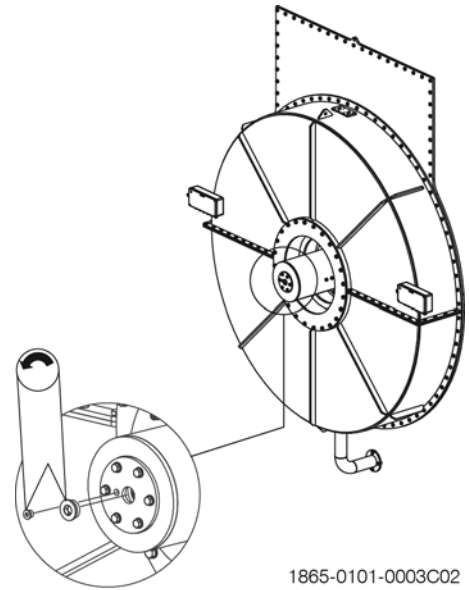


1865-0101-0003C01

2. B: Mechanical

Stop the engine.

Unscrew the two plugs from the cover at the front of the engine.



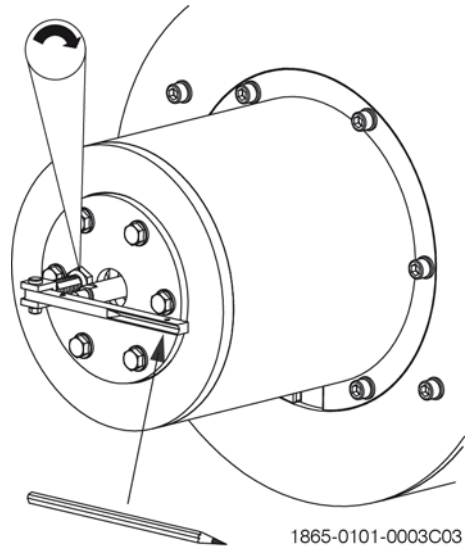
1865-0101-0003C02

3. Crankshaft

Mount the shaft piece in the end of the crankshaft.

Screw the measuring arm into the small threaded hole beside the centre hole, so that the arm is perpendicular to the shaft piece. Tighten the lock nut.

Attach a pencil to the arm.



1865-0101-0003C03

NOTICE

To obtain a correct measurement, the tip of the pencil should protrude **10 mm** from the end of the arm.

4. Start the engine

Start the engine, and let the speed rise to the number of revolutions at which the measurement is to be taken. (Preferably 90% and 100% of MCR.)

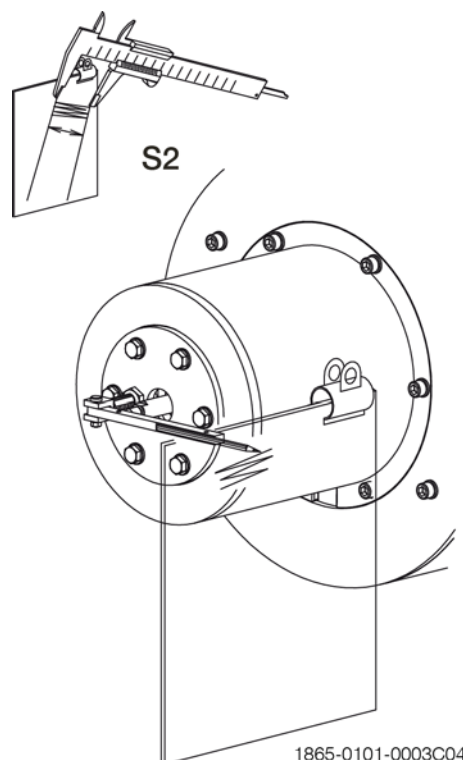
When measuring, press the measuring arm against the shaft piece with one hand. With the other hand, move a sheet/block of paper, clipped on to a solid backing plate, lightly downwards against the tip of the pencil.

To ensure a certain inertia, the backing plate should have a mass of approx. 1-2 kg.

The axial movements **S2** recorded on the paper must be measured with a slide calliper as shown in the sketch.

It is necessary to compensate for the ratio in the tool before comparing the measured value **S2** with the *normal service value S1*.

See description 7045-0100.



1865-0101-0003C04

5. Standard measuring tool

For a standard measuring tool (**L1** = 38 mm and **L2** = 200 mm), the ratio is 5.3. Therefore, **S1** can be calculated as follows:

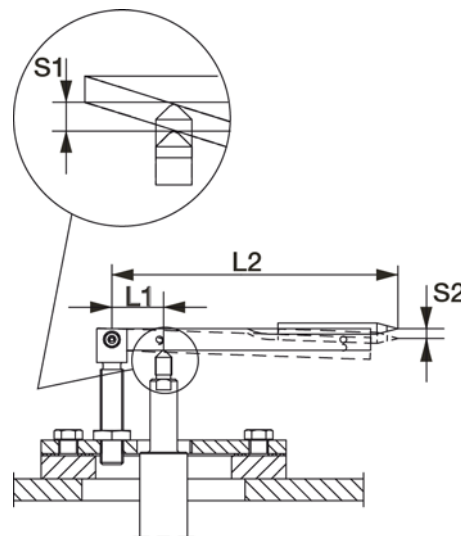
$$S1 = S2 / 5.3$$

If a non-standard tool is used, **S1** can be calculated as follows:

$$S1 = S2 \times (L1 / L2)$$

If the peak-to-peak value exceeds the *normal service value*, it is necessary to overhaul the axial vibration damper.

See overhaul procedure.



1865-0101-0003C05

WARNING

Before starting the work under the suspended upper part, secure the upper part with, e.g. a wire rope or another tackle. Observe safety precautions when working in the crankcase.
See description 0545-0100

NOTICE

Dismantling of the axial vibration damper is carried out from the crankcase of cylinder No. 1.

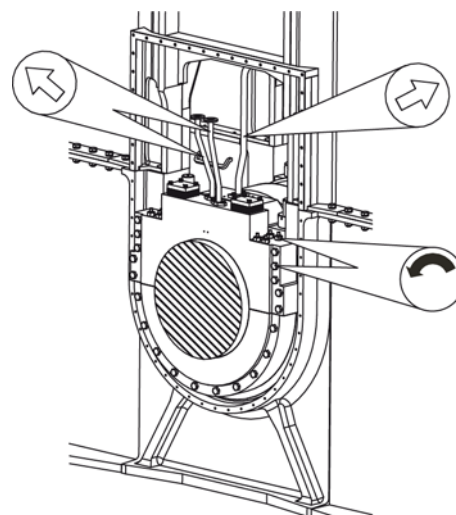
1. Turn the engine to 90° after TDC

Unfasten the lubricating oil pipes for the main bearing and axial vibration damper.

Loosen and remove the nuts from the inner studs and the nuts from the outer studs.

Loosen and remove the horizontal screws.

Only the upper part of the housing needs to be removed, while the lower half remains mounted on the bedplate.



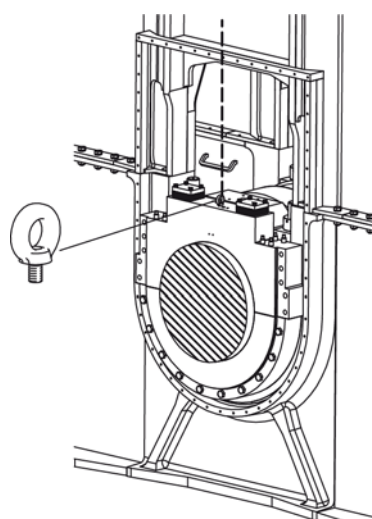
1865-0101-0004D01

2. Eye bolt

Screw in an eye bolt in the centre lifting hole on the upper part.

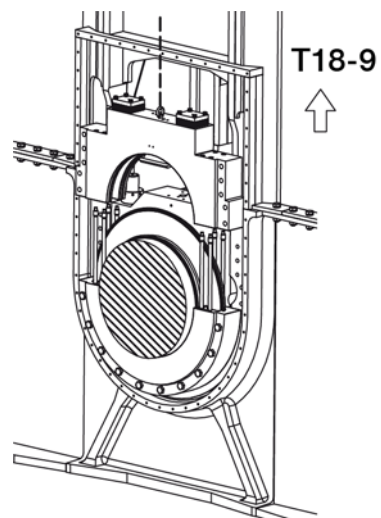
WARNING**Safe working load (SWL)**

Always use lifting gear with sufficient SWL.
See data.



1865-0101-0003D02

3. Engines with chain box fore
Mount a tackle in the bracket above the axial vibration damper inside the chain box.
4. Engines without chain box fore
Mount a tackle below the fore end platform, and remove the cover on the lifting hole above the axial vibration damper.
5. Raising the upper part of the damper
By means of the tackle and wire rope, separate and raise the upper part of the damper housing to a position at which it is possible to change the oil seals and springs.



1865-0101-0003D03

1. Oil sealing rings

Dismantle and remove the springs from the oil sealing rings.

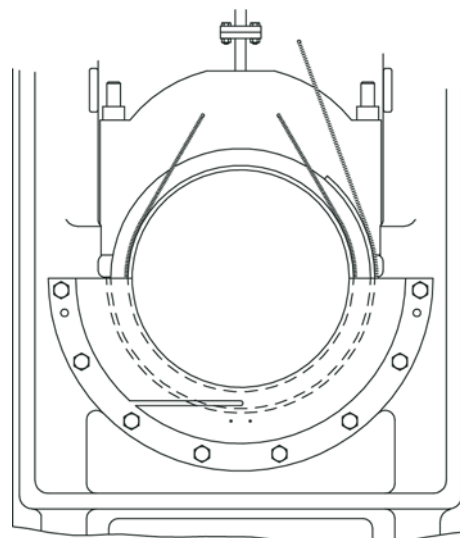
Remove the oil sealing rings.

NOTICE

It is recommended to discard both the springs and the oil sealing rings.

When mounting the new oil sealing rings, first insert the lower half of the rings in the lower housing.

Then press the tension springs into the groove between the oil sealing ring half and the housing.



1865-0101-0003O01

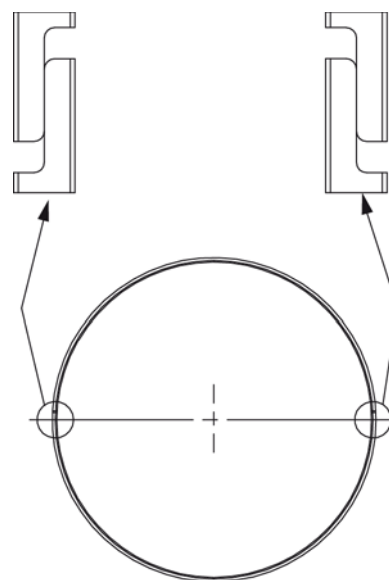
2. Hook on the new tension springs

Mount all the upper halves of the oil sealing rings in such a way that the clearance at both joints on each oil sealing ring is the same.

Now hook the new tension springs into place, ensuring that they are centered in the grooves of the oil sealing rings.

NOTICE

The lower half of the oil sealing rings will protrude above the centerline.



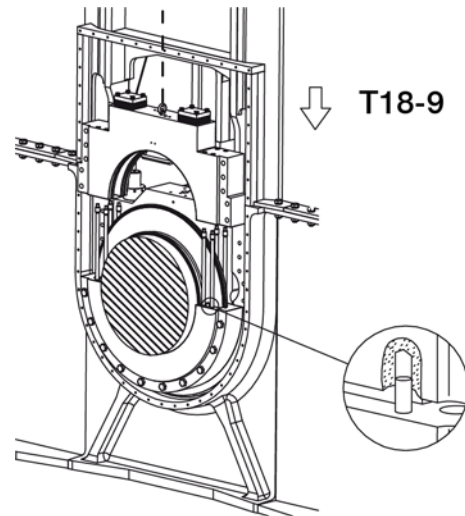
1865-0101-0003O02

1. Damper housing

Release and carefully lower the upper part of the damper housing.

When reaching the oil sealing rings, take care that the rings enter the sealing ring grooves correctly.

Before landing the upper part on the lower part, be sure that the guide pins have entered the guide pin holes.



1865-0101-0003M01

2. Vertical nuts

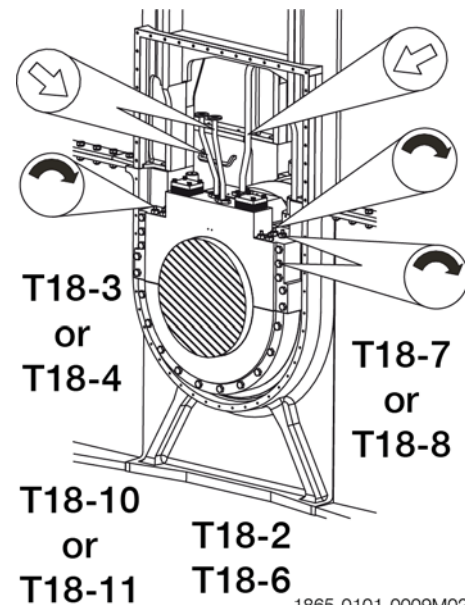
Mount and tighten the vertical nuts.
See data.

Mount and tighten the horizontal screws.
See data.

NOTICE

Search the crankcase to ensure that there are no tools, shackles or rags left behind.

Mount the lubricating oil pipes.



1865-0101-0009M02

3. Engines without chainbox fore

Mount the cover for the lifting hole above the axial vibration damper.

NOTICE

After overhaul of the axial vibration damper, it is recommended to check the axial vibration.
See checking procedure.

Safety Precautions

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply



Data

Ref.	Description	Value	Unit
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1070-0300	-	Hydraulic tools for large parts
1470-0500	-	Hydraulic tools - chain tightener
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	023	Hydraulic pump, hand operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	060	Hose with unions, 5000 mm
7670-0100	118	3-way distributor block, complete

WARNING

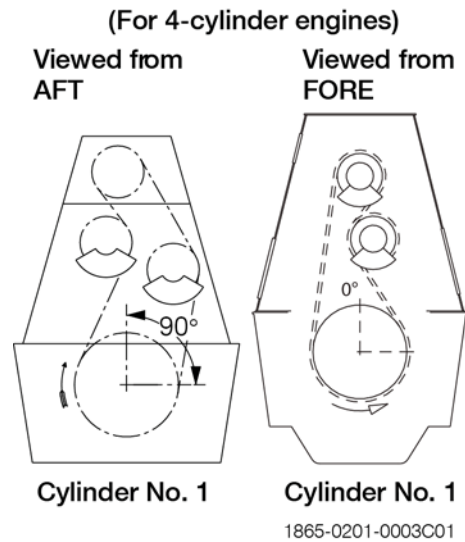
Observe safety precautions when working in the crankcase.
See description 0545-0100.

1. Correct mounting

If dismantling has been necessary, the fly weights must be assembled in the correct position in relation to the engine crankshaft. Incorrectly mounted flyweights can cause (heavy) vibrations of the engine.

NOTICE

The following applies to a **clockwise-rotating engine**.



2. Aftmost 2nd Order Moment Compensator

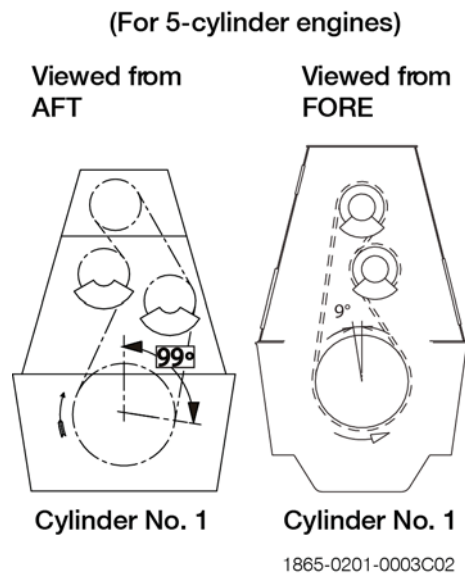
Turn the crankthrow of cylinder No. 1 in the **ahead** direction to the position shown in the figures for 4, 5, 6-cylinder engines, respectively.

Check that the flyweights point vertically downwards (max. deviation one-half chain wheel tooth pitch).

Mount the chain.

Tighten the chain in accordance with the instruction.

See work card 1465-0501.



3. Foremost 2nd Order
Moment
Compensator

Turn the crankthrow of cylinder No. 1 in the **ahead** direction to the position shown in the figures for 4, 5, 6-cylinder engines, respectively.

Check that the flyweights point vertically downwards (max. deviation one-half chain wheel tooth pitch) and then mount the chain.

Tighten the chain in accordance with the instruction.

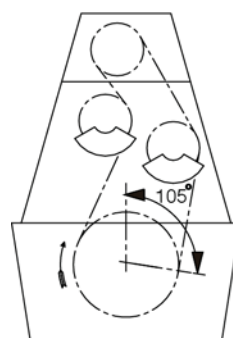
See overhaul procedure.

NOTICE

For an **anticlockwise-rotating** engine, the degrees mentioned in the respective figures must be **before** TDC, not **after** TDC.

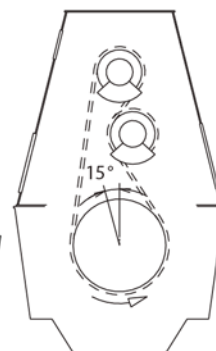
(For 6-cylinder engines)

Viewed from
AFT



Cylinder No. 1

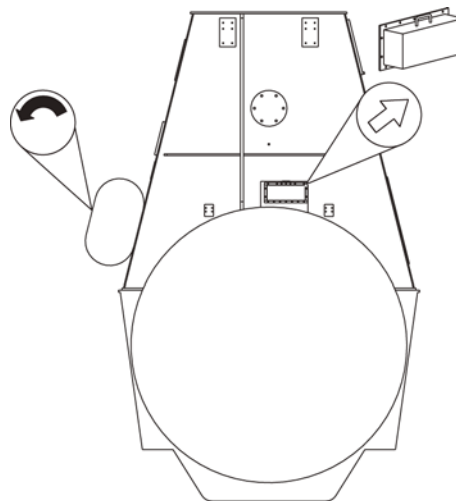
Viewed from
FORE



Cylinder No. 1

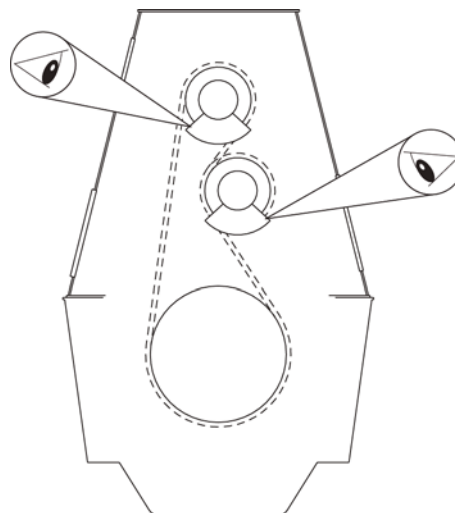
1865-0201-0003C03

1. **Chain tightener cover** At the front of the engine, open the foremost door on the exhaust side of the engine and remove the cover to the chain tightener hydraulic nut.



1865-0201-0003O01

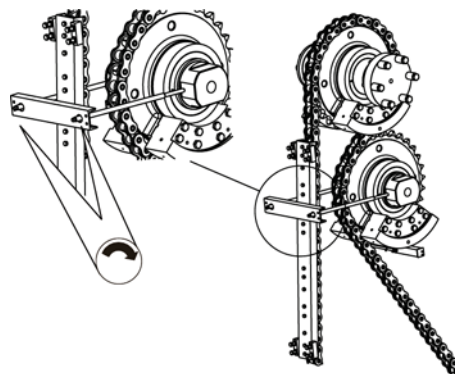
2. **Turn the flyweights** When tightening the chain, bring the two flyweights to a vertical downward position.



1865-0201-0003O02

3. **Tighten the hydraulic nuts** Mount the chain tightening tool with the hydraulic nut on the exhaust side of the web plate and the dowel pin through the chain wheel.

Tighten the hydraulic nuts by hand.

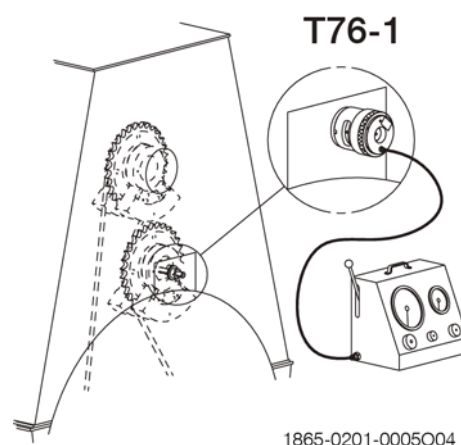


1865-0201-0003O03

4. Hydraulic nut on the chain tightener

Loosen the hydraulic nut on the chain tightener.

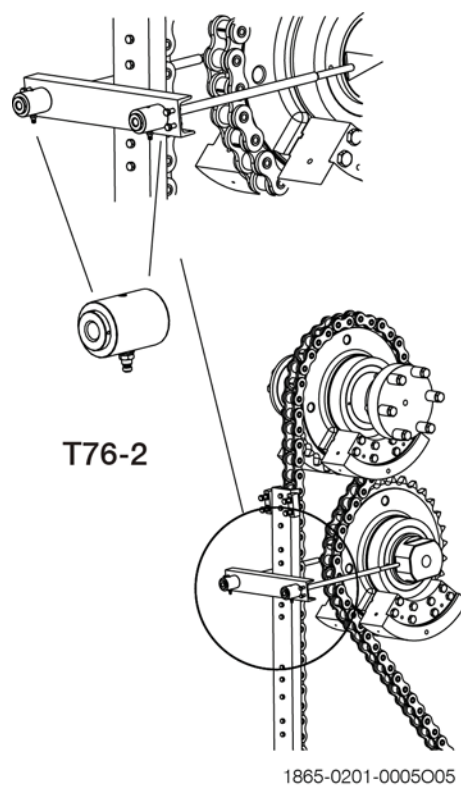
For use of hydraulic tools, see work card 7665-0101.



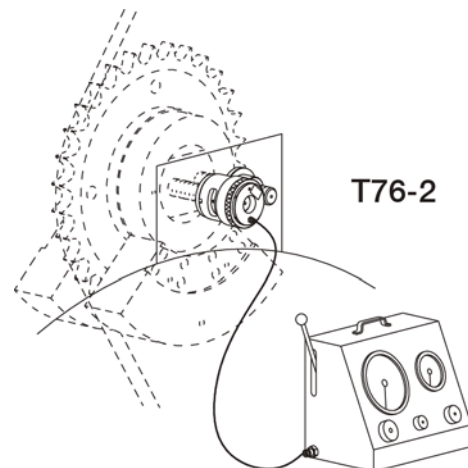
5. Tighten the hydraulic nuts

Tighten the hydraulic nuts using the provided hydraulic jacks.

For correct tightening pressure, see data.

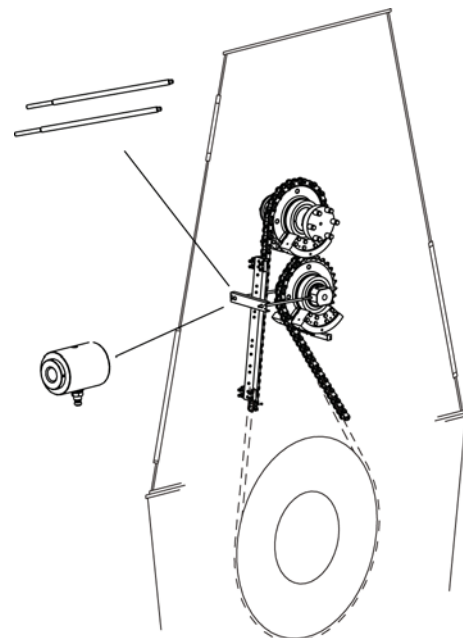


6. Hydraulic nut on the chain tightener
- Tighten the first hydraulic nut on the chain tightener, then tighten the second nut and finally re-tighten the first nut.
See data.



1865-0201-0005O06

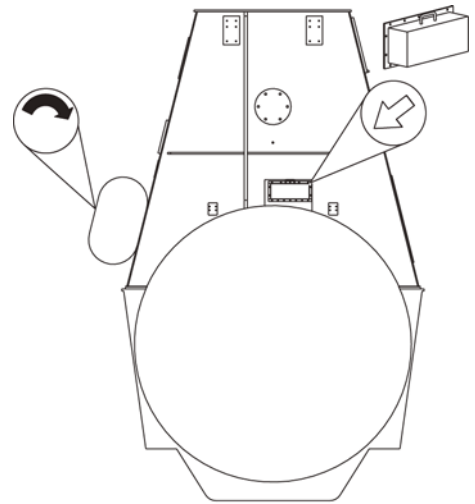
7. Remove the hydraulic tools
- Loosen the hydraulic nut on the chain tightening tool.
- Remove the hydraulic tools and the chain tightening tool from the engine.



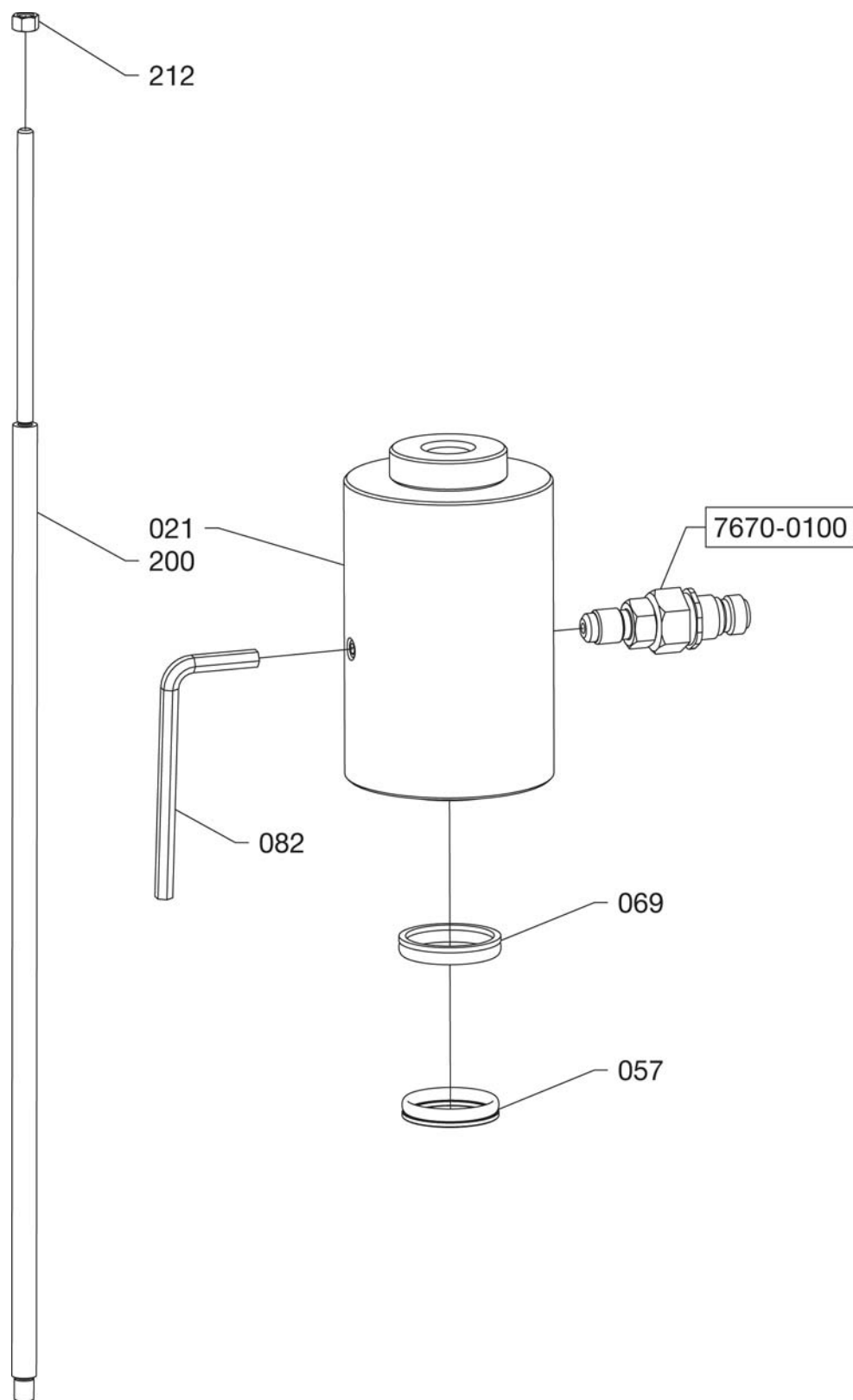
1865-0201-0003O07

8. Mount the cover

Mount the cover to the chain tightener nuts and close the door to the moment compensator.



1865-0201-0003O08



Item No.	Qty	Item Designation
021	-	Hydraulic jack, complete
057	-	Sealing ring with back-up
069	-	Sealing ring with back-up
082	-	Hex key
200	-	Stud
212	-	Nut

Preface Chapter	Cylinder Unit	2240-0100-0002
Description	Cylinder Condition	2245-0100-0005
	Inspection of Nimonic Exhaust Valve Spindles	2245-0200-0004
Drawing	Inspection Through Scavenge Ports	2255-0100-0004
	Factors Influencing Cylinder Wear	2255-0105-0003
	Cylinder Oil Feed Rate During Running-in	2255-0125-0005
	Cylinder Condition Report	2255-0130-0003
	Calculation of Condensate Amount	2255-0135-0002
	Overview Of Piston Rings	2255-0145-0001
	Liner Condition	2255-0150-0001
Work Card	Exhaust Valve High-Pressure Pipe, Data	2265-0100-0018
	Exhaust Valve High-Pressure Pipe	2265-0101-0015
	Exhaust Valve, Data	2265-0200-0024
	Exhaust Valve	2265-0201-0025
	Cylinder Cover, Data	2265-0300-0021
	Cylinder Cover	2265-0301-0017
	Piston, Data	2265-0400-0012
	Piston	2265-0401-0018
	Piston Rod Stuffing Box, Data	2265-0500-0013
	Piston Rod Stuffing Box	2265-0501-0008
	Cylinder Liner, Data	2265-0600-0018
	Cylinder Liner	2265-0601-0013
Tool Plate	Exhaust Valve Panel Tools	2270-0200-0042
	Exhaust Valve Hydraulic Tools	2270-0240-0017
	Cylinder Cover Panel Tools	2270-0300-0014
	Cylinder Cover Hydraulic Tools Spares	2270-0315-0019
	Cylinder Cover Support Tool	2270-0330-0005
	Cylinder Cover Lifting Tools	2270-0350-0001
	Piston Panel Tools	2270-0400-0035
	Piston Guide Tool	2270-0430-0001
	Piston Rod Hydraulic Tools	2270-0440-0007
	Piston Support Tools	2270-0470-0010
	Piston Lifting Tools	2270-0480-0001
	Cylinder Liner Tools	2270-0610-0001
	Cylinder Liner Lifting Tools	2270-0640-0004

General

Exhaust Valve

Each cylinder is equipped with an exhaust valve, which is mounted in a central bore in the cylinder cover. The valve housing is attached with four studs and nuts to form a gastight seal against a seat in the cylinder cover.

Valve housing

The valve housing has an exchangeable bottom piece. The bore for the valve spindle is provided with an exchangeable spindle guide liner.

The valve housing is water cooled. The cooling water is passed to the valve housing after it has passed the cylinder cover. The water is discharged from the upper part of the valve housing.

On the front of the valve housing there is a cleaning cover through which the cooling water space can be checked and cleaned.

Valve spindle

The part of the spindle stem which travels within the sealing arrangement of the air cylinder is coated with a wear resistant mixture of metal carbide and super alloy, applied by the HVOF process.

On the lower cylindrical part of the valve spindle a vane wheel is fitted which causes the valve spindle to rotate while the engine is running.

Pistons:

At the top of the spindle, two pistons are fitted:

1. Air piston.

The piston serves to close the exhaust valve. The piston is locked to the spindle by a two-piece conical ring.

2. Hydraulic piston.

The piston serves to open the exhaust valve. The hydraulic piston has two piston rings and a damper arrangement, designed to dampen the closing of the valve.

Air cylinder

The air cylinder is mounted on top of the valve housing. Air for closing the exhaust valve is supplied through a non-return valve to the space below the piston.

A safety valve is mounted in the bottom of the air cylinder. The safety valve is connected to the drain pipe which leads to the camshaft housing.

Hydraulic cylinder

The hydraulic cylinder is attached with studs and nuts on the air cylinder on top of the exhaust valve housing.

The exhaust valve is opened by the valve spindle being forced down by the piston in the hydraulic cylinder. A throttle valve designed for deaerating the oil system is fitted at the top of the cylinder.

The Control Oil Level (COL) system incorporated into the design of the hydraulic cylinder housing ensures that air chamber under the air piston is air tight.

Piston

The piston consists of two main parts:

- Piston Crown

- Piston Skirt

The piston crown is tightened to the upper end of the piston rod, and the piston skirt is tightened to the piston crown.

The piston crown is provided with three small grooves for the fitting of lifting tools.

The piston crown is provided with chromium plated grooves for four piston rings.

Piston ring No. 1 is a Controlled Pressure Relief ring (CPR).

Piston ring No. 2, 3 and 4 have oblique cuts:

- piston ring No. 3 has a right-hand cut, and
- piston rings Nos. 2 and 4 have left-hand cuts.

On the ME series the piston rings are provided with alu-coating to improve the running-in stability and to reduce the running-in period. Handle with care, as impact may cause the coating to crack and peel off.

Piston Rod

The piston rod has a through-going bore for the cooling oil pipe, which is secured to the piston rod top.

Cooling oil is supplied through a telescopic pipe connection on the guideshoe or on the crosshead and passed through a bore in the piston rod foot and through the cooling oil pipe in the piston rod, to the piston crown.

The oil is passed on, through a number of bores in the thrust part of the piston crown, to the space around the cooling oil pipe in the piston rod.

From the bore in the piston rod foot, the oil is led through the crosshead to a discharge spout and to a slotted pipe inside the engine framebox as well as through a control device for checking the flow and temperature.

Crosshead

The piston rod foot rests on a face cut out in the crosshead pin.

A shim is inserted between the piston rod and the crosshead. The thickness of the shim is predetermined to match the actual engine layout.

The piston rod is fastened to the crosshead pin with screws or studs and nuts. The nuts are tightened with hydraulic tools.

Stuffing Box

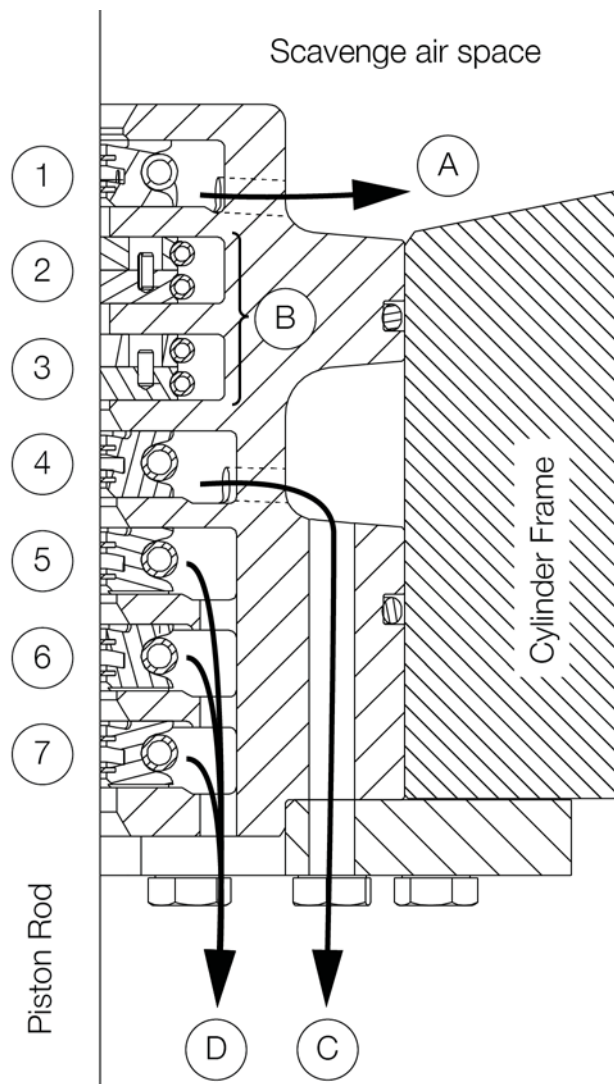
The bore for the piston rod between the scavenge air space and the crankcase is mounted with a piston rod stuffing box, which is designed to prevent the lubricating oil in the crankcase from being drawn up into the scavenge air space.

Scraper/sealing rings

The stuffing box also prevents scavenge air (in the scavenge air space) from leaking into the crankcase.

The stuffing box housing consists of two parts, which are bolted together.

The housing is provided with seven machined ring grooves:



- A) Scraper ring, sludge drain
- B) Sealing rings
- C) Scraper ring, lubrication oil drain (to drain box)
- D) Scraper rings, lubrication oil drain (return to crankcase)

- Groove number one (the uppermost groove) contains a scraper ring with oblique edges, which serves to prevent sludge from the scavenge box from being drawn down to the other rings. Drain bores in the groove ends in the scavenge air space. The scavenge air space is drained with pipes on the manoeuvring side.
- Groove number two and three contains two sealing rings which serves to prevent the air from the scavenge air space to leak into the crankcase.

- Groove number four contains a scraper ring without a relief groove on the lowermost side and bores to relieve the remaining oil from the piston rod to a drain pipe. The drain pipe ends in a funnel on the manoeuvring side of the engine, which enables the sealing/scraping performance to be checked.
- Groove number five, six and seven contains scraper rings with relief grooves on the lowermost side. Their purpose is to scrape the lubrication oil off the piston rod and return it through the stuffing box housing to the crankcase.

The scraper/sealing rings are cut in sections or segments. Gaps at the ends of the ring segments ensures that the rings will bear against the piston rod even in worn condition.

Cylinder Liner and Cooling Jacket

The cylinder liner is fitted with a cooling jacket. The cooling water is supplied at the lower part of the cooling jacket.

On slimtype liners, the water continues directly to the upper part of the cooling jacket, whereas on the borecooled type liner, the water first passes through the cooling bores. From the top of the cooling jackets, the water flows through water connections to the cooling jacket on the lower part of the cylinder cover.

Leakage of cooling water is prevented by silicone rubber rings.

The cylinder liner is tightened against the top of the cylinder frame by the tensioning force from the cylinder cover studs being transmitted via the cylinder cover.

Scavenge air ports

The part of the cylinder liner which is located in the scavenge air space of the cylinder frame is provided with a number of scavenge air ports, which are uncovered by the piston when this is in its bottom position. The scavenge air ports are bored at an oblique angle to the axis of the cylinder liner so as to give the scavenge air a rotary movement in the cylinder.

Cylinder lubrication

In the free part of the cylinder liner, between the cooling jacket and the cylinder frame, there are a number of bores with non-return valves for the supply of lubricating oil to the cylinder.

See also Chapter 30 "Lubricating System".

PC-ring

A piston cleaning (PC) ring is mounted at the top of the cylinder liner. The purpose of the PC-ring is to prevent the building up of deposits on the piston topland and, in turn, prevent the wiping away of the cylinder lubricating oil. Consequently, the PC-ring contributes to reducing the wear of liners and rings.

Cylinder Cover

The cover has a central bore for the exhaust valve, which is attached by means of four studs and nuts. The cover furthermore has bores for the fuel valves, starting valve, starting air inlet and indicator cock.

Cooling

A cooling jacket is mounted on the lower part of the cylinder cover, whereby a cooling water space is formed.

Another cooling water space is formed around the exhaust valve seat, when the exhaust valve is installed. These two spaces communicate through a large number of cooling bores in the cover.

The water is supplied from the cooling jacket surrounding the cylinder liner and passes through water connections to the cooling jacket surrounding the cylinder cover and, further on, through the cooling bores, to the space around the exhaust valve seat.

From here the water is discharged to the main cooling water outlet pipe.
See also Chapter 50 "Cooling Water System".

Tightening

The cylinder cover is tightened against the top of the cylinder liner with nuts and long studs fitted in the cylinder frame. The nuts are tightened with hydraulic tools.

Sealing between the cylinder cover and cylinder liner is obtained by means of a sealing ring of mild steel.

Indicator Valve

Each cylinder is fitted with an indicator valve, which communicates with the combustion chamber of the cylinder through a bore.

Operating Instructions!

When opening the indicator valve, the spindle must be screwed right back to the stop in order to avoid burns and carbon in the guide.

NOTICE



For indicator valves of the double-seated design with a spring-loaded closing face:

In order to prevent overstressing, close the valve lightly before starting the engine, and retighten the valve when the engine has reached its normal service temperature.

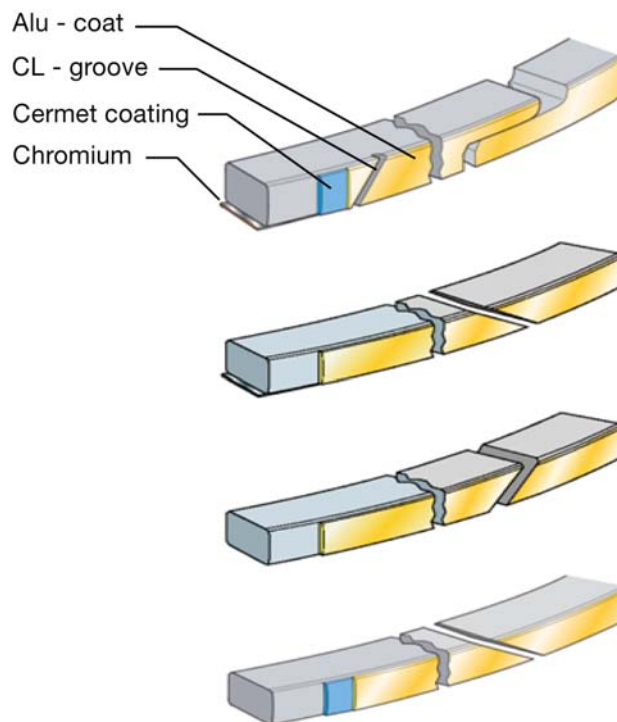
1 General

It is important to keep the engine crew updated with information from the latest Service Letters issued by MAN Diesel & Turbo.

To obtain and maintain a good cylinder condition involves the control of many factors. Since most of these factors can change during the service period – and can be influenced by service parameters within and outside the control of the engine room staff – it is of great importance that running conditions and changes are followed as closely as possible. By means of continual monitoring, it is normally possible to discover abnormalities quickly and thereby, take countermeasures at an early stage. In particular, it is advisable to regularly check the cylinder condition by means of inspection through the scavenge ports from the scavenge air receiver (35-98 bore) and via the small covers on the manoeuvring side as well – especially concentrating on the piston ring condition.

2 Piston Ring Function

All MAN B&W two-stroke engines are equipped with four piston rings made in a cast iron alloy. The function of the piston ring is to give a gas-tight sealing of the clearance between the piston and cylinder liner. This seal is brought about by the gas pressure above and behind the piston ring, which forces it downwards, against the bottom of the ring groove, and outwards against the cylinder wall. In order to ensure optimum sealing, it is therefore important that the piston rings, the grooves, and the cylinder walls, are of proper shape, and that the rings can move freely in the grooves (since the piston will also make small horizontal movements during the stroke). The lubrication of the piston rings influences the sealing as well as the wear and deposits.



Large bore ring pack configuration (most 80-98 engine types): Four rings with alu-coat for running-in, a CPR top ring, cermet coating on ring Nos. 1 and 4 and chromium on the lower face of ring Nos. 1 and 2. Most other engine types are normally configured without cermet coating and chromium, but always with alu-coat as standard.

Experience has shown that unsatisfactory piston ring function is one of the main factors contributing to poor cylinder condition. For this reason, regular scavenge port observations are strongly recommended as a means of judging the ring condition.

The ring pack consists of one high ring with double S-lock (the uppermost) and three low rings with oblique cut ring ends.

In order to make the uppermost piston ring more resistant against ring breakage, especially at the ring lock, it is approx. 30 % higher than ring 2 – 3 – 4 which are all of the same height, and alternating cut left and right.

Coating

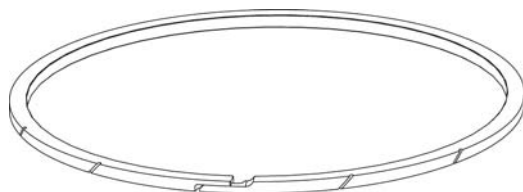
To ease running-in, all piston rings have a 0.3 mm layer of aluminium bronze. This reduces the running-in time considerably, on the test-bed, at the sea trial and in service, as well as after piston overhaul.

Large-bore engines (80-98) have hard coating on the uppermost ring and on ring No. 4, so as to ensure a long-term satisfactory cylinder condition and to increase the tribological stability / scuffing margin, see drawing 2255-0145.

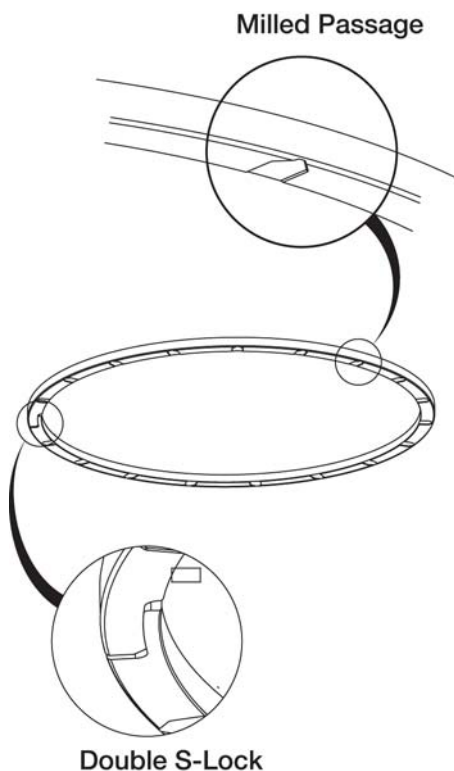
Furthermore, some rings have Cr plating on the lower face on ring No. 1 (uppermost) and ring No. 2 to endure higher levels of abrasive particles. By hard-chrome plating the lower face, the surface structure becomes smooth and prevents abrasive particles from being trapped, thereby reducing the ring groove wear.

The hard coating (cermet coating) on the uppermost piston ring is introduced to reduce the wear on the top ring and to ensure that the CL (controlled leakage) grooves in extreme cases are not prematurely worn out.

CPR (controlled pressure relief) Ring, CL and POP Versions

**CPR-CL**

In order to control the pressure drop across the ring pack and, especially, to avoid a too high pressure drop across the uppermost ring so-called CL (controlled leakage) grooves are used on the uppermost piston ring on all large bore engines (60 -98). The number of grooves, the distribution on the circumference and the depths depend on the cylinder bore.

**CPR-POP**

For small-bore engines (26-50), the depths of the grooves would not be deep enough to accept a reasonable wear potential. Instead, rings with grooves placed on the lower face are used. The designation for this ring type is POP (port on plane).

Cylinder Condition

Description

2245-0100-0005

3 Scavenge Port Inspection

3.1 General

The scavenge port inspection provides useful information about the condition of cylinders, pistons, skirts, piston rods and rings.

The inspection consists of a visual examination of the piston, piston skirts, rods, piston rings and the lower part of the cylinder liner directly through the scavenge air ports, and measurements of the ring clearance, the CL grooves, the POP groove opening and the thickness of possible piston ring coating.

To reduce the risk of a scavenge box fire, even though this phenomenon is very rare on modern engines, remove any oil sludge and carbon deposits in the scavenge air box and receiver in connection with the inspection. With the relevant pumps running an evaluation can be made of the fuel valves sealing tightness, the piston tightness for lube oil and the cylinder cover's sealing tightness for cooling water.

The port inspection should be carried out at the first stop after a long voyage, e.g. by anchoring if possible, to obtain the most reliable result with regard to the effectiveness and sufficiency of the cylinder lubrication and the combustion cycle (complete or incomplete). A misleading result may be obtained if the port inspection is carried out after arrival at harbour, since manoeuvring to the quay and low-load running, e.g. river or canal passage, requires increased cylinder oil dosage, i.e. the cylinders are excessively lubricated. Further, during low load, the combustion cycle might not be as effective and complete as expected, due to the actual fuel oil qualities and service (running) condition of the fuel injection equipment. It is highly recommended to take this information into consideration when evaluating the cylinder condition.

The inspection must take place at least twice a month, if in port anyway.

3.2 Procedure

For the inspection procedure, see work card 2265-0401.

Scavenge port inspections are best carried out by two persons. The more experienced person inspects the surfaces and states his observations to an assistant, who records them and later enters them in MAN Diesel & Turbo standard forms. Keep cooling water, fuel oil and cooling oil circulating, so that possible leakages can be detected.

**WARNING**

ALWAYS bring the turning gear switch into the scavenge air receiver during inspection.

Block the starting air supply to the main starting valve. Open the indicator valves.

Block the hatch cover to the receiver to prevent it from closing by accident.

Bring in bottles with drinking water for consumption in the scavenge air receiver. Take care when moving around in the receiver and bring proper lighting. Pockets for thermometers are placed in head level.

Hard hat is also recommended. Remember to take breaks to replenish fluid lost from sweating, especially in hot climates.

Engage the turning gear. Remove the inspection covers on the fuel pump side of the cylinder frame, and clean the openings. Open the doors or the cover(s) on the scavenge air receiver. Do not enter the scavenge air receiver before it has been thoroughly ventilated. Begin the inspection on the cylinder with the piston nearest BDC. Inspect the piston, skirts, rods, rings, and cylinder wall. Wipe the running surfaces clean with a rag to ensure correct assessment of the piston ring condition.

Use a powerful lamp to obtain a true impression of the details. Bring in a small camera to make documentation of the condition of the scavenge port inspection etc. Instead of flash use the lamp as the light source.

Record the results on drawing 2255-0100 and use the symbols as shown to ensure easy interpretation of the observations.

Keep the records to form a log book of the cylinder condition. Measure the total clearance between the piston rings and the ring grooves. Measure the CL-groove depths and the thickness of the ring coating, if applicable. Continue the inspection on the next cylinder with its piston nearest BDC, and so on according to the firing order. Note down the order of inspection for use at later inspections. Check the non-return valves (flap valves/butterfly valves) in the auxiliary blower system for easy movement and possible damage and inspect the condition of the water mist catcher. Remove any oil sludge and carbon deposits in the scavenge air boxes and receiver. If fuel oil or excessive system oil is found, the fuel valve or pulled pistons should be pressure tested. Record the observations on drawing 2255-0100.

3.3 Observations

3.3.1 Scavenge Receiver Condition

Check and note the condition of the scavenge receiver.



Scavenge Receiver, NO SLUDGE

Note: Water washing from defect water mist catcher could cause a very clean scavenge air receiver.



Scavenge Receiver, SLUDGE – S

Normal picture. Indicates good cylinder condition.



Scavenge Receiver, MUCH SLUDGE – MS

Remove any oil sludge and carbon deposits in scavenge receiver.

3.3.2 Leakage

Check the piston crown top for any leakages (remember to keep cooling water, fuel oil and lubricating oil circulating during the inspection).



Leaking oil - LO

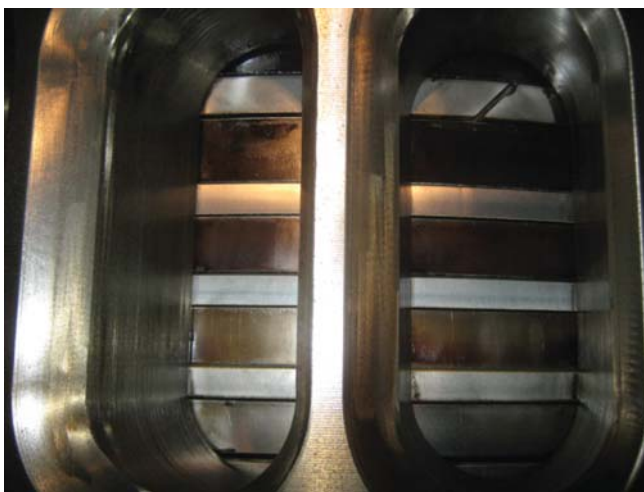
If oil is found on the piston, determine if it is fuel oil or lube oil. Fuel oil will be black and sticky, indicating a fuel valve is leaking. Lube oil will be brown and non-sticky, indicating it could be from an exhaust valve.



Leaking water - LW

Water on a piston indicates a cooling system leak. If water is found, it is important to determine what the cause is. Use either a mirror or photo, to establish if the leak is from the cylinder cover, exhaust valve or a cracked liner.

3.3.3 Piston rings: in good condition

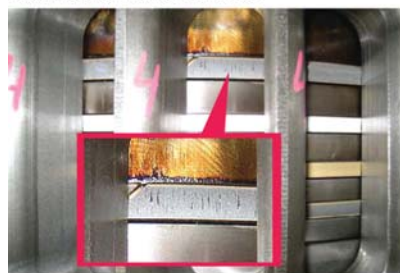


When good and steady service conditions have been achieved, the running surfaces of the piston rings and cylinder liner will be worn bright (this also applies to the ring undersides and the "floor" of the ring grooves which, however, cannot be seen until a piston is pulled).

In addition, the rings will move freely in the grooves and also be well oiled, intact, and not unduly worn. The ring edges will be sharp when the original roundings have been worn away, but should be without burrs.

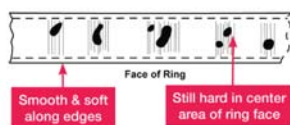
3.3.4 Piston rings: micro-seizure

LOCAL & ALL OVER MICRO-SEIZURES



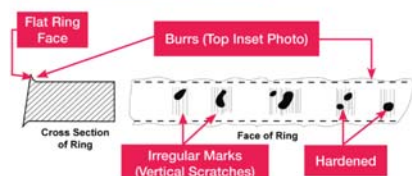
LOCAL MICRO-SEIZURES – mz

STILL ACTIVE MICRO-SEIZURES – MAZ



OLD MICRO-SEIZURES – OZ

ACTIVE & INACTIVE MICRO-SEIZURES



Temporarily increase the cylinder oil dosage; If seizures are observed.

If micro-seizures as observed on the piston rings are not properly attended, by reducing the p_{max} and engine load on the respective unit, and by increasing the lubrication feed rate, according to instructions (1.2 g/kWh), scuffing of the cylinder liner can occur, causing momentarily high wear of all combustion chamber parts.

If, over a period of time, the oil film is partially interrupted or disappearing, so that dry areas are formed on the cylinder wall, these areas and the piston ring surfaces will, by frictional interaction, become finely scuffed and hardened, i.e. the good "mirror surface" will have deteriorated.

In case of extreme micro-seizures (for scuffing see item 5.6.1), sharp burrs may form on the edges of the piston rings.

A seized surface, which has a characteristic vertically-striped appearance, will be relatively hard, and may cause excessive cylinder wear. Due to this hardness, the damaged areas will only slowly disappear (run-in again) if and when the oil film is restored.

As long as the seizure is allowed to continue, the local wear will tend to be excessive. Seizure may initially be limited to part of the ring circumference, but, since the rings are free to "turn" in their grooves, it may eventually spread over the entire running face of the ring.

The fact that the rings move in their grooves will also tend to transmit the local seizure all the way around the liner surface.

If extreme seizures (for scuffing see item 5.6.1) have been observed, it is recommended that the cyl. oil feedrate is temporarily increased to 1.2 g/kWh.

If load reduction of more than one unit is required, please contact MAN Diesel & Turbo for advice.

3.3.5 Piston rings: scratching

Scratching is caused by hard abrasive particles originating from the ring itself or, more likely, from the fuel oil or air intake. With regards to liner and ring wear, the actual scratching is not necessarily a serious problem, but the particles can have serious consequences elsewhere (see Item 5.5).

3.3.6 Piston rings: sticking



If, due to thick and hard deposits of carbon, the piston rings cannot move freely in their grooves, dark areas will often appear on the upper part of the cylinder wall (this may not be visible at the port inspection). This indicates a lack of sealing, i.e. combustion gas blow-by between piston rings and cylinder liner.

The blow-by will provoke oil film breakdown, which in turn will increase cylinder liner wear. Sticking piston rings will often lead to broken piston rings. The free movement of the rings in the grooves is essential and can be checked either by pressing them with a wooden stick (through the scavenge ports) or by turning the engine alternately clockwise and counter-clockwise to check the free vertical movement.

3.3.7 Piston rings: breaking/collapse

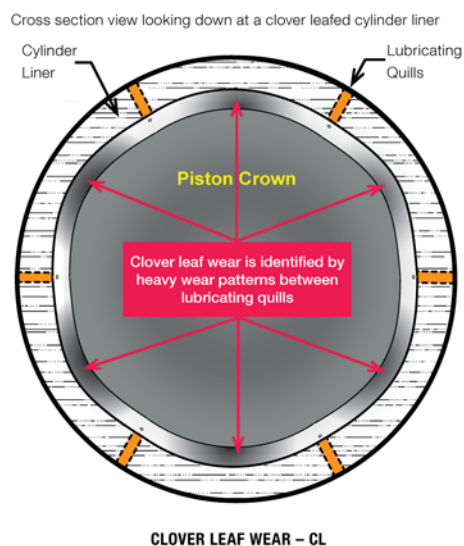
Broken piston rings manifest themselves during the scavenge port inspection by their:

- lack of elastic tension when the rings are pressed into the groove with a stick
- blackish appearance
- fractured rings
- missing rings or missing ring parts.

Piston ring breakage is caused by a phenomenon known as “ring collapse”. However, breakage may also occur due to continual striking against wear ridges on the cylinder liner TDC area, or other irregularities on the cylinder wall. Collapse occurs if the gas pressure behind the ring is built up too slowly and, thereby, exerts an inadequate outward pressure. In such cases, the combustion gas can penetrate between the liner and ring, and violently force the ring inwards in the groove. This type of sudden “shock” loading will eventually lead to fracture – especially if the ring ends “slam” against each other. This phenomenon is, however, seldomly observed on modern engines.

The mentioned slow pressure build-up behind the rings can be due to:

- carbon deposits in the ring groove
- too small vertical ring clearance
- partial sticking
- poor sealing between the ring and the groove floor
- “clover-leafing” (see below).



“Clover-leafing” is a term used to describe longitudinal corrosive liner wear at several separate points around the liner circumference – i.e. in some cases the liner bore may assume a “clover-leaf” shape.

3.3.8 Piston Rings: Blow-by

Leakage of combustion gas past the piston rings (blow-by) is a consequence of sticking, collapsed or broken of rings.

At the later stages, when a complete blow-by occurs, it is usually due to sticking rings or ring breakage caused by collapse.

Blow-by is indicated by black, dry areas on the rings and also by larger black dry zones on the upper part of the liner wall. This can only be seen when overhauling the piston or when exchanging the exhaust valve.

3.3.9 Deposits on pistons

Usually, some deposits from the cylinder oil will accumulate on the side of the piston crown (top land). Carbon deposits on the ring lands (the area on the pistons between the piston rings) indicate lack of gas sealing at the respective rings, see drawing 2255-0100. The piston cleaning ring between the cylinder cover and liner normally removes superfluous and harmful deposits on the pistons.

If the deposits are abnormally thick, their surfaces may be smooth and shiny from rubbing against the cylinder wall. Such contact may locally wipe away or absorb the cylinder oil film, resulting in bore polish, micro-seizure and increased wear of liner and rings. In some instances, mechanical clover-leafing can occur, i.e. vertical grooves of slightly higher wear in between the lubricating quills.

Such conditions may also be the result of a combustion condition which overheats the cylinder oil film. This could be due to faulty or defective fuel valves or insufficient turbocharger efficiency.

3.3.10 Lubricating Condition

Note if the “oil film” on the cylinder wall and piston rings appears to be adequate, see Item 3.1. Black or brownish coloured areas may sometimes be seen on the liner surface. This indicates corrosive wear, usually from sulphuric acid (see item 5.4), and should not be confused with grey-black areas, which indicates blow-by.

These deposits are often only of cosmetic nature and will not lead to wear issues.

The phenomenon is often connected to humidity in the scavenge air and may disappear when the vessel enters cold and less humid areas.

See item 5.4 and chapter 3045-0110.

3.4 Replacement of piston rings

It is recommended to replace the complete set of piston rings at each piston overhaul to ensure that the rings always work under optimal service conditions, thereby giving the best ring performance. Stretching the rings leads to stresses and care must be taken not to open the rings more than necessary when installing them on the piston.

4 Cylinder Overhaul

To ensure correct recording of all relevant information, it is recommended that the "Cylinder Condition Report" (drawing 2255-0130) is used.

4.1 Intervals between piston overhaul

It is recommended to decide the interval between piston overhaul based on the condition of the units observed at scavenge port inspections and not on fixed intervals. In other words: It is not a good idea to pull piston No. 4, based on running hours, if it is piston No. 6 that needs overhaul.

Also base the actual intervals between piston overhauls on the previous wear measurements and observations from scavenge port inspections. Often the guiding intervals between piston overhauls can be prolonged considerably without any harm to the cylinder condition, provided frequent scavenge port inspections are carried out.

Regarding procedures for the dismantling and mounting of pistons, see work card 2265-0501. Remove the piston cleaning (PC) ring between the liner and the cylinder cover, and mark the position of the ring to allow fitting of the PC-ring in the same position as it is worn together with the liner. Carefully remove any coke deposits and wear ridges from the upper part of the liner before fitting the piston.

Regarding the procedure for checking the PC-ring, see work card 2265-0601. The PC-ring is part of the liner and will not need to be exchanged unless it is broken.

4.2 Initial inspection and removal of the piston rings when the piston has been pulled



Only use the standard MAN Diesel & Turbo ring opener for fitting and removal of piston rings. Only expand the rings sufficiently to fit over the piston. This opener prevents local overstressing of the ring material, which in turn would often result in permanent deformation causing blow-by and broken rings. Straps to expand the ring gap, or tools working on the same principle, should never be used.

4.3 Cleaning

Clean the piston rings. Clean all ring grooves carefully. If carbon deposits remain, they may prevent the ring from forming a perfect seal against the floor of the groove. Remove deposits on the piston crown and ring lands. Remove any remaining coke deposits from the upper section of the liner.

4.4 Measurement of ring wear

Please refer to work card 2265-0501

4.5 Inspection of cylinder liner

The aim is to obtain controlled corrosive wear (0.03 - 0.05mm / 1000h) of the liner surface by applying different cylinder oil feed rates, depending on the fuel oil sulphur content (Alpha ACC lubrication algorithm), to avoid liner polishing and subsequent seizures.



4.5.1 Cylinder wear measurements

See work card 2265-0601.

Before measuring the cylinder wear with a pin gauge:

- ensure that the tool and cylinder liner temperature values are close
- record the tool and cylinder liner temperatures on drawing 2255-0130 to enable correction
- If possible take a “zero” measurement.

Measure the wear with the pin gauge at the vertical positions marked on the guide rail. Measure in both transverse and longitudinal directions. The guide rail ensures that the wear is always measured at the same positions. Record the measurements on drawing 2255-0130.

Tools with electronic measurement equipment can be used through the scavenge ports if dismantling of the cylinder cover is not possible.

4.5.2 Correction of wear measurements

Correct the actual wear measurements by multiplying with the following factors, if the temperature of the cylinder liner is higher than the temperature of the tool. This enables a comparison to be made with earlier wear measurements.

Δt° (T _{liner} - T _{tool})	C Factor
10	0.99998
20	0.99976
30	0.99964
40	0.99952
50	0.99940

Example (90 bore):

Δt measured: 30 °C

Corrected value: $901.3 \times 0.99964 = 900.98$ (i.e. a reduction of $901.3 - 900.98 = 0.32$ mm)

However, a zero measurement can be made in the top of the cylinder liner, above ring No. 1 (TDC), where there is no wear. The wear can then be calculated.

4.5.3 Maximum wear

The maximum allowable wear of cylinder liners is in the interval of 0.4% to 0.8% of the nominal diameter, depending on the actual cylinder and piston ring performance. When the interval between necessary piston overhauls becomes too short, for instance due to ovality, it is time to renew the liner and the PC ring.

4.5.4 Checking liner surface

Inspect the liner wall for scratches, micro-seizures, wear ridges, corrosive wear, and surface structure if possible.

If corrosive wear is suspected, or if a ring is found broken, take extra wear measurements around the circumference at the upper part of the liner. Press a new piston ring into the cylinder. Use a feeler gauge to check for local clearances between the ring and liner. This can reveal any "uneven" corrosive wear, see item 3.3.

Be aware that if the liner is not ovally worn and the highest wear does not exceed 0.3% of the liner diameter, it is possible to increase the expected service life of the liner by re-establishing the wave cut shape on the running surface by machining either in situ or at one of the MAN Diesel & Turbo service centres. However, please note, wave-cut machining (by grinding) does not compensate for liner ovality. To compensate for liner ovality, causing premature ring breakage, liner honing is recommended.



Black shiny areas are often found on the liner surface just above the scavenge air ports. These areas of black deposits, called lacquer formations, are harmless and are formed by a combination of water in the scavenge air and cylinder oil. The layer can be rather difficult to remove and can be left as it is.

Cylinder Condition

4.6 Piston skirt, crown and cooling space

The piston skirt is made of cast iron and is equipped with two bronze rings to reduce the risk of scuffing. Some engines have a special molybdenum coating on the skirts instead of the two bronze rings.



Scuffing of the skirt is rare and mostly of cosmetic nature, and is not always a sufficient reason for exchange.

If the burning/corrosion condition of the piston crown exceeds the maximum permissible, send the piston crown for reconditioning. The maximum permissible burning, see work card 2265-0401.

Inspect the crown for cracks by dye checking or similar.

Pressure-test the piston assembly to check for possible cooling oil leakages.

If the piston is taken apart, for instance due to oil leakage, check the condition of the joints between the crown, the piston rod, and the skirt. Inspect the cooling space and clean off any carbon/coke deposits.

Replace the O-rings. Check that the surfaces of the O-ring grooves are smooth. This is to prevent twisting and breakage of the O-rings. Polish the grooves with emmery paper if leakages are found and new O-rings must be installed. Pressure test the piston after assembling.

For safety reasons, the measurements of the burning of the crowns must not take

Description

2245-0100-0005

place with the piston and cylinder cover in situ by placing the template on the crown via the scavenge ports. The cylinder cover must be dismantled or the piston pulled.

4.7 Piston ring grooves

Check the piston ring grooves as described in work card 2265-0401.

If the ring groove wear exceeds the values stated in data sheet 2265-0400, send the piston crown ashore for reconditioning (new chrome plating).

If the ring groove wear is exceeding the limits the ring grooves may need re-welding and machining before re-chroming.

4.7.1 Chrome plating macro cracks

The hard chrome plating of the ring grooves is defined to be micro cracked. This ensures that the strong tensile residual stresses in the plated chrome layer are partly released.

During operation (thermal influence), the chrome plating in the piston ring grooves may crack into a macro pattern. This is normal and acceptable and not expected to cause further deterioration. More macro-cracks may develop during operation.

4.8 Reconditioning of the running surfaces of liner and skirt

If there are micro-seized areas on the liner or skirt:

- Scratch-over manually with a coarse carborundum stone (grindstone), moving the grindstone crosswise at an angle of 20 to 30 degrees in horizontal direction. This is done to break up the hard surface glaze.
- Leave the "scratch marks" as rough as possible. It is not necessary to completely remove all signs of "vertical stripes" (micro-seizure).

If horizontal wear ridges are found in the cylinder liner, by the top ring TDC position it is recommended to create a circumferential groove by milling or grinding. The groove serves to prevent the build-up of a new wear ridge and protect the new top ring from breakage.

Two methods (grinding and milling) of removing wear ridges are described in work card 2265-0601.

4.9 Piston ring gap (new rings)

Check the gap as described in work card 2265-0401.

4.10 Fitting of piston rings

Fit the piston rings. See also item 3.4. Push the ring back and forth in the groove to make sure that it moves freely.

Only use the MAN Diesel & Turbo standard piston ring opener and do not open the gap excessively, see also item 4.2.

4.11 Piston ring clearance

When the rings are in place, check and record the vertical clearance between the ring and ring groove.

Furthermore, insert a feeler gauge of the thickness specified in work card 2265-0401, and move it all the way round the groove both above and below each piston ring. Its free movement will confirm the proper clearances as well as cleanliness.

4.12 Cylinder lubrication (Alpha and ME Lubricator) and mounting of piston

Check the cylinder lubrication during piston overhaul:

With the piston dismantled, press Pre-lubrication on the HMI panel and check that pipes and joints are leak-proof and that oil sprays out from each lubricating orifice on the liner.

If any of the above-mentioned inspection points have indicated that the cylinder oil amount should be increased or decreased adjust the feed rate as described in chapter 3045-0110.

Mount the piston, see work card 2265-0401.

Before mounting the overhauled piston, remove any remaining deposits from the upper part of the liner.

- With the piston dismantled, press Pre-lubrication on the HMI panel and check that pipes and joints are leak-proof and that oil sprays out from each lubricating orifice on the liner.
- If any of the above-mentioned inspection points have indicated that the cylinder oil amount should be increased or decreased adjust the feed rate accordingly as described in chapter 3045-0110.
- Coat the piston and liner with clean cylinder oil.
- Before mounting the overhauled piston, remove any remaining deposits from the upper part of the liner.

See the separate instruction book for Alpha Lubricator.

4.13 Running-in

If new or reconditioned cylinder liners and/or piston rings are installed, allowance must be made for a running-in period.

4.13.1 Running-in of cylinder liners and rings

The following text refers to drawing 2255-0125 and the mentioned feed rates are valid for a cylinder oil of BN70 standard. The actual obtained feed rate should always be corrected according to the actual BN. In the following the terms "High topland" and "Semi high topland" are used for the pistons. The topland is the designation for the top of the piston crown from the uppermost piston ring groove to the top of the piston.

For the semi high topland the whole area from the uppermost piston ring groove to the top of the piston can be observed at the same time through the scavenge ports. For the high topland pistons only part of the topland can be observed. The previous engine types were in many cases equipped with pistons with low topland, where the whole topland and a number of the rings could be observed at the same time through the scavenge ports.

4.13.1.1 Large-bore engines (60-98)

Running-in periods are classified in three categories:

1. Breaking-in (0-500h)
2. Running-in, phase 1 (500-1500 h)
3. Running-in, phase 2 (1500-3000 h)
4. After conclusion of running in

The purpose of adding extra lubricating oil during the running-in period is to:

- flush away wear particles
- build up an oil film in a not yet run-in cylinder

The running-in process has been eased and shortened considerably with alu-coat running-in coating on all four piston rings. Cylinder liner running-in is facilitated by semi-honed liner surface.

It is recommended to carry out frequent scavenge port inspections during the first 2500 hours.

Breaking-in (0-500 hours)

Piston ring and liner breaking-in takes 500 running hours maximum. A fixed, relatively high lubrication feed rate during the breaking-in period is recommended.

During breaking-in, the running-in coating on the piston rings will gradually wear off, and the plateaus of the wave shape of the cylinder liner running surface will smoothen. During this process extra lubricating oil is required to flush away wear particles and build a satisfactory oil film between the still relatively rough sliding surfaces.

During breaking-in, it is recommended to check the piston rings through the scavenge ports every 100 hours. Do not proceed to the next lubrication step if the scavenge air port inspection reveals seizures or other irregularities.

A five hour stepwise load increase from 50% load to max load is recommended. When running in new piston rings in well running liners, 5-hour load-up from 50% load to max load is also recommended. The load limitation can be set for a single cylinder unit by adjusting the individual fuel pump index.

Running-in phase 1 (500-1500 hours)

After the first 500 running hours, standard sulphur-dependent lubrication can be applied and the Alpha ACC algorithm can take over the lubrication control.

For a BN70 oil, MAN Diesel & Turbo recommends a running-in phase 1 feed rate of $0.26 \text{ g/kWh} \times \text{fuel oil sulphur content in \%}$.

At approx. 1500 hours, alu-coating is usually worn through and the base material or the cermet coating on the top and bottom rings is visible.

When reaching 1500 running hours, carefully check the piston rings and the cylinder liner through the scavenge ports. If the alu-coating is worn through, proceed to running-in, phase 2.

Running-in phase 2 (1500 – 3000 hours)

If no irregularities are found, a feed rate reduction to 0.23 g/kWh x sulphur % (BN70 oil) is recommended.

Inspect the piston rings and the cylinder liner through the scavenge air ports at 3000 running hours. If no irregularities are found, it is recommended to reduce to a feed rate of 0.20 g/kWh x sulphur % (BN70 oil).

If, at any point, signs of micro-seizures or high wear are found it is recommended to switch to the previous setting, i.e. 0.26 g/kWh (BN70 oil).

After conclusion of running-in

After reaching the actual final feed rate setting this should be continuously verified by regular inspections of the components wear condition. If signs of micro seizures or high wear is found, it is recommended to switch to the previous setting providing established stable conditions.

4.13.1.2 Small-bore engines (26-50 bore)

The following text refers to drawing 2255-0125, and the feed rates are valid for a cylinder oil of BN70 standard. The actual feed rate obtained should always be corrected according to the actual BN as stated in the mentioned table.

Running-in

During the first running-in, a relatively high fixed dosage is recommended: 1.5 g/kWh for the first 250 hours succeeded by 1.2 g /kWh for another 250 hours. After these 500 hours of initial running-in, where ample oil is used for flushing away wear particles from the sliding surfaces, ACC running with the factor 0.34g/kWh x S% should be introduced.

The next 2000 hours should be used for a gradual reduction towards the basic setting, i.e. the ACC factor 0.26 g/kWh x S%.

Regulation from the upper ACC factor of 0.34 g/kWh x S % to the basic setting of 0.26 g/kWh x S% should take place stepwise over a 2000 hour period. The size of the steps may depend on the evaluation of the actual lubrication and deposit condition appearing from scavenge port inspections.

After reaching the actual final feed rate setting, this should be continuously verified by regular inspections of the components wear condition. If signs of micro-seizures or high wear are found, it is recommended to switch to the previous setting providing established stable conditions.

4.13.2 Running-in of a single cylinder

If only one cylinder has been overhauled, the fuel pump index for the cylinder in question can be decreased in proportion to the required load reduction, under the condition that the torsional vibration in the propeller shaft will allow it.

As the vibration condition due to the reduction of the fuel pump index of one cylinder is very similar to running the engine with one cylinder in misfire, a barred engine speed range may apply. Consult the class-approved report on the torsional vibration of the actual propeller shaft system and avoid any barred speed range during running-in.

Before starting the engine, fix the fuel rack for the pertaining cylinder at 16% of MCR index.

Increase the index stepwise in accordance with the breaking-in schedule.

Regarding the pressure rise $p_{comp} - p_{max}$, see comp. max., see chapter 6645-0140. If the engine is fitted with the Turbo Compound System (TCS), the TCS must be out of operation if running-in with reduced index is chosen so as to safeguard the TCS gear equipment.

Manoeuvring and low load

In practice, the engine must be able to operate freely in the whole manoeuvring range. The situation where a low load has to be maintained for an extended period, the breaking-in programme should be suspended until higher loads are continued. At this point the running-in programme should also be continued.

4.13.3 Running-in of rings after a piston overhaul

When running-in new piston rings in already run-in and well running liners based on standard BN70 cylinder oil, the breaking-in time is recommended to 5 hours from 50% to 100% load. **The cylinder oil feed rate should be increased by 25% for the first 24 running hours.**

4.13.4 Feed rates

Feed rate recommendations for different engine types may be found in our latest service letters.

5 Factors Influencing Cylinder Wear

5.1 General

Drawing 2255-0105 gives a summary of the most common causes of cylinder wear. The following gives a brief explanation of the most important aspects, and of the precautions to be taken to counteract them.

5.2 Materials

Check that the combination of piston ring type and cylinder liner material complies with the engine builder's recommendations. For engines in guarantee, always follow the engine builder's recommendations.

5.3 Cylinder oil

Check that the quality and feed rate are in accordance with the recommendations in chapter 3045-0110.

5.4 Corrosive wear

5.4.1 The influence of sulphur in the fuel

Corrosive wear is caused by formation and condensation of water and sulphuric acid on the cylinder wall.

In order to minimise condensation, the engine design incorporates optimised temperature level of the liner wall, based on the actual engine layout.

To reduce the risk of corrosive attack:

- Keep the cooling water outlet temperatures within the specified interval, see chapter 4265.
- Use only approved alkaline cylinder lubricating oils, see chapter 3045-0110.
- Preheat the engine before starting, as described in chapter 6645.
- Check that the drain from the water mist catcher(s) functions properly, and water droplets are prevented from entering the cylinders, see item 5.4.4.
- Check the condition of the water mist catcher(s) for cracks in the frame and correct mounting at every inspection through scavenge ports. Check for correct mounting through inspection and mounting covers twice a year.

It is important that any corrosion tendency is ascertained as soon as possible. If corrosion is prevailing:

- Check cylinder feed rate, see item 5.3.
- Increase feed rate.
- Check alkalinity, see item 5.3.
- Check timing of the cylinder oil injection.
- Check cooling water temperatures and the drain from the water mist catcher, as above. The amount of described condensate can be read from drawing 2255-0135.

In case of too small cylinder oil feed rate or too low alkalinity, the alkaline additives may be neutralised too quickly or unevenly, during the circumferential distribution of the oil across the liner wall. This systematic variation in alkalinity may produce "uneven" corrosive wear on the liner wall, see item 3.3.7 regarding 'clover-leafing'.

5.4.2 Sodium chloride (salt)

Seawater (or salt) in the intake air, in the fuel, or in the cylinder oils, will involve the risk of corrosive cylinder wear. The corrosion is caused by sodium chloride (salt), which forms hydrochloric acid.

To prevent salt water from entering the cylinder, via the fuel and cylinder oil:

- Centrifuge the fuel carefully (run two centrifuges in parallel with reduced flow)
- Do not use the bunker tanks for ballast water.

5.4.3 Cleaning agents (air cooler) (to be used with stopped engine only)

The air side of the scavenge air cooler can, if the necessary equipment is installed, be cleaned by means of cleaning agents dissolved in freshwater.

Follow the supplier's instructions strictly for:

- Dosage of the agent
- Use of the cleaning system

After using chemical agents, flush with clean freshwater to remove the agent from the cooler and air ducts.

Cleaning of the air side of the air cooler must only be carried out during engine standstill. During cleaning care should be taken to avoid cleaning agents from entering the scavenge air receiver and air box, causing condensation and piston rod corrosion.

5.4.4 Water condensation on air cooler tubes

Depending on the temperature and humidity of the ambient air and the temperature of the seawater, water may condense on the coldest air cooler tubes.

Water mist catchers are installed directly after the air coolers on all MAN B&W engines to prevent water droplets from being carried into the cylinders.

If water enters the cylinders, the oil film may be ruptured and cause scuffing and wear (clover leafing) on the liner surfaces between the cylinder lube oil inlets. It is very important that the water mist catcher drains function properly!

5.5 Abrasive wear

5.5.1 Particles

Abrasive cylinder wear can be caused by hard particles entering the cylinder via the fuel oil, e.g. catalytic fines, or air, e.g. dust/sand, or the cylinder oil due to insufficient cleaning of the storage tank, see item 5.5.2, 'Fuel Oil Treatment'.

Catalytic fines originating from the refinery process are in fact one of the most common reasons for abrasive liner wear as well as piston crown ring groove wear. These particles consist of aluminium oxide and silicon oxide, which are both heav-

ily abrasive. The catalytic fines are in fact reused as much as possible at the refineries, but it may happen that a batch disappears at the final link in the refinery process, i.e. into the residual heavy fuel.

The size of the particles vary from submicron up to 30 micron, and the shape is often close to being circular.

The limit for catalytic fines in fuel oils (aluminium + silicon) delivered onboard is 60 ppm (weight) according to the latest ISO 8217 fuel standard. By using the fuel cleaning systems onboard (centrifuges), the amount of catalytic fines should be reduced by 80%, i.e. a fuel containing 60 ppm should not contain more than 12 ppm at the engine inlet. For bunkers containing less cat fines we expect a proportional reduction at the engine inlet.

A suspicion that catalytic fines are the reason for a sudden liner and ring wear can be confirmed (or be denied) by taking replicas of worn liner and/or piston ring surfaces. PrimeServ, Copenhagen can assist with expertise in such matters. The investigation also includes judgement of the liner surface structure (open graphite, closed graphite).



The occurrence of the particles is unpredictable. Therefore, always clean the fuel oil as thoroughly as possible by centrifuging with a slow flow rate, to remove the abrasive particles, i.e. if two centrifuges are running they should run in parallel.

Abrasive wear can occur on:

1. The running surfaces of the liner and piston rings.

Scratching on the piston ring running surface is one of the first signs of abrasive particles and can be observed during scavenge port inspections or piston overhauls. Scratching is often seen as a large number of rather deep “trumpet shaped” grooves (see drawing 2255-0145).

Usually, micro-seizures do not occur, i.e. the ring surface remains soft. However, if excessive micro-seizures (scuffing) do occur, the ring surface becomes hard. This can be checked with a file (a file test can only take place when the piston is pulled, and rings have been dismantled).

2. The upper and lower sides of the piston rings.

Particles caught between the upper horizontal ring/groove surfaces will cause pitting – “pock-marks” – on the upper ring surface (see drawing 2255-0145). “Pock-marks” may also arise during a prolonged period of ring collapse. Even if the running surface of the top ring has a satisfactory appearance, the condition of the ring's upper surface will reveal the presence of abrasive particles coming with the fuel.

3. The upper edge of the piston rings.

When particles pass down the ring pack via the ring joint gaps, they will cause a "sand blasting" effect on the upper edge of the ring below, that protrudes from the piston ring groove, i.e. this is only seen on ring Nos. 2, 3, and 4.

5.5.2 Fuel oil treatment

Correct fuel oil treatment and proper maintenance of the centrifuges are of the utmost importance for cylinder condition, exhaust valves and fuel injection equipment. Water and abrasive particles are removed by means of the centrifuges:

- The ability to separate water, depends largely on the specific gravity of the fuel oil relative to the water at the separation temperature. Other influencing factors are the fuel oil viscosity (at separation temp.) and the flow rate. Keep the separation temperature as high as possible, i.e. always above 98 degrees
- The ability to separate abrasive particles depends on the size and specific weight of the smallest impurities that are to be removed and, in particular, on the fuel oil viscosity (at separation temp.) and the flow rate through the centrifuge.
- Keep the flow rate as low as possible. Run centrifuges in parallel.
- If in doubt about the efficiency of the centrifuges call in a service engineer from the manufacturer. It is worthwhile.
- It should be noted that the viscosity of the fuel have a high impact on the separation. For example, if the fuel temperature is lowered by approximately 3 degrees Celsius, the efficiency of the cleaning drops to almost half.

For more information on fuel oil see chapter 4245.

5.6 Adhesive wear

5.6.1 Scuffing

Apart from the factors mentioned under item 3.3 (blow-by, deposits, cylinder oil deficiencies, etc.) scuffing can be due to:

- Unsatisfactory running-in conditions (especially if previous micro-seizures have not been successfully counteracted during a cylinder overhaul). As regards running-in, see item 4.13.
- Incorrect and too high lubrication feed rate (chemical bore polish)
- Too rapid changing of engine load
- Water intrusion
- Presence of vast amounts of particles, e.g. cat fines
- Excessive wear of CPR top ring CL-grooves, beyond minimum depth
- PC-ring malfunction, top-land deposits interacting with cylinder liner surface (mechanical bore polish).

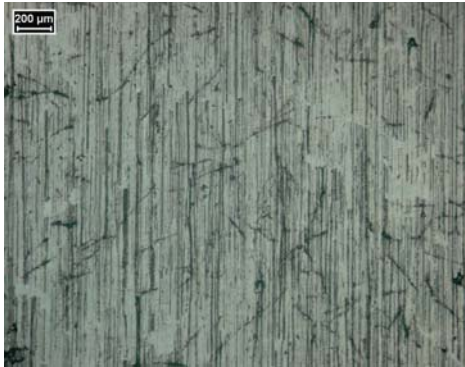
5.6.2 Bore polish

Bore polish as a result of over-lubrication and excessive neutralisation of the sulphuric acid, or as a result of top land deposits, will result in a closed graphite structure and reduce the ability of the running surface to maintain a proper oil film. A closed graphite structure will furthermore be less capable of reducing the extension and spreading of seizures, compared to an open structure.

When there is limited corrosive liner wear, e.g. 0.03-0.05 mm/1000 hours, the

structure normally becomes open and, hereby, the risk of seizure is drastically reduced. Therefore, it is an advantage to have a certain amount of controlled corrosive wear.

Cylinder liner surface



Closed grafite structure



Open grafite structure

Introduction

These instructions are a supplement to *work card 2265-0201*, and should be used in combination with that procedure during inspection and overhaul of all Nimonic spindles on MAN Diesel & Turbo engines.

All general data, including specified wear limits for the spindle used on your engine type, are given in *data 2265-0200*. Note down the actual engine data in the “data”-box in the relevant chapters of these instructions.

The procedure is divided into the following eight sections:

1	Spindle identification
2	Inspection intervals
3	Inspecting the contact condition of the seat
4	Checking the seat for gas leakage
5	Cleaning and evaluation
6	Inspecting the valve stem wear layer
7	Grinding the spindle seat
8	Exhaust Valve Condition Report

Sections **3** to **7** are each divided into four steps:

- What to do
- Acceptance criteria
- Remarks
- Further action

1 Spindle Identification

Markings:

The tops of Nimonic spindles are marked:
“Nim”, “Nim80A”, “N80A”, “N80”, or “NCF80A”.

If in doubt, please contact MAN Diesel & Turbo, Copenhagen.

2 Inspection Intervals

Inspection	Inspections:		
	Initial	Second	Subsequent
Normal hours of service:	After 6,000 hours	After 24,000 hours (35-40 ME-B, only 16,000 hours)	Every 24,000 hours (35-40 ME-B, only 16,000 hours)
Recommended:	After 6,000 hours (50-60 ME/MC 3-6,000 hours)	Based on condition at initial inspection	Based on condition at initial and second inspections *)

*) If the spindle condition is very good, the condition of other exhaust valve parts may prove to be the decisive factor in determining the future overhaul/inspection intervals.

Also see 'Checking and Maintenance Schedule', chapter 0760-0301.

3 Inspecting the Contact Condition of the Seat

What to do:

NOTICE

Do not clean the spindle disc before inspection !



Visually check that there is inner contact.



Fig. 1 shows inner contact between the seats of the spindle and bottom piece, corresponding to slow/low-load/manoeuvring condition.

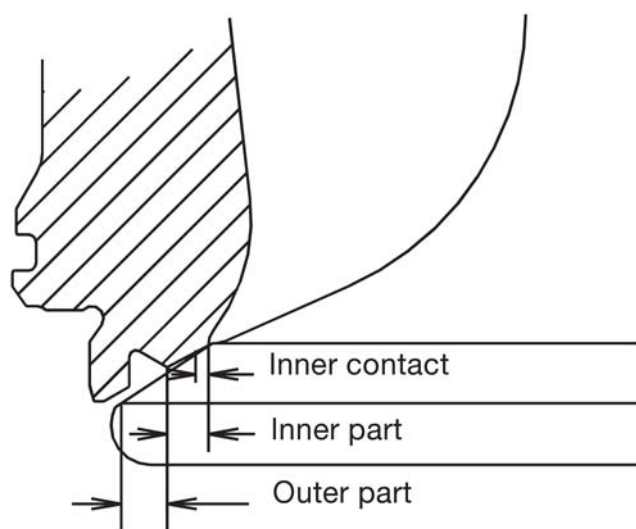


Figure 1: Inner contact, and zone designation

Acceptance criteria:

There must be contact around the entire **inner** circumference of the seat.

Remarks:

When the valve heats up in service, the angular difference between the spindle and bottom piece seatings will decrease. At steady, full load, the seatings will be parallel, as shown in **Fig. 2**. Thus, inner contact must be maintained in order to be sure of parallel contact during running.

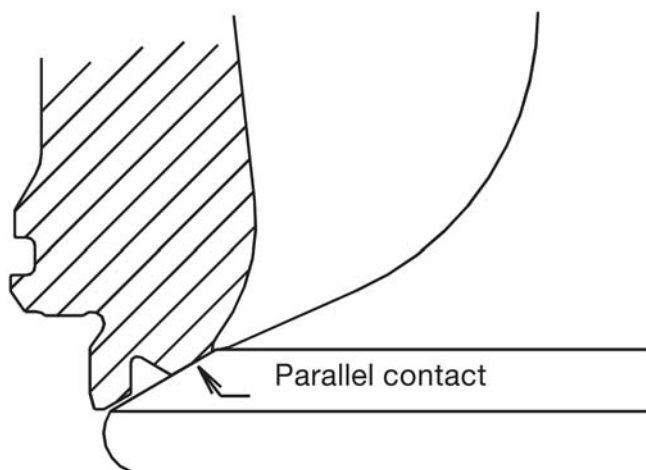


Figure 2: Contact condition during running

If there is no inner contact, outer contact (**Fig. 3**) will occur during running, and this will increase the risk of blow-by.

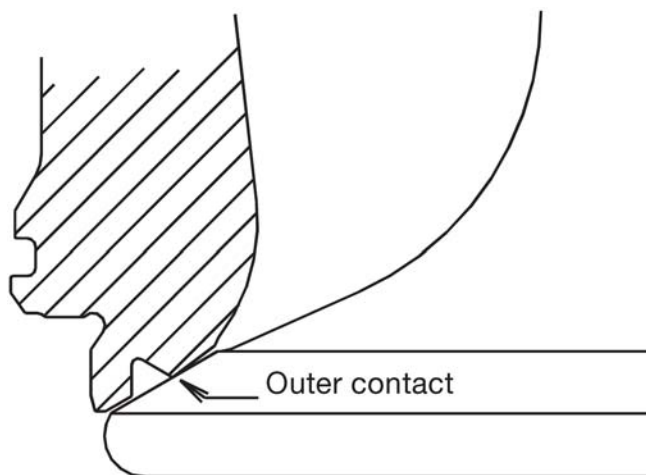


Figure 3: Outer contact, increased risk of blow-by

Further action:

 Fill in section 8 'Exhaust Valve Condition Report'.

If the seat contact is incorrect, grind the spindle seating, as described in section 7. However, before grinding, proceed to section 4, 5 and 6.

4 Checking the Seat for Gas Leakage

What to do

NOTICE



Do not clean the spindle disc before inspection !



Visually check the inner part of the seating for blow-by (Fig. 4 and Photo 1).

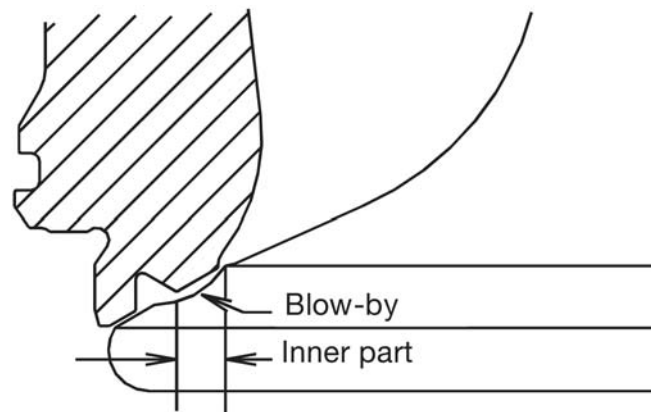


Figure 4: Blow-by



Photo 1. Blow-by

Acceptance criteria:

There must be no blow-by “tracks” across the inner part of the seat
(Figs. 1 + 4, and Photo 1).

Remarks:

Blow-by indications may be associated with large/deep dent marks, and will often form a “gas-jet-fan” in the deposits on the disc cone (Photo 1).

The surface of a serious blow-by track/groove will usually show signs of hot corrosion, i.e. it will have an “elephant skin” texture.

Minor leakages. Small, faint, fan-shaped leakage indications on the spindle cone, just inside the seat area (Photo 2), are harmless.



Photo 2: Minor leakages, and “fans”

Further action:

 Fill in section 8: ‘Exhaust Valve Condition Report’.

If blow-by has been found, then grind the seat, as described in section 7. However, before grinding, proceed to sections 5 and 6.

5 Cleaning and Evaluation

What to do:

- Clean the seat with coarse emery cloth. Observe and note down the size and number of dent marks. Also note any possible crack indications.
- Check the outer part of the seat for high temperature corrosion (Fig. 1 and Photo 3).

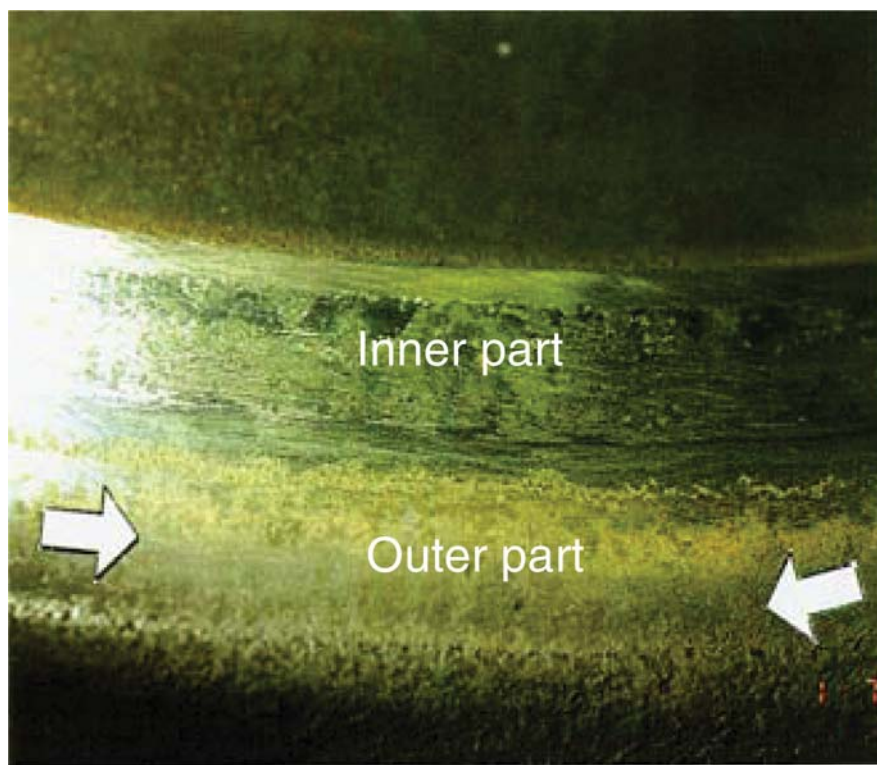


Photo 3: Example of high-temperature corrosion at outer part after 33,000 hours

- Clean the contact faces on which the measuring template is to be applied, and measure:
 - the burn-off on the disc underside,
 - the total amount the seat has been ground.

(See work card 2265-0201.)

Acceptance criteria:

Dent marks, of varying number and size (up to 8-10 mm), will be seen on the seating after a few thousand service hours. The first marks may appear as early as after testbed running. In general, dent marks are acceptable and should not necessitate grinding of the seat. If, however, the marks have caused blow-by, then the seat must be ground/reconditioned.

Cracks. Any indications of cracks in the seat area should be checked carefully. If cracking is confirmed, contact MAN Diesel & Turbo.

High-temperature corrosion on the outer part of the seat may result in a measurable difference in level between the inner and outer seat zones. In that case the spindle must be ground. However, this will not normally happen before 20 – 30,000 hours after the previous grinding.

Wear Allowances:

- Burn-off on disc underside, (F1)
- Total grinding of seat, (G1).

Fill in data from
wc 2265-0201

F₁:

G₁:

Remarks:

Burn-off rate (disc underside). The number of service hours before shore-side reconditioning usually depends upon the burn-off rate of the disc underside.

Engine type: *)	Max. permissible burn-off (mm)
26MC	5
35MC 35ME-B	6
40ME-B	6
42MC	7
46MC-C	8
50MC/MC-C 50ME/ME-C	8
60MC/MC-C 60ME/ME-C	9
65ME-C	9
70MC/MC-C 70ME/ME-C	10
80MC/MC-C 80ME/ME-C	14
90MC/MC-C 90ME/ME-C	17
98MC/MC-C 98ME/ME-C	20

*) Also valid for stationary engines (power plants).

Further action:

 Fill in section 8: 'Exhaust Valve Condition Report'.

If the burn-off or grinding limits have been reached, contact MAN Diesel & Turbo for advice on reconditioning.

If the seat and the disc underside are acceptable with respect to section 3, 4, and 5, then the spindle can be reinstalled without grinding after section 6 has been carried out. Otherwise, proceed to section 6 and 7.

6 Inspecting the Valve Stem Wear Layer

What to do:

- Clean the valve spindle stem.
- Measure the diameter of the spindle stem in the area shown in work card 2265-0201.
- Check the surface condition of the chrome-plated/HVOF-coated area.

Acceptance criteria:

Min. diameter: Must not be less than that stated in work card 2265-0201. **Cracking ("meshwork cracking") of chrome/HVOF:** Slight cracking of the lowermost part of the chrome plating/HVOF-coating (Photo 4) has no significance, and is therefore acceptable.

Peeling-off: The chrome plating/HVOF-coating must not show peeling-off.

Fill in data from
wc 2265-0201

D- _____:
min. diameter of
spindle stem:

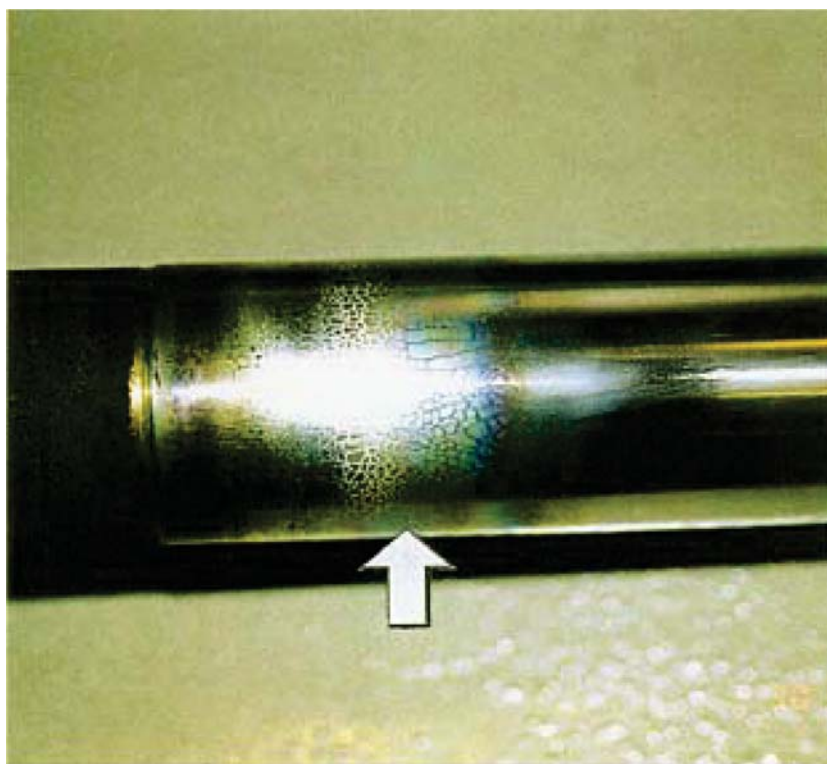


Photo 4: Slight cracking ("meshwork cracking") of wear layer

Further action:

✍ Fill in section 8: 'Exhaust Valve Condition Report'.

If the spindle stem is acceptable, proceed to section 7. Otherwise, contact MAN Diesel & Turbo for advice on reconditioning.

7 Grinding the Spindle Seat

What to do:

- Mount the spindle in the grinding machine and, using the dial-gauge positioned just inside the area of inner contact, (**see Fig. 5**), true-up to within a maximum of 0.05 mm. This is done in order to minimize the amount of material removed during grinding.

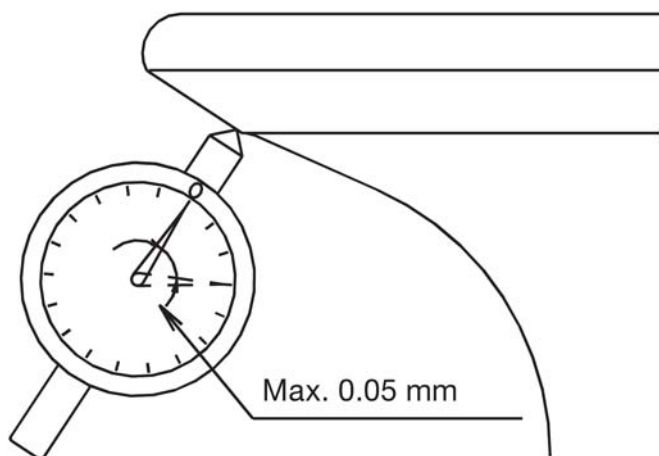


Figure 5: Truing-up the spindle

Grind the seat according to the special instructions from the grinding machine supplier.

See also MAN Diesel & Turbo Service Letter SL95-332/UM, "Grinding of Nimonic Exhaust Valve Spindles".

Fill in data from
wc 2265-0201

D-_____:

Offset angle:

Keep the grinding to a minimum!

After full contact between grindstone and seat is reached at the beginning of the grinding process:

Normally	Limit the grinding to 0.2 mm.
Rare cases	Remove 0.3 mm or more.
Blow-by	Continue the grinding until the blow-by marks are removed.
Dent marks	It is not necessary to continue grinding until all dent marks have been removed.

Photo 5 shows an overhauled Nimonic valve spindle which is ready for further service.



Photo 5: Acceptable seat condition after grinding

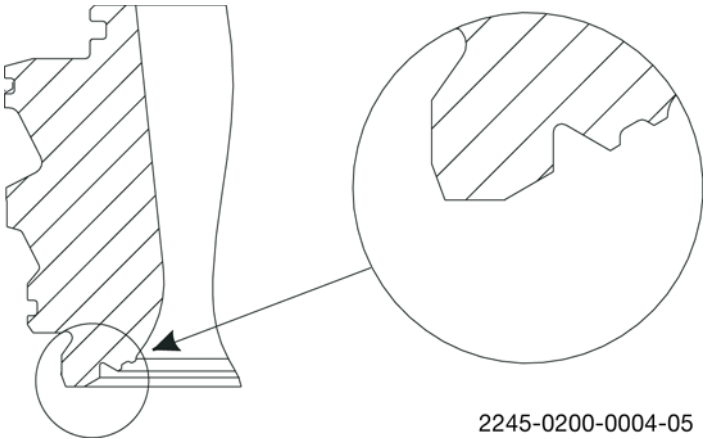
Acceptance criteria:

The ground surface. The grindstone must have removed material from the whole width and the whole circumference of the seat. There must be no signs of blow-by.

Max. grinding depth: must not exceed the limit (G1) stated in *work card: 2265-0201*.

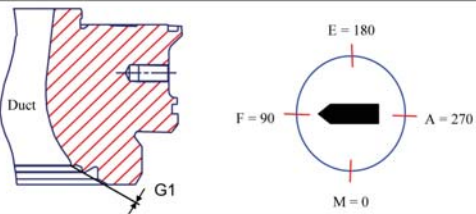
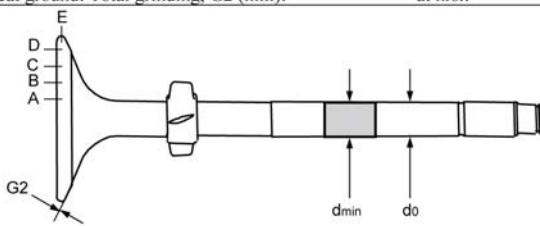
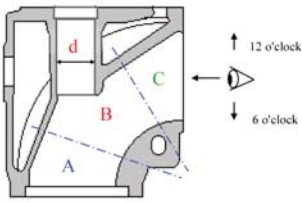
If the seat surface is still not acceptable when the max. grinding depth has been reached, contact MAN Diesel & Turbo for advice on reconditioning.

Fill in data from wc 2265-0201
G ₁ :



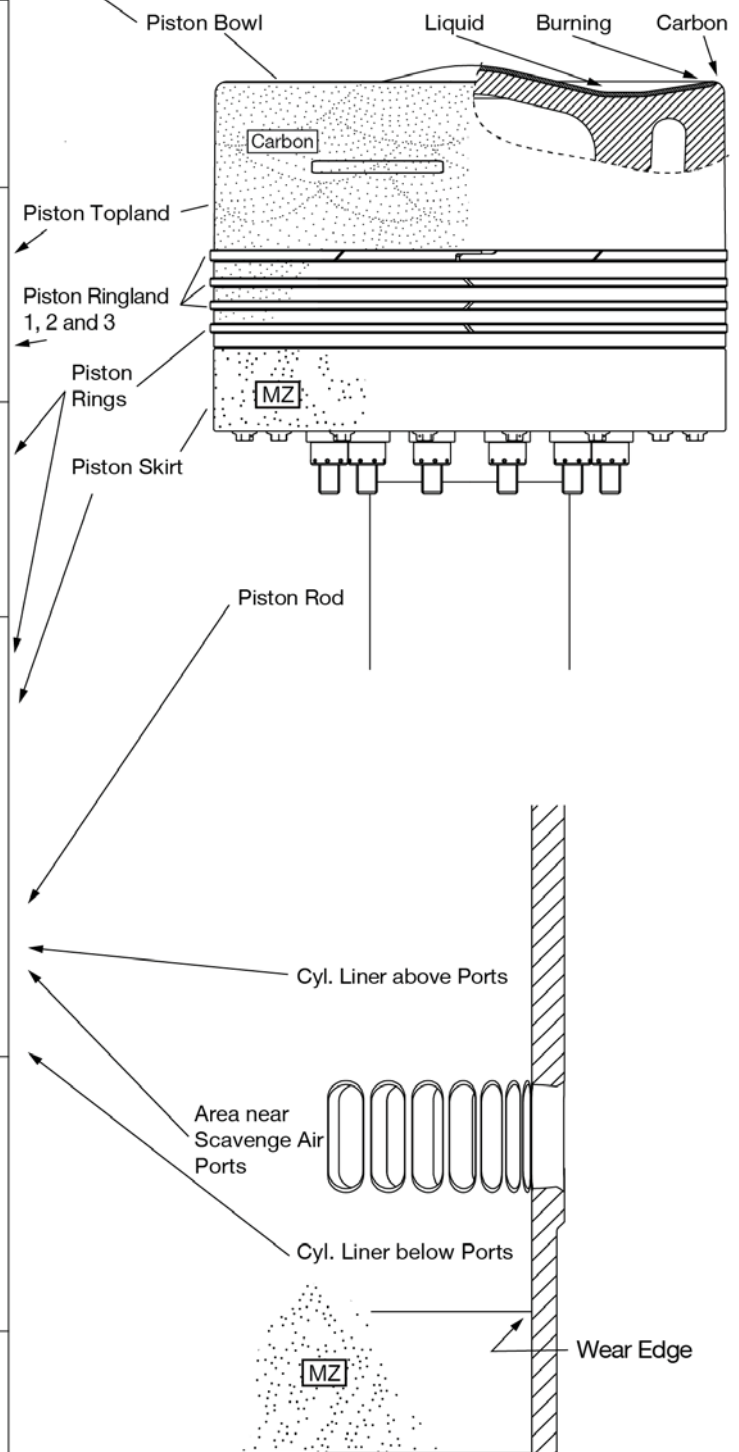
2245-0200-0004-05

8 Exhaust Valve Condition Report

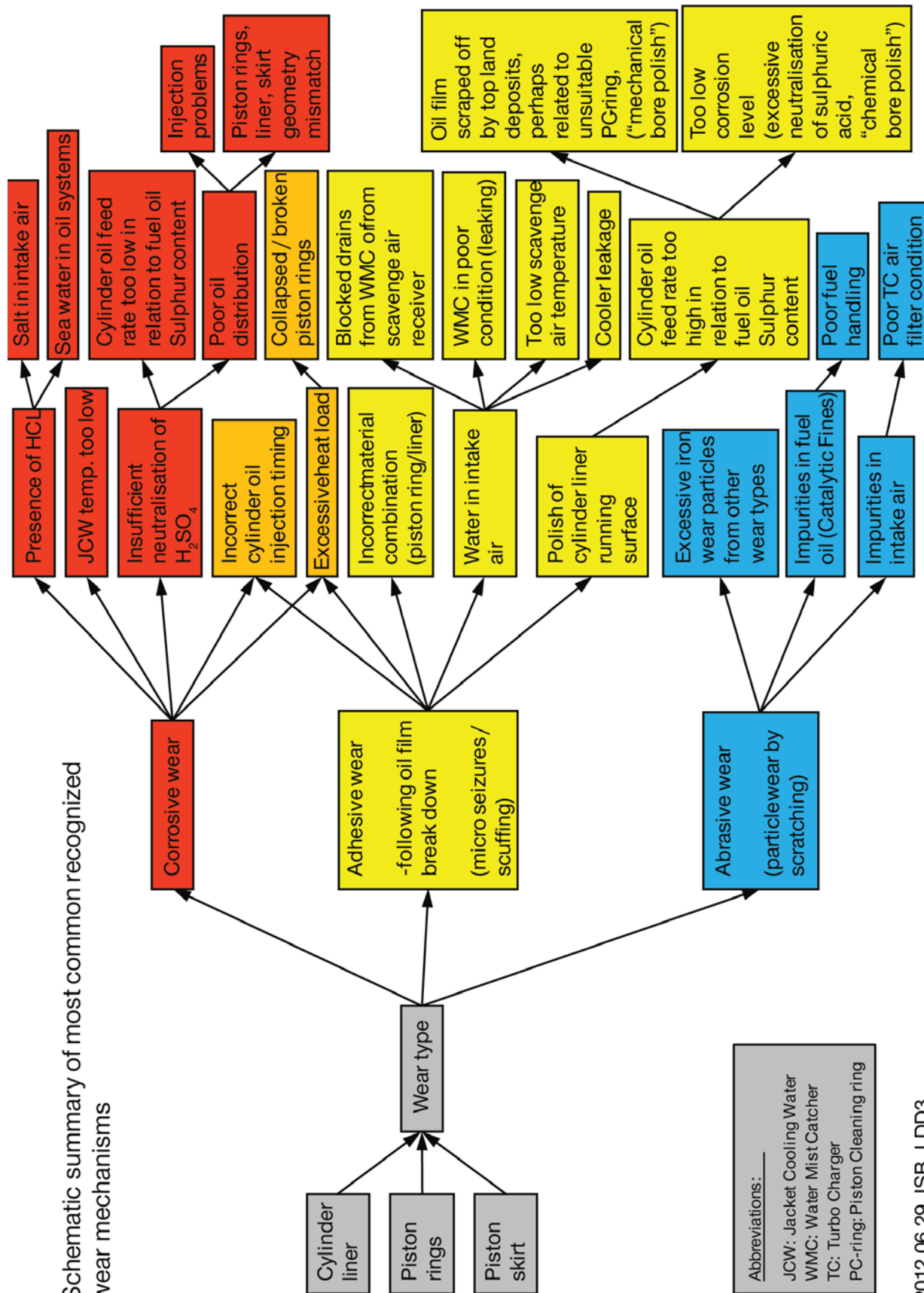
Exhaust Valve Condition Report							
Vessel:				No.:			
Eng. builder:		Eng. no.:		No. of cyl.:		Eng. type:	
Valve no.:		Valve hours:		Kept as spare (yes/no):		Test (yes/no):	
Valve dismantled from cyl.:		Date (yymmdd):		Engine hours (total):			
Valve checked/overhauled by:		Date (yymmdd):		Engine hours (Total):			
Valve mounted on cyl.:		Date (yymmdd):		Engine hours (total):			
Remarks:							
BOTTOM PIECE							
Type:		Marking:		Seat material:			
Drawing no.:		Hours since last overhaul:		Hours total:			
Cracks (yes/no):		Blow-by (yes/no):		Seat contact (inner/outer/parallel):			
No. of dent marks larger than $\varnothing = 7$ mm:				Seat ground: Total grinding, G1 (mm): at hrs.:			
Deposit in chamber: Extend on circumference (mm):				Maximum deposit thickness in duct (mm):			
Angular position of max. deposit (0° = manouvre side):							
Deposit in way of fuel valves (yes/no):							
Remarks							
SPINDLE							
Marking:		Base material:		Disc underside material:			
Seat material:		Stem surface:		Drawing no.:			
Hours since last overhaul:		Hours total:					
Cracks (yes/no):		Blow-by (yes/no):		Seat contact (inner/outer/parallel):			
Spindle disc max burn-off (mm):		at position (A, B, C, D or E):		Burn-off rate (mm/1000 hrs):			
No. of dent marks larger than $\varnothing = 7$ mm:				Seat ground: Total grinding, G2 (mm): at hrs.:			
Stem diameter d_0 above sealing area (mm):							
Min. stem diameter d_{min} at sealings (mm):							
Wear of stem sealing ring (%):							
Remarks							
HOUSING							
Marking:		Drawing no.:		Hours since last overhaul:		Hours total:	
Spindle guide diameter				Spindle guide, hours total			
Minimum / Top (mm)		Maximum / Top (mm)					
Minimum / Bottom (mm)		Maximum / Bottom (mm)					
Corrosion							
Section	A		B		C		
mm							
Position (o'clock)							
Remarks:							

Inspection through Scavenge Ports															
Vessel:				IMO nr.:				Builder/no.:							
Number of cylinders:		Eng. type:		Eng. hrs.:		Checked by:		Date:							
Weeks pr. port calls:				Normal service load (% of MCR):				MEP lubricator type (Y/N):							
Cyl. oil consump. (l/24 hrs):				at load %		Cyl. oil type:		Position: ☐ Exhaust ☐ Manoeuvre							
	Condition and Symbol	Engine Part	Cylinder No.												
			1	2	3	4	5	6	7	8	9	10	11	12	
Deposits	Intact - * Burning - BU Leaking oil - LO Leaking water - LW No deposit - * Light deposit - LC Medium deposit - MC Excessive deposit - EC Polished deposit - PC	Piston crown													
		Topland													
		Ringland 1													
		Ringland 2													
		Ringland 3													
Ring breakage	Intact - * Collapsed - C Broken opposite ring gap - BO Broken near gap - BN Several pieces - SP Entirely missing - M	Ring 1													
		Ring 2													
		Ring 3													
		Ring 4													
		Ring 1													
Ring movement	Loose - * Sluggish - SL Sticking - ST	Ring 2													
		Ring 3													
		Ring 4													
		Ring 1													
		Ring 2													
Surface condition	Clean, smooth - * Running surface, Black, overall - B Running surface, Black, partly - (B) Black ring ends > 100 mm - BR Scratches (vertical) - S Micro-seizures (local) - mz Micro-seizures (all over) - MZ Micro-seizures, still active - MAZ Old MZ - OZ Machining marks still visible - ** Wear-ridges near scav. ports - WR Scuffing - SC Clover-leaf wear - CL Rings sharp-edged Top/Bot. - T/B	Ring 3													
		Ring 4													
		Piston skirt													
		Piston rod													
		Cylinder liner abv. scav. ports													
		Cylinder liner near scav. ports													
		Ring 1													
		Ring 2													
		Ring 3													
		Ring 4													
Lubrication condition	Optimal - * Too much oil - O Slightly dry - D Very dry - DO Black oil - BO	Piston skirt													
		Piston rod													
		Cylinder liner													
		Scavenge box													
		Scav. receiver													
		Flaps and nonreturn valves													
		Intact - *													
Running hours since last overhaul															

	Condition and symbol
	Intact - * Burning - BU Leakage Oil - LO Leakage Water - LW
Deposites	No deposit - * Light deposit - LC Medium deposit - MC Excessive deposit - EC Polished deposit - PC
Ring breakage	Intact - * Collapsed - C Broken opposite ring gap - BO Broken near gap - BN Several pieces - SP Entirely missing - M
Ring movement	Loose - * Sluggish - SL Sticking - ST
Surface condition	Clean, smooth - * Burning surface, Black, overall - B Burning surface, Black, partly - (B) Black ring ends > 100 mm - BR Scratches (vertical) - S Micro-seizures (local) - mz Micro-seizures, (all over) - MZ Micro-seizures, still active - MAZ Old MZ - OZ Machining marks still visible - ** Wear-ridges near scav. ports - WR Scuffing - SC Clover-leaf wear - CL Rings sharp-edged Top/Bot. - T/B
Lubrication condition	Optimal - * Too much oil - O Slightly dry - D Very dry - DO Black oil - BO
Deposites	No Sludge - * Sludge - S Much sludge - MS
	Intact - *



Schematic summary of most common recognized wear mechanisms



2012.06.29, JSB, LDD3

Factors Influencing Cylinder Wear

Drawing

2255-0105-0003

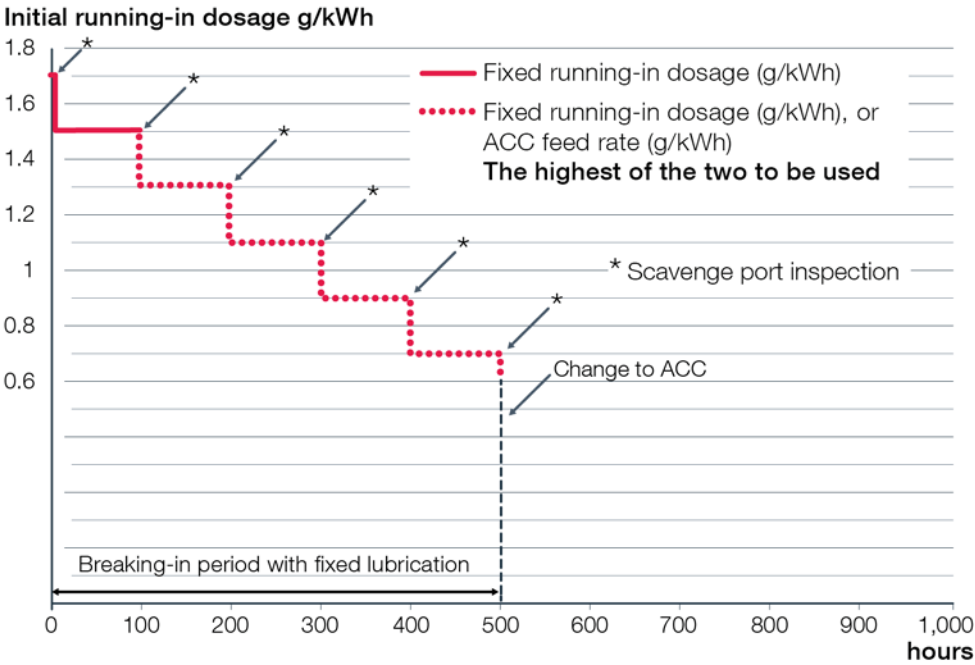
Guiding cylinder oil feed rates

All ME/ME-C/ME-B/ME/MC/MC-C and ME-GI engines

With electronically controlled lubrication system

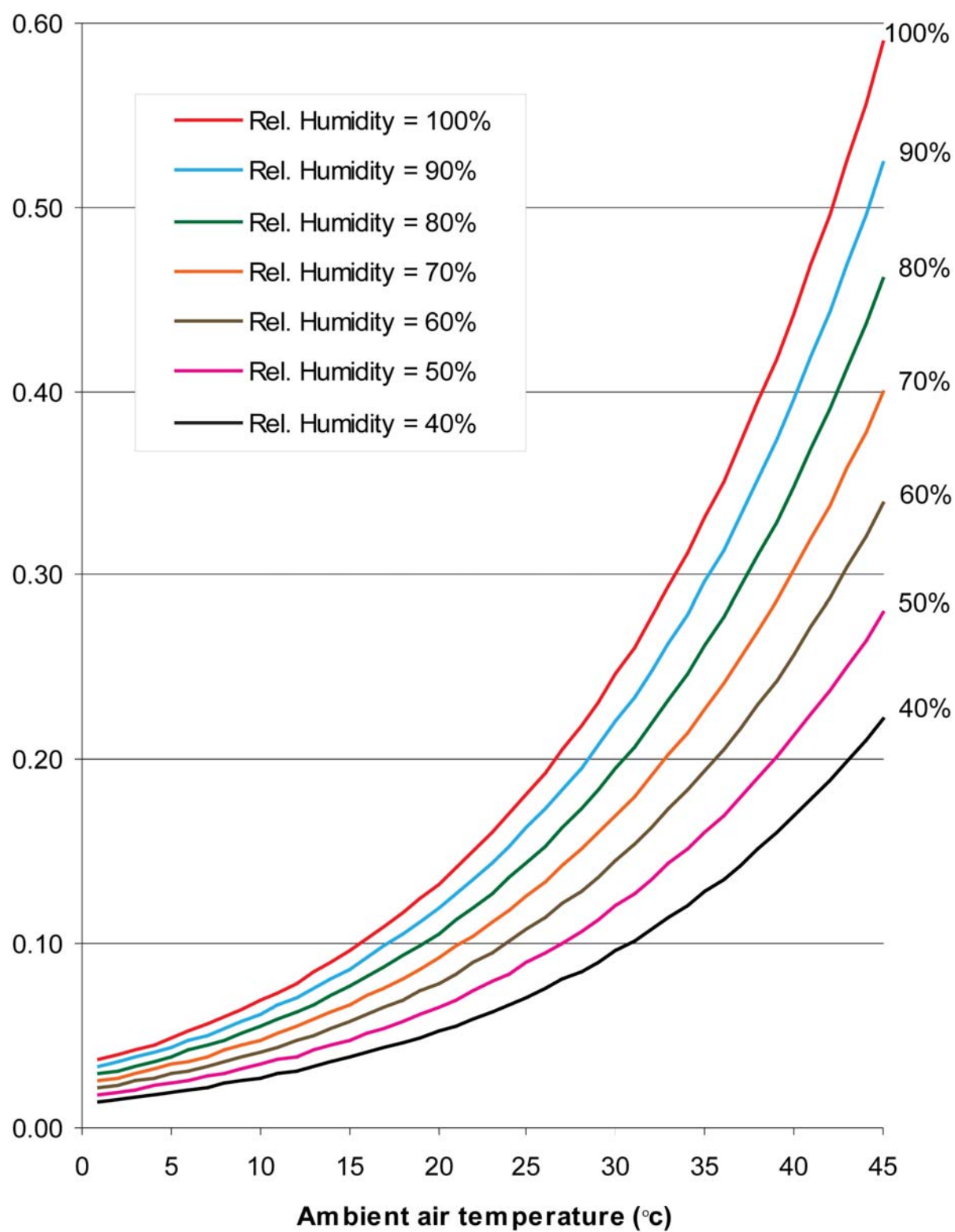
	Mk 8-8.1 and newer Standard BN 100	Mk 7 and older Standard BN 70-100
Viscosity range	SAE 50	SAE 50
ACC setting	0.40-0.20 g/kWh x S%	0.34-0.20 g/kWh x S%
Guiding minimum feed rate	0.60 g/kWh	0.60 g/kWh
Maximum feed rate during running-in	1.7 g/kWh	1.7 g/kWh
Part-load control	Proportional with load. At lower loads control is automatically changed to proportional with rpm. Breakpoint from power to rpm-dependent lubrication to be set to 25% load.	
Running-in new or reconditioned liners and new piston rings	Feed rate: First 5 hours: 1.7 g/kWh From 5 to 500 hours: Stepwise reduction from 1.5 - 0.6 g/kWh or ACC factor x fuel sulphur (using the highest feed rate) Engine load: Test bed: Stepwise increase to max. load over 5 hours In service: 50% to max. load in 16 hours	
Familiarizing ACC Factor	Starting at 0.40 g/kWh x S% (Fig. 6a)	Starting at 0.34 g/kWh x S% (Fig. 6b)
	Reducing in steps of 0.04 g/kWh x S% after min. 600 hours where the feed rate has been sulphur dependent (above min. feed rate) or using feed rate sweep or continuous drain oil analysis. If the engine is retrofitted with means to improve part or low-load fuel consumption, the ACC factor must be reassessed.	
Running-in new rings in already run-in and well running liners	From 50% to max. load in 5 hours Feed rate 0.9 g/kWh for 24 hours. If the fuel sulphur and applied ACC factor combination results in a specific feed rate higher than 0.9 g/kWh (use the calculation feed rate), no extra lubrication is needed.	
Manoeuvring and load change situations	During starting, manoeuvring and load changes, increase feed rate by means of the "LCD" by 25% of the actual figure and kept at this level for ½ hour after the load has stabilised.	
Lubrication of cylinders that show abnormal conditions	Frequent scavenge port inspections of piston rings and cylinder liners are very important for maintaining a safe cylinder condition. If irregularities are observed, adjustments of the lube oil feed rate should be considered. In case of scuffing, sticking piston rings or high liner temperature fluctuations, raise the feed rate to 1.20 g/kWh and lower the pmax and mep. As soon as the situation has been stabilised, set the lubrication feed rate and pressures back to normal. In case of high corrosive wear, the ACC factor is to be increased to the highest ACC factor (0.40 g/kWh x S% for BN 100) and be reduced in steps of only 0.02 g/kWh x S% when the wear has been confirmed as normal.	

Breaking-in New Liners



If a liner or piston crown is exchanged, two reports must be filled-in!

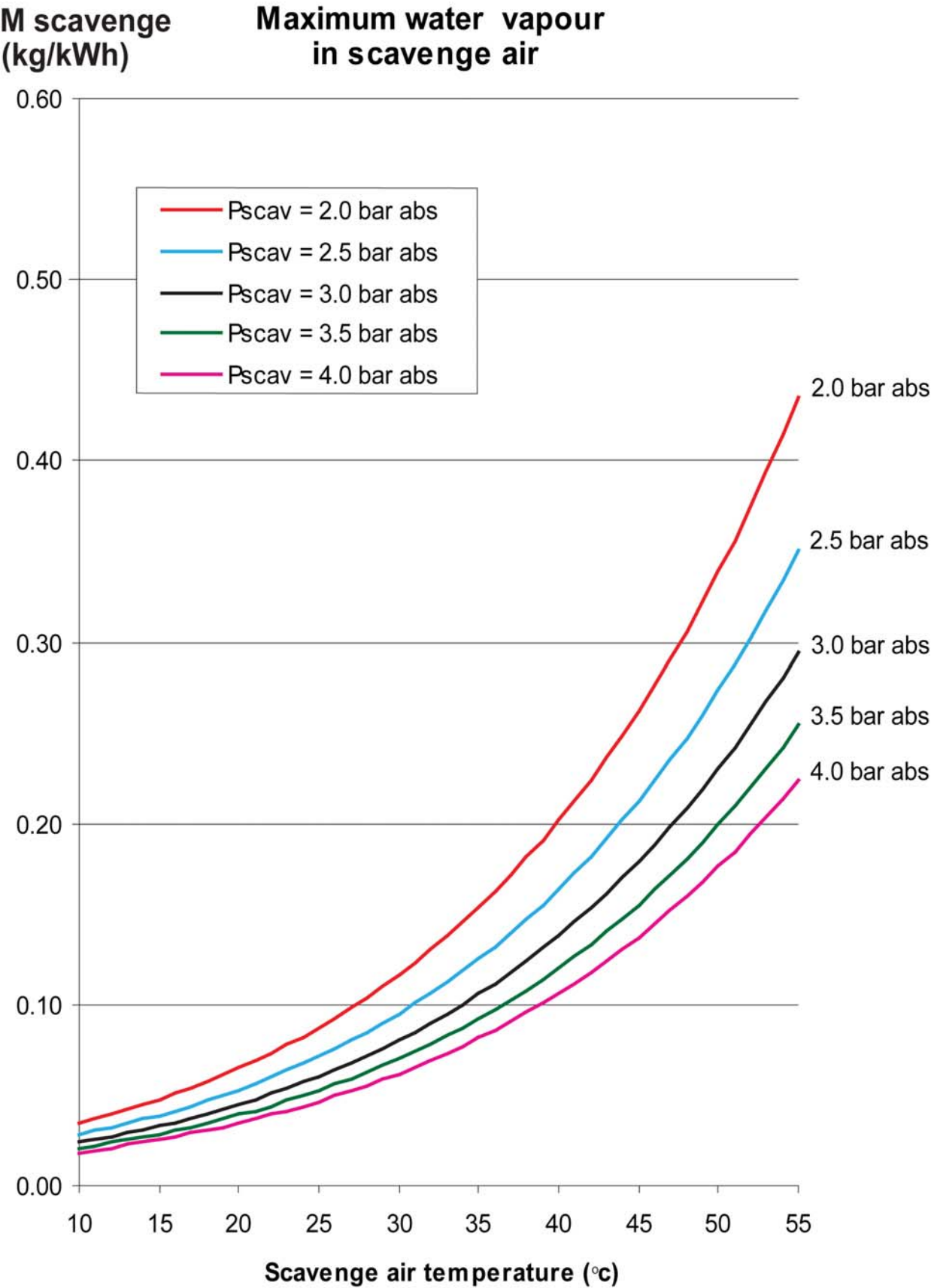
Cylinder Condition Report																
Vessel:			L.I. no.:		Eng. builder:			Eng. no.:			Checked by:					
No. of cyl.:		Eng. type:		Eng. hrs.:		Date (yymmdd):			Inspected unit no.:							
Voyage info																
Weeks pr. port calls:			Normal service load (% of MCR):				Lub. part load control:				Lub. type:					
Cyl. oil consumption (l/24 hrs):			at load %:				Cyl. oil type:									
Cylinder liner																
Liner hours:			Insulation pipe (Y/N):			PC ring (Y/N):			Liner material:							
Drawing no.:			Frame type:			Liner cool type:			Liner honed (Y/N):							
Producer/Marking:			Wear type:			Liner honed (Y/N):			Shims (mm):							
Cyl. cover tightened (Y/N):			Temp. between liner and measuring tool (°C):			Shims (mm):										
Measuring point	0	1	2	3	4	5	6	7	8	9	10	11	A1 (Additional)	A2 (Additional)		
Depth (mm)																
Diameter (mm)	F-A															
	E-M															
E: Exhaust M: Manoeuvre A: Aft F: Fore All measuring points are defined from the distance of the mating surface from the cylinder cover. Pos. 0: The middle of the none sliding part above the top piston ring at TDC. Pos. 1-4: The middle of the rings at TDC. Pos. 5 & 6: Equally positioned between pos. 4 and 7 (1/3 of distance). Pos. 7: Lubrication quill level. Pos. 8 & 9: Equally positioned between pos. 7 and 10 (1/3 of distance). Pos. 10: 100 mm. above the scav. air ports. Pos. 11: The middle of the none sliding part below the bottom piston ring at BDC.																
Liner remarks																
Piston rings																
	Base material	Coating	Profile	Manufacturer	Lock type	CL grooves	Broken									
Ring 1																
Ring 2																
Ring 3																
Ring 4																
Ring 5																
	Width of ring (mm)					Free ring gap "F" (mm)	Ring grooves									
	A	B	C	D	E		Height, H (mm)									
Degrees							F	E	A	M						
Ring 1																
Ring 2																
Ring 3																
Ring 4																
Ring 5																
Hours since last overhaul:																
Piston																
Crown hours:			High topland (Y/N):			Reason for examination										
Bronze ring (Y/N):			Oros piston (Y/N):			Routine piston overhaul ☐ (If either of these boxes are ticked, below boxes must be kept blank) Test ☐										
Max burning 1 (mm)						Liner	Piston Crown	Piston Rings	Piston Skirt							
Position 1 (degree)						Cracks	Burning	Broken	Leaking							
Max burning 2 (mm)						Scuffing	Cracks	Collapsed	Scuffing							
Position 2 (degree)						Leak	Leaking	Sticking	Piston Rod							
Max burning 3 (mm)						High Groove				Stuff. box						
Position 3 (degree)						Wear										
Piston remarks																

**M ambient
(kg/kWh)****Water vapour in intake**

Calculation of Condensate Amount

Drawing

2255-0135-0002

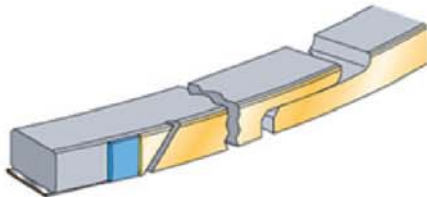


Large Bore Ring Configuration:

K80 Mk. 9, K90 & K98, S90 Mk. 8-9

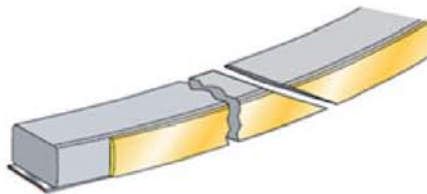
1st ring

CL-grooves:	CPR E4-180
Base material:	Vermicular cast iron, CV1
Hard coating:	Cermet coating
Running-in coating:	Alu coating
Bottom face:	Chrome plating



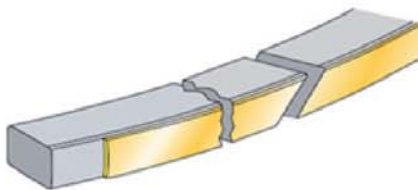
2nd ring - left cut

Base material:	Grey cast iron, CF5
Running-in coating:	Alu coating
Bottom face:	Chrome plating



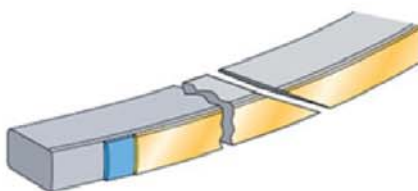
3rd ring - right cut

Base material:	Grey cast iron, CF5
Running-in coating:	Alu coating



4th ring - left cut

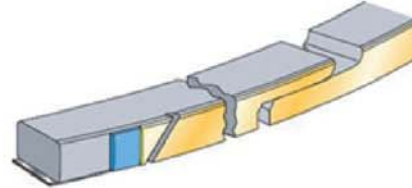
Base material:	Grey cast iron, CF5
Hard coating:	Cermet coating
Running-in coating:	Alu coating



Alternative Heavy Duty Ring Configuration:

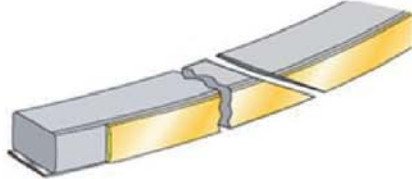
1st ring

CL-grooves:	CPR E4-180
Base material:	Vermicular cast iron, CV1
Hard coating:	Cermet coating
Running-in coating:	Alu coating
Bottom face:	Chrome plating



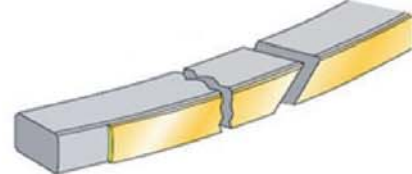
2nd ring - left cut

Base material:	Grey cast iron, CF5
Running-in coating:	Alu coating
Bottom face:	Chrome plating



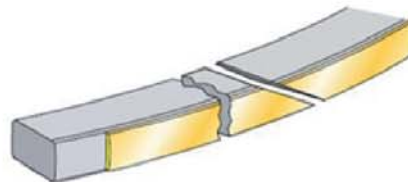
3rd ring - right cut

Base material:	Grey cast iron, CF5
Running-in coating:	Alu coating

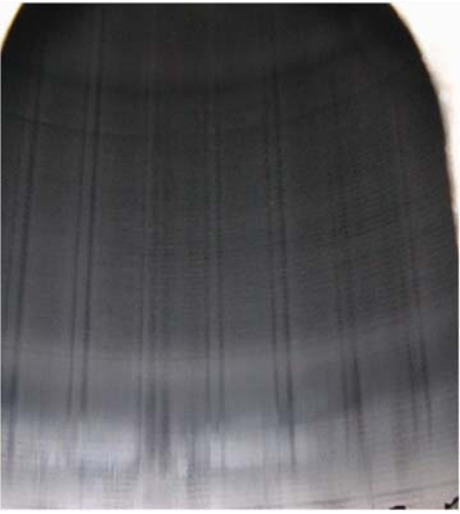
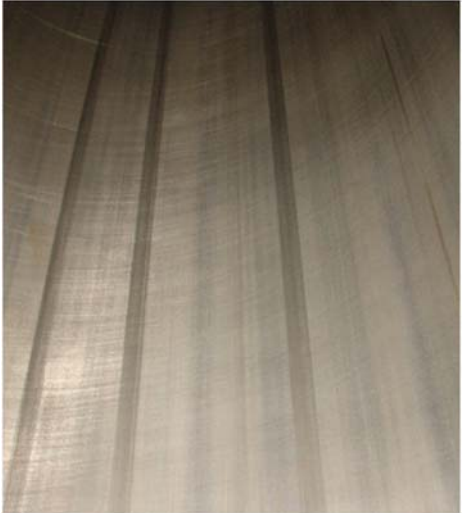


4th ring - left cut

Base material:	Grey cast iron, CF5
Running-in coating:	Alu coating



Normal Condition	Cold Corrosion
	
Normal liner condition. Light corrosive surface. Wave cut machining marks still visible on the lower part of the liner.	Cold Corrosion. Normal cold corrosion on the lower liner part, the corrosion facilitates good lubrication oil film, and the liner wear rates are acceptable.
Top cold Corrosion	Liner Black Deposits
	
Excessive Corrosive top part of the liner. Heavily corrosive surface, may lead to high liner wear and high ovality.	Black Deposits (black lacquer). The result of high humidity in the scavenging air, impacting the cylinder oil, producing alkaline material, forming a patch of deposits. Harmless to the engine and will be worn away when the air becomes dryer.

Bore Polish	Port Rib Marks
	
Liner Polish. Excessive piston top land deposits will eventually lead to liner polish and oil film break down. Possibly related to missing or malfunctioning PC-ring in combination with too high oil feed rates.	Port Rib Marks. Often seen in connection with excessive top land deposits due to too high cylinder oil feed rates, in combination with a cooler liner port area by cold climate and low load operation. (Not harmful).
Seizure stripe	Scuffing (Macro seizures)
	
Micro Seizures. Deriving from local oil film break down, must be treated with increased oil feed rate to make the rings run in again. May otherwise evolve into scuffing.	Scuffing (Macro seizures). The result of complete oil film break down is high friction and seizures leading to heavy liner wear. The liner must be exchanged or machined.

Safety precautions

For detailed sketch
see 0545-0100

☐	Engine stopped
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

Data

Ref.	Description	Value	Unit
T22-01	High-pressure pipe, tightening torque	cross-tightened 80	Nm
T22-02	Distance of high pressure pipe lower edge to pressure flange	24	mm
T22-03	High-pressure pipe	80	kg

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
7670-0200	-	Torque spanners
2270-0200	113	Grinding tool - High-Pressure Pipe

WARNING**Secure the engine and depressurise the HCU**

Make sure the engine is stopped and blocked according to the safety precautions. *See data.*

Depressurise the HCU. *See work card 4565-0501.*

NOTICE

Great care must be taken to ensure that the area around the workplace is clean before and during any dismantling of the hydraulics.

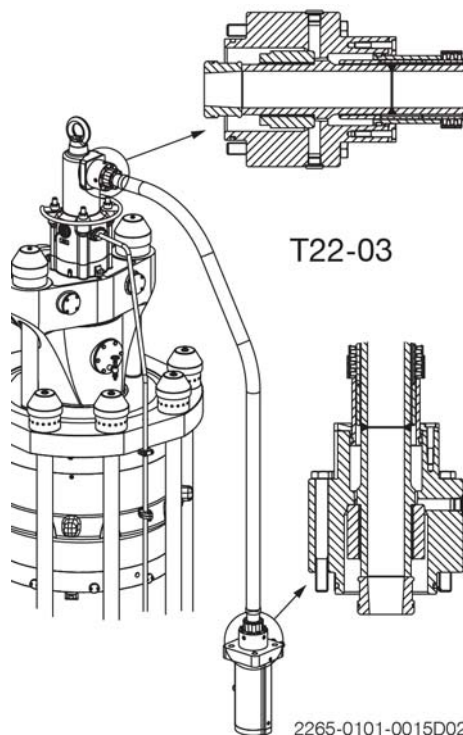
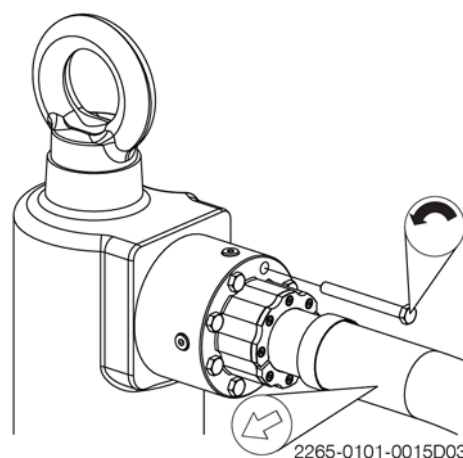
1. Removing the high-pressure pipe Remove the screws at both ends of the high-pressure pipe.

NOTICE**Oil spill risk**

Loosen the screws for the high-pressure pipe and lift the pipe slightly away from the actuator to let the oil in the pipe drain through the drain holes in the actuator.

Attach a sling and use the engine room crane to lift the high-pressure pipe away from the engine.

2. Check the high-pressure pipe condition After removing the hydraulic high-pressure pipe, check the high-pressure pipe sealing surfaces.



1. The thrust piece

The two ends of the pipe are identical and should both be overhauled as follows.

Remove the thrust piece from the actuator and exhaust valve.

Remove and discard the O-rings from the thrust piece and the thrust flange.

The thrust piece and two O-rings are found at both ends of the pipe and are in both cases identical.



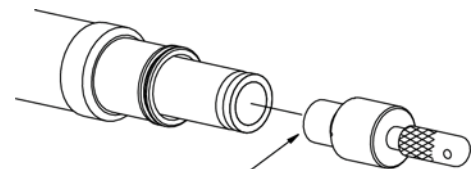
2265-0101-0015001

2. Pipe ends

After removal of the thrust pieces, check the surfaces of the high-pressure pipe for marks and, if necessary, grind the pipe ends by means of the grinding tool. This is done by inserting the end of the tool into the pipe and applying grinding paste.

Start grinding with a coarse grinding paste, for example Carborundum No. 200, and finish with a fine grinding paste, for example Carborundum No. 500.

After the grinding, clean the high - pressure pipe and the thrust piece.

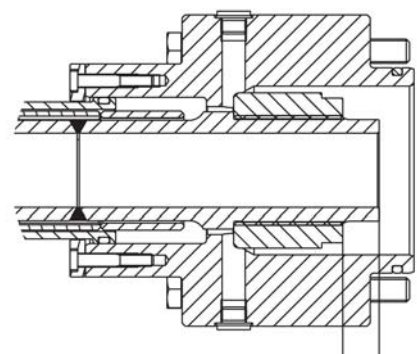
**Carborundum No. 200/500**

2265-0101-0002004

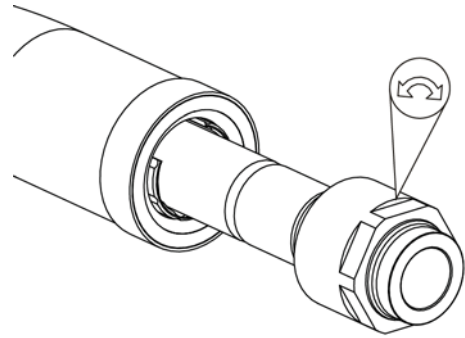
3. The thrust bushing

After reconditioning the contact surfaces of the pipe, the position of the thrust bushing should be inspected. Measure the distance from the edge of the thrust bushing to the contact surface at both ends of the pipe. This measurement is to correspond with the value stated in Data, T22-02. The thrust bushing is screwed in place on the inner steel tube and normally does not require any adjustment.

The thrust bushing should be screwed all the way in until it reaches its mechanical stop point.

**T22-02**
2265-0101-0015003

4. Possible adjustment If however the distance, as stated in T22-02 is not correct, the position of the thrust bushing can be adjusted by means of a suitable wrench or spanner which can be inserted in the end of the pipe.



2265-0101-0015O04

Exhaust Valve High-Pressure Pipe • Overhaul

Work Card
2265-0101-0015

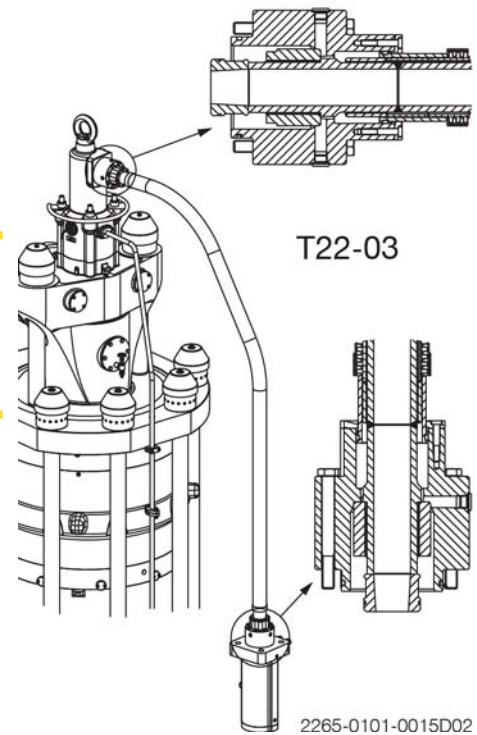
1. Mount the high-pressure pipe

If not already done, mount new O-rings, lubricated with a little lubricating oil, on the thrust flanges.

Mount the high-pressure pipe on the engine.

NOTICE

When mounting the high-pressure pipe, take care not to damage the sealing surfaces of the pipe/thrust pieces.



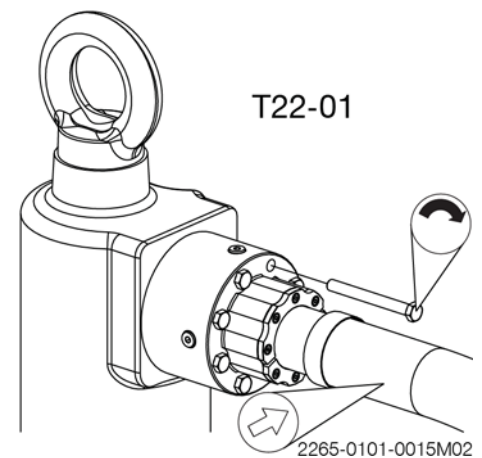
2. Tighten screws

Mount the pipe to the exhaust valve and actuator, and tighten the screws.

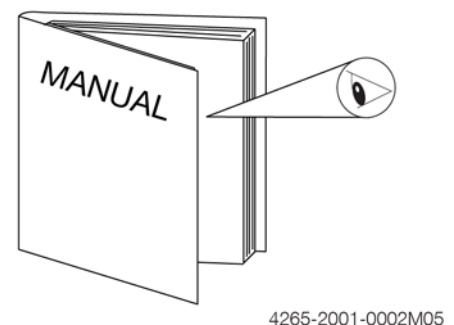
First, tighten the screws by hand.

Finally, tighten the screws diagonally to the torque stated *in data*, using a torque spanner.

For correct use of the torque spanner, see work card 7665-0301.



3. Pressurise the HCU *See work card 4565-0501.*



Safety**Precautions**

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Shut off air supply to exhaust valve - Only with stopped lub. oil pumps
○	Engage turning gear
○	Shut off cooling water
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T22-06	Safety valve, opening pressure	23	bar
T22-08	Oil cylinder, tightening torque	230	Nm
T22-09	Safety valve, tightening torque	70-100	Nm
T22-11	Throttle valve, tightening torque	20	Nm
T22-13	Bottom piece seat, grinding angle	29.9 - 30.0	°
T22-14	Valve spindle seat, grinding angle	30.3 - 30.4	°
T22-15	Check measurement G2	0 - 2.3	mm
T22-16	Gap of bottom piece seat	1.0	mm
T22-17	Spindle, max. burn-off	9.0	mm
T22-18	Spindle, max. grinding	2.0	mm
T22-19	Spindle stem, measuring area, min.	280	mm
T22-20	Spindle stem, measuring area, max.	410	mm
T22-21	Spindle stem, min. diameter	71.8	mm
T22-22	Bushing max. diameter	73.0	mm
T22-24	Oil cylinder max. inside diameter	85.4	mm
T22-25	Piston rings, min. thickness	3.2	mm
T22-26	Damper piston, min. distance	50.4	mm
T22-27	Damper piston, max. distance	51.4	mm
T22-28	Exhaust valve, complete	760	kg
T22-29	Exhaust valve housing	500	kg
T22-30	Oil cylinder	130	kg
T22-32	Spindle	100	kg
T22-33	Bottom piece	50	kg
T22-34	Air piston	10	kg
T22-125	Orifice plug, tightening torque	20	Nm
T76-01	Hydraulic pressure, dismantling	1400-1650	bar

Data (continued)

Ref.	Description	Value	Unit
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
2270-0200	066	Lifting tool for exhaust valve
2270-0200	080	Test equipment for exhaust valve
2270-0200	091	Gauge for exhaust valve spindle
2270-0200	113	Grinding tool for high pressure pipe
2270-0200	137	Bridge gauge for exhaust valve
2270-0200	149	Tool for hydraulic piston
2270-0200	162	Lifting tool for exhaust valve
2270-0200	186	Grinding ring for exhaust valve bottom piece
2270-0210	-	Exhaust valve, grinding tools
2270-0240	-	Exhaust valve, hydraulic tools
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	106	5-way distributor block, complete
7670-0200	-	Torque spanners
7670-0410	066	Slide caliper

Checks with running engine**1. Check bottom piece seals**

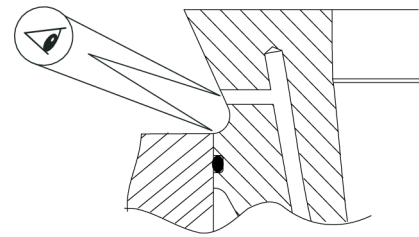
With the exhaust valve mounted in the cylinder cover, ensure that the cooling water inlet and outlet to the cylinder cover and exhaust valve are open.

Check the tightness of the sealing rings between the bottom piece and the exhaust valve housing. If water flows from the small bore on the manoeuvring side of the exhaust valve, the lowermost sealing ring is leaking.

If water flows from any of the rings, the exhaust valve must be dismantled and the sealing rings replaced.

2. Exhaust valve performance condition

See description 6345-0300.



2265-0201-0012C01

Checks with stopped engine

1. Simple check
In connection with port stays, at an interval of e.g. one month, a check of all exhaust valves is recommended.
2. Check spindle drop-down time
Check the position of the exhaust valve spindles on the MOP.

Shut off and release the air spring on the valve next to the engine-side manoeuvring stand.

Check the drop-down time for all spindles:
 - Spindles dropping down within 30 minutes: Check and overhaul, *see checking procedure 'Check air cylinder sealing'*.
 - Spindles dropping down between 30 minutes and 1 hour: Keep under observation.
 - Spindles dropping down after 1 hour: OK.

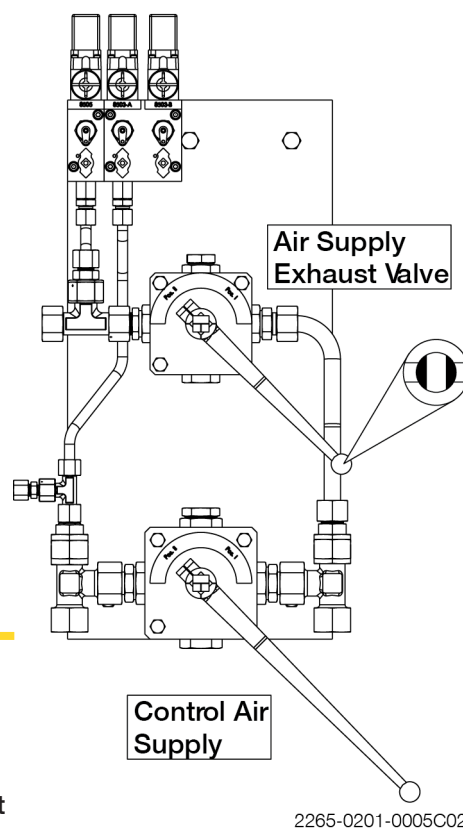
NOTICE

If the air cylinder is fitted with new sealing rings, the time at which the valve is closed may vary considerably from the above stated, especially for new exhaust valves.

- Hole for drain oil **B**: If yes, the leakage comes from the safety valve or the air piston. Check the safety valve **C**. If air still is coming out, the leakage comes from the air piston: change and overhaul.
- Non-return valve **A**: Remove the air supply to the non-return valve on the air cylinder and check for leakage. If it leaks, replace the valve.

NOTICE

The checks are for guidance only, minor leaks are difficult to detect.



2265-0201-0005C02

3. Check air cylinder sealing

Connect compressed air to the non-return valve **A** on the air cylinder.

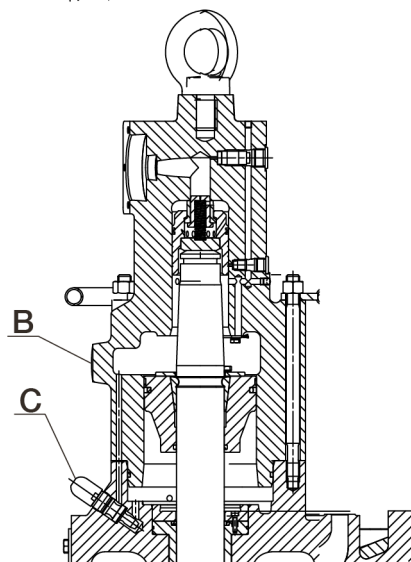
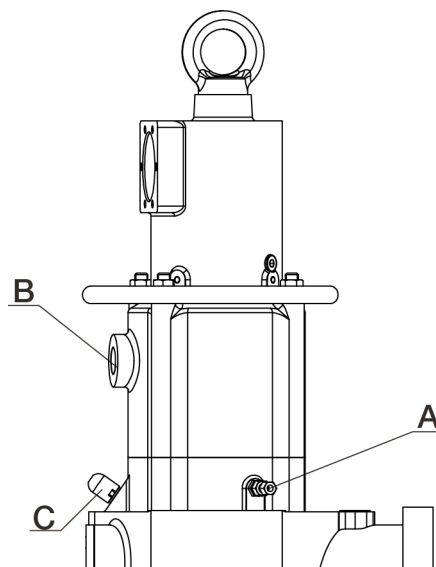
Disconnect and remove the drain oil pipe **B** from the oil cylinder.

Check if air is coming out from:

- Hole for drain oil **B**: If yes, the leakage comes from the safety valve or the air piston. Check the safety valve **C**. If air still is coming out, the leakage comes from the air piston: change and overhaul.
- Non-return valve **A**: Remove the air supply to the non-return valve on the air cylinder and check for leakage. If it leaks, replace the valve.

NOTICE

The checks are for guidance only, minor leaks are difficult to detect.



2265-0201-0017C03

1. Shut off cooling water Close the cooling water inlet and outlet connections.

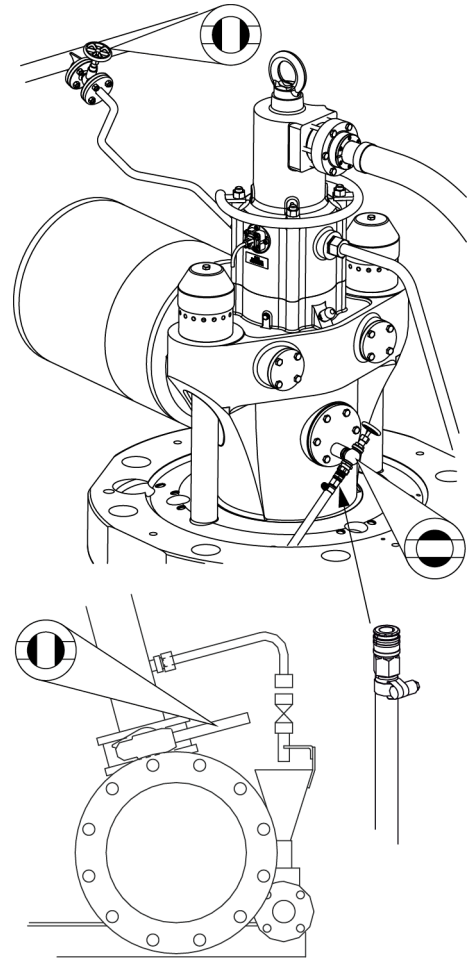
Drain the exhaust valve.

Attach the hose with coupling to the angle valve. Attach the other end of the hose to the drain hole in the cylinder cover.

Drain off the rest of the cooling water from the exhaust valve.

Remove the coupling and hose and close the valve.

Shut off and relieve the air supply to the exhaust valve.

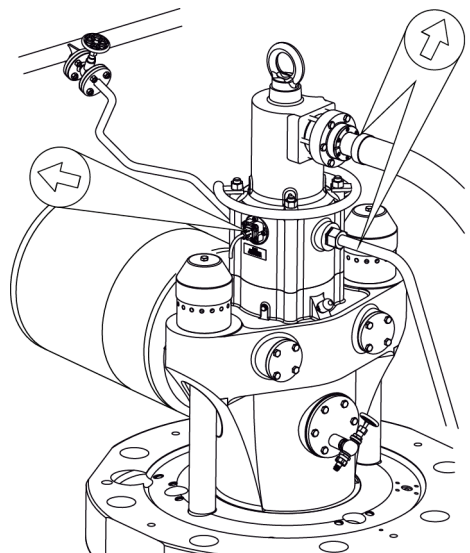


2265-0201-0017D01

2. Remove the oil pipe connections Remove the high-pressure pipe for the hydraulic valve actuator.
See work card 2265-0101.

Remove the drain oil pipe from the exhaust valve.

Disconnect or remove the valve position sensor, depending on the sensor type.



2265-0201-0017D02

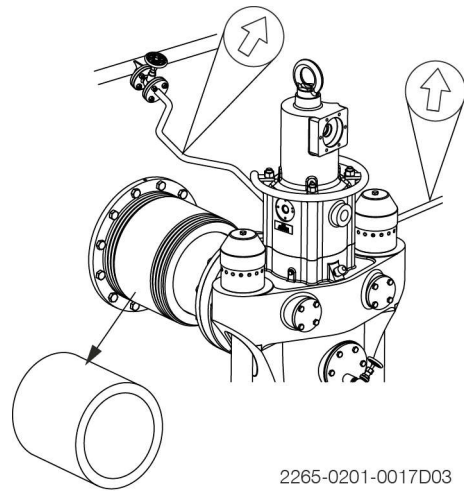
3. Disconnect pipes

Disconnect the cooling water connections from the exhaust valve and the air pipe for the air spring.

Remove the plate jacket and insulation from the intermediate pipe.

Loosen the screws which attach the intermediate pipe to the exhaust valve housing.

Support the intermediate pipe with a chain block and remove the screws.



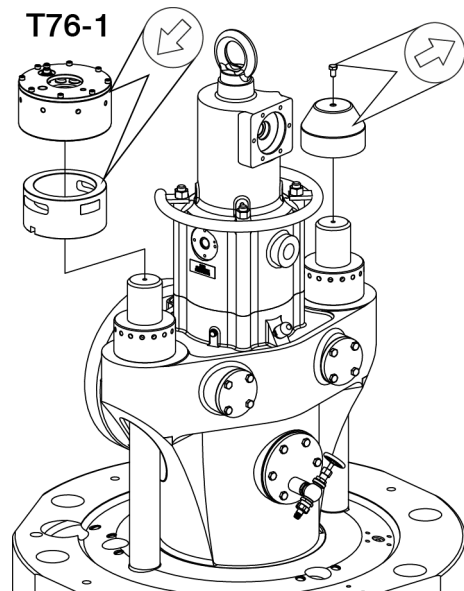
2265-0201-0017D03

4. Remove the nuts

Remove the protective caps from the exhaust valve studs.

Loosen and remove the nuts.

For use of the hydraulic tools, see work card 7665-0101.



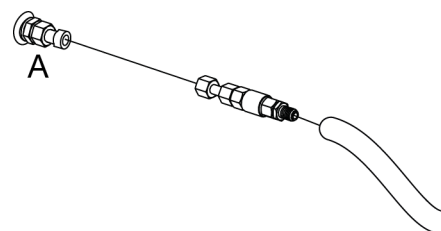
2265-0201-0017D05

5. Close the valve

Supply 7 bar working air to the air cylinder, by means of an air hose and the special coupling, through non-return valve **A**.

See checking procedure.

The valve is thereby kept closed when removed from the engine.



2265-0201-0001D06

**CAUTION****Keep valve closed**

The 7 bar working air must be connected during the entire lift of the exhaust valve.

6. Lift exhaust valve

Check that all connections to the valve are removed.

Attach the crane to the eye bolt mounted on top of the valve and start lifting the exhaust valve. During the lift - check that the valve goes clear of all other engine components.

NOTICE

Before attempting to lift the exhaust valve, check the position of the oil piston damper in the top of the oil cylinder.

The check is carried out by looking into the oil duct. If the oil piston moves downwards during valve lifting, the parts are not kept together and the alternative lifting procedure must be followed. *See dismantling procedure 'Special lift'.*

**WARNING****Safe working load (SWL)**

Always use lifting gear with sufficient SWL.
See data.

**WARNING**

Keep clear of the exhaust valve during lift

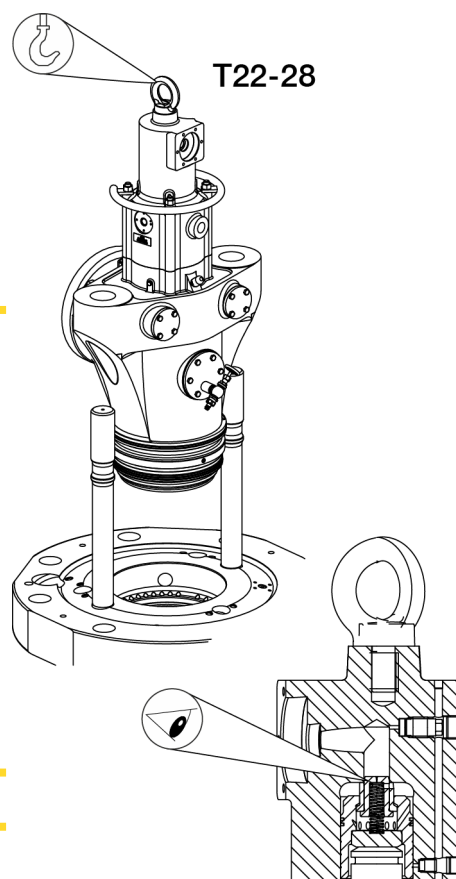
Land the exhaust valve on a wooden plate on the platform.

Disconnect the 7 bar working air hose.

7. Clean and recondition

Carefully clean the exhaust valve bore in the cylinder cover.

If required, recondition the seating and sealing surfaces of the bore.
See work card 2265-0301.



2265-0201-0017D07

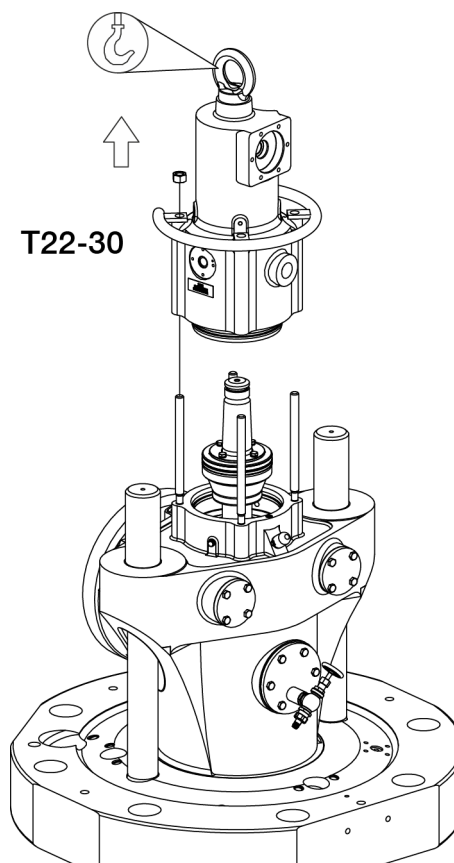
CAUTION**Special lift**

If the bottom piece is stuck in the cylinder cover or by other means not kept retained to the exhaust valve housing, the exhaust valve should be removed by lifting directly in the valve spindle stem.

1. Remove the oil cylinder

Remove the oil cylinder from the exhaust valve.
See overhaul procedure.

Land the oil cylinder on a wooden support.



2265-0201-0017D08

2. Mount spindle top lifting tool

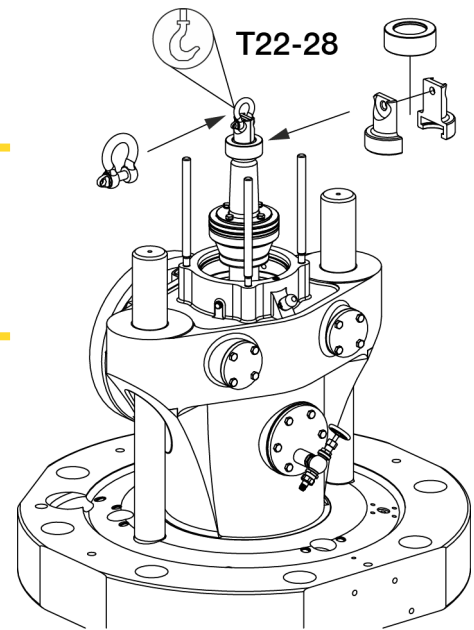
Mount the two lifting tool halves in the recess and lock them with the ring. Mount the shackle.



Impact hazard

Before lift, ensure that the two-part lifting tool and the ring are fully engaged.

Use the engine room crane to lift the exhaust valve away .



2265-0201-0017D09

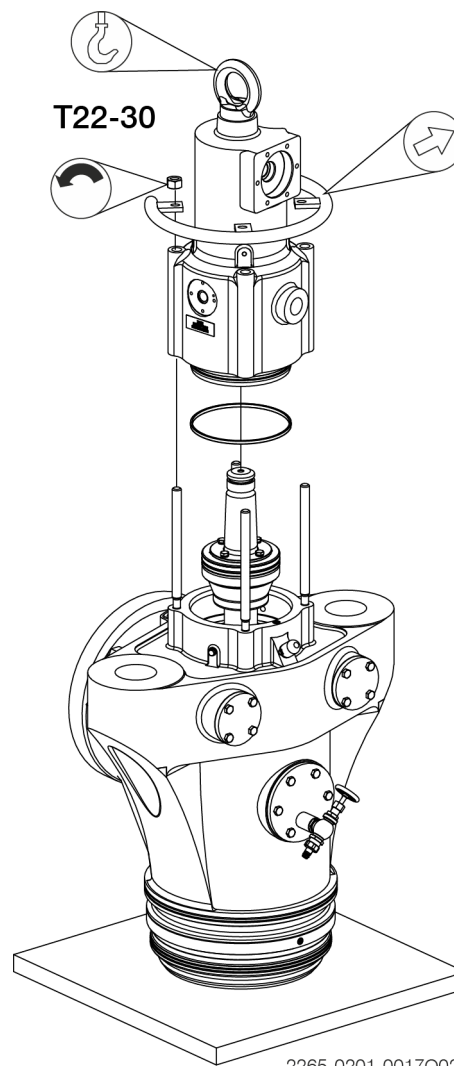
1. Remove oil cylinder

Place the exhaust valve on a wooden support on the platform.

Remove the nuts and, depending on valve model, the handrail from the oil cylinder.

Lift away and place the oil cylinder on a wooden support.

Remove and discard the oil cylinder O-ring.

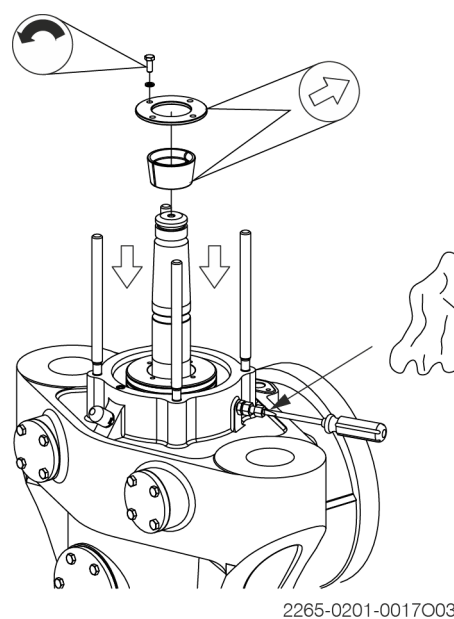


2. Remove the conical locking ring

Relieve the air pressure through the non-return valve from below the piston. Use a small screwdriver to press the ball into the non-return valve. Cover the non-return valve with a rag to catch the oil drops.

Remove the bolts from the flange on top of the air piston and dismount the flange.

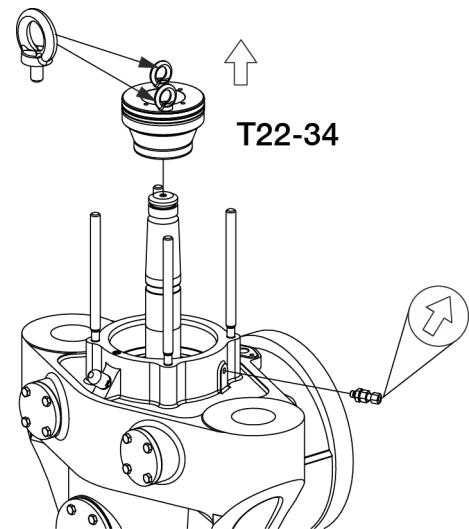
Loosen the air piston from the conical locking ring by means of a tin hammer, and remove the conical locking ring.



3. Remove air piston

Unscrew the non-return valve from the air cylinder/valve housing.

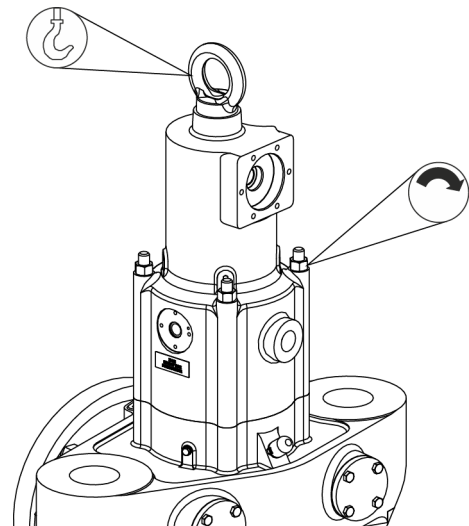
Mount two eye bolts in the top of the air piston. Remove the air piston from the air cylinder.



2265-0201-0017O04

4. Mount oil cylinder for lifting

Use the oil cylinder as a lifting tool for the exhaust valve housing. Lift the oil cylinder with the crane, and guide it down over the studs for the oil cylinder. Mount the four nuts so that the load from the valve housing is evenly distributed.



2265-0201-0017O06

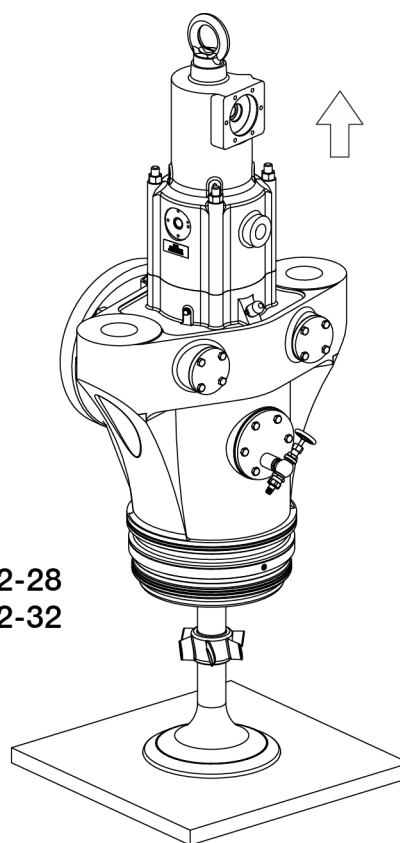
5. Remove spindle

Use the oil cylinder as a lifting tool for the exhaust valve housing. Lift the oil cylinder with the crane, and guide it down over the studs for the oil cylinder. Mount the nuts so that the load from the valve housing is evenly distributed.

Lift the valve housing clear of the valve spindle. **Take care** – when the groove for the conical ring at the top of the spindle pass the internal O-ring in the guide bushing.

Land the valve housing on a wooden support.

T22-28
T22-32



2265-0201-0017O07

6. Remove bottom piece

Unscrew and remove the lock screws which retain the bottom piece. Lift the valve housing approx. 10 mm.

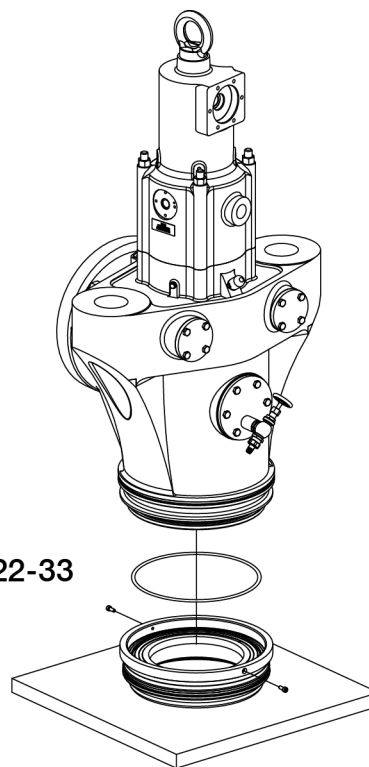
If the bottom piece has become stuck, use a tin hammer to release it.

Lift the valve housing away and land it on a wooden support.

Remove and discard the bottom piece sealing rings.

Remove the oil cylinder.

T22-33



2265-0201-0017O08

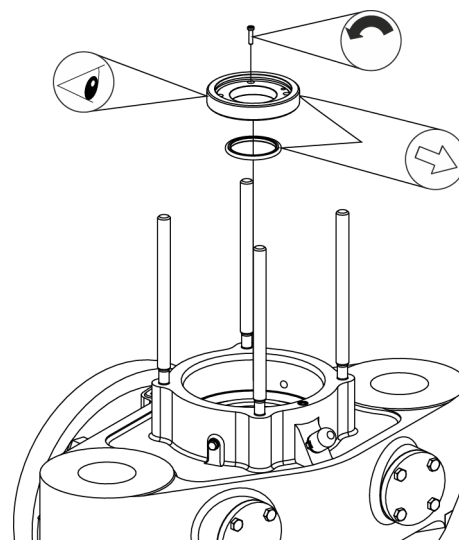
7. Remove seals and spring disc

Remove the spring disc on top of the guide bushing.

Remove and discard the O-rings and the inside sealing ring.

Inspect the spring disc for knocks and burrs. If necessary replace the disc.

Use threads in the flange to remove it.



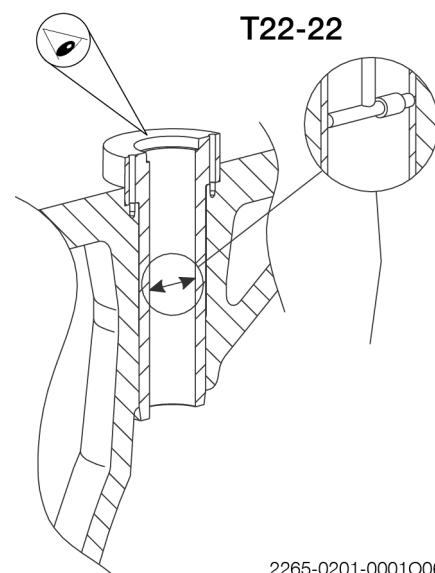
2265-0201-0017010

8. Inspect the guide bushing

Clean the exhaust valve housing.

Inspect the spindle guide bushing for wear and measure the inside diameter.

If the diameter has exceeded *T22-22* the bushing must be replaced.



2265-0201-0001006

9. Replace the guide bushing

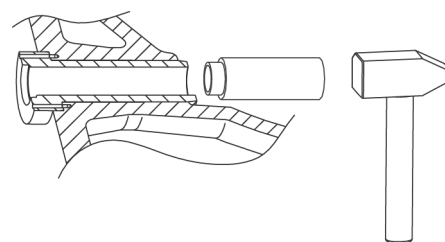
If it proves necessary to replace the bushing, place the valve housing on one side.

Knock out the bushing with a hammer and a suitable mandrel.

Return the housing to an upright position.

Mount a new bushing and O-ring for sealing between bushing and exhaust valve housing.

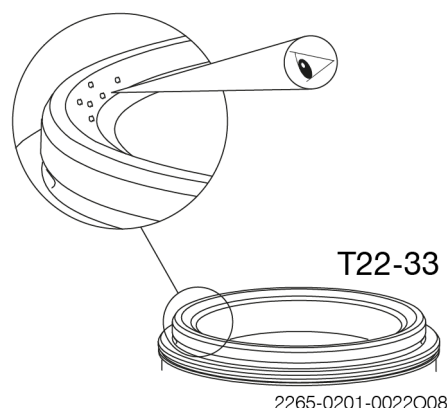
Tighten the screws.



2265-0201-0001007

10. Inspect bottom piece Turn the bottom piece upside down by using tackles and wire slings.

Before cleaning the bottom piece, inspect and evaluate the seating.
See description 2245-0200.

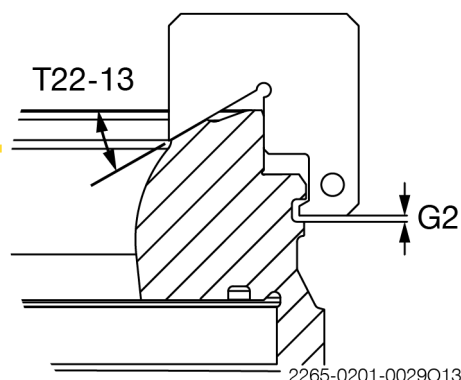


11. Measure bottom piece Inspect the seating of the bottom piece carefully for damage and check with the bottom piece template.

NOTICE

Before using the bottom piece template, thoroughly clean the contact faces on the valve housing seat with a steel brush.

Small dent marks in the bottom piece seating are acceptable and need not be ground away, provided that the dent marks do not allow blow-by of exhaust gas from the combustion chamber to the exhaust gas receiver.



Take measurements **G2**, using a feeler gauge. Compare the results with the figures stated in data T22-15.

All measurements should be taken at four diametrically opposite points on the circumference of the bottom piece seating.

If burn marks are visible on the bottom piece seating, then the bottom piece seat must be ground.

If the template rests on the lower surface in the groove, i.e. **G2** = 0, then the bottom piece seating must be discarded and replaced with a new bottom piece. Further grinding or reconditioning is not recommended.

12. Grind bottom piece seating

If it is necessary to grind the seating, proceed as follows:

NOTICE

The bottom piece grinding machine is an optional tool.

If it proves necessary to grind the seating surface and the tool is not available, please contact an authorized MAN Diesel & Turbo repair shop.

Before placing the bottom piece in the grinding machine, turn the grinding head away from the grinding table.

Mount and secure the bottom piece in the grinding machine. Using a dial gauge, check that the bottom piece is correctly centred.

Adjust the grinding head to achieve the correct grinding angle *T22-13*.

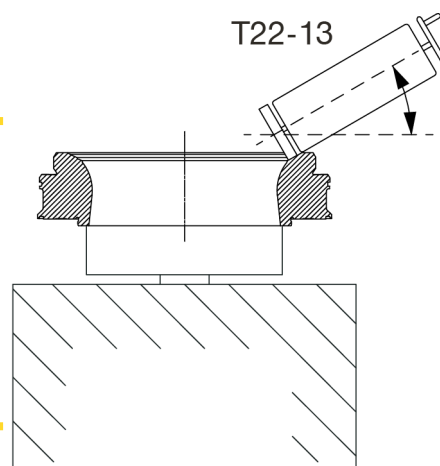
NOTICE

As the grinding angle is very important for correct operation of the exhaust valve, make absolutely sure that the grinding head is correctly adjusted.

During grinding, use the bottom piece template frequently to ensure that maximum grinding is not exceeded.

After grinding, inspect the bottom piece seating again, using a feeler gauge and the bottom piece template, to measure how much material has been ground away.

For use of the grinding machine, see separate instructions from the grinding machine manufacturer.



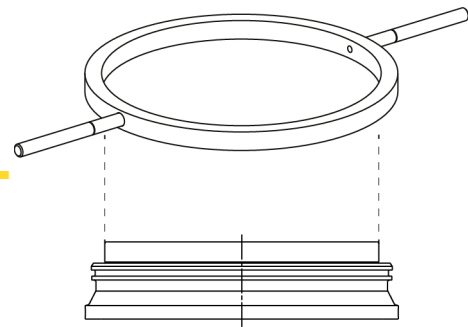
2265-0201-0005014

13. Bottom piece sealing face

After grinding the inside seating of the bottom piece, grind the outside seating using carborundum 200 and the special grinding tool.

NOTICE

Turn the special grinding tool by hand, alternately turning clockwise and anti-clockwise.



2265-0201-0025014

Grind until a smooth surface is achieved.

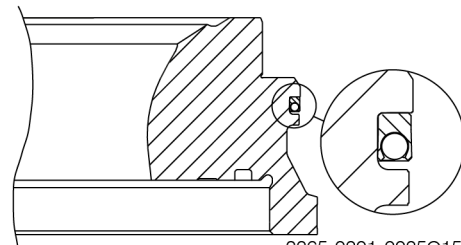
Clean the bottom piece.

14. Renew bottom piece sealing ring

Make sure that the groove for the sealing ring is clean.

Heat the U-seal in 100°C hot water for minimum five minutes and then mount it in the groove immediately.

Turn the bottom piece right side up using tackles and wire slings. Take care not to damage seatings or sealing rings.



2265-0201-0025015

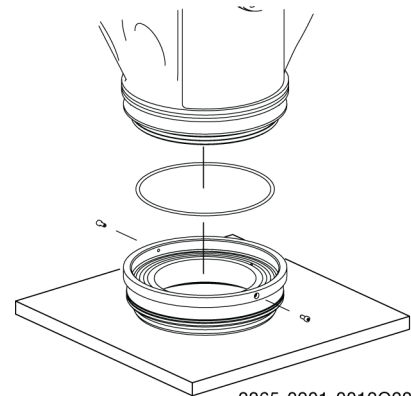
15. Mount bottom piece

Use the oil cylinder as a lifting tool for the exhaust valve housing.

Check that the face on the valve housing is clean.

If present, check that the guide pin in the bottom piece enters the hole in the bottom of the exhaust valve housing.

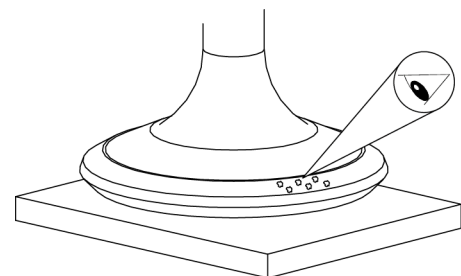
Land the exhaust valve housing on the bottom piece. Mount and tighten the retaining screws for the bottom piece.



2265-0201-0012023

16. Inspect spindle seating

Before cleaning, inspect and evaluate the spindle seating.
See description 2245-0200.



2265-0201-0001013

17. Spindle top lifting tool If it is necessary to tilt the spindle, use the spindle top lifting tool.

Mount the two lifting tool halves in the recess and lock them with the ring. Mount the shackle.



Impact hazard

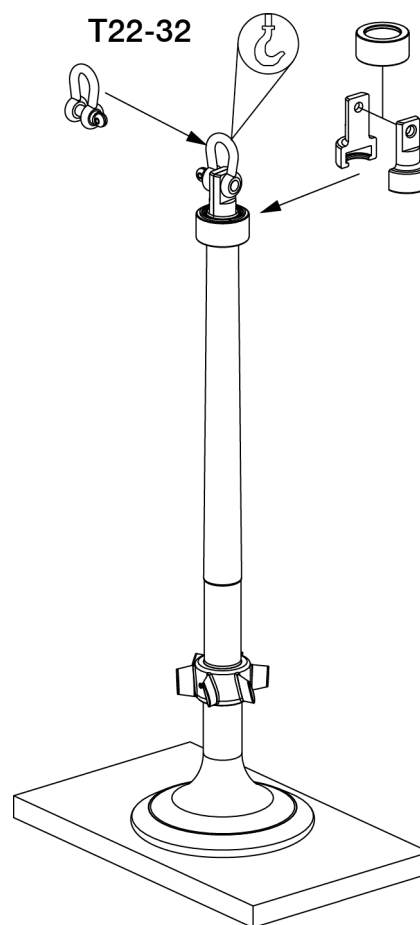
Before lift, ensure that the two-part lifting tool and the ring are fully engaged.

Lift the spindle with the engine room crane and land it on one side on a wooden support.



Impact hazard

Always remove the spindle top lifting tool before transporting the spindle upside down.

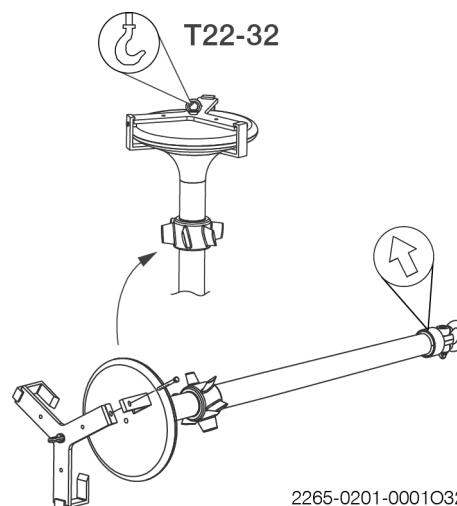


2265-0201-0001O31

18. Spindle disc lifting tool For upside down transport of the spindle, remove the spindle top lifting tool from the exhaust valve spindle.

Mount the spindle disc lifting tool.

Lift the spindle with the engine room crane



2265-0201-0001O32

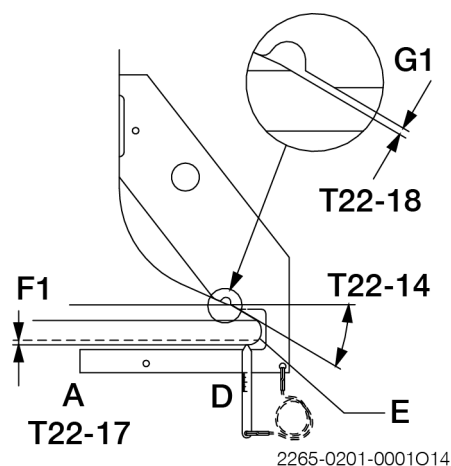
19. Measure the spindle

Inspect the seating of the valve spindle for burn marks. Check the burn-off **F1** of the valve spindle by measuring along the spindle template from point **A** to point **D** and in point **E**.

NOTICE

Before using the spindle template, thoroughly clean the contact faces on the valve spindle with a steel brush.

Small dent marks in the valve spindle seating are acceptable and need not be ground away, provided that the dent marks do not allow blow-by of exhaust gas from the combustion chamber to the exhaust gas receiver.



All measurements should be taken at four diametrically opposite points on the circumference of the valve spindle. Make sure that the most burned-off point is measured.

If burn marks are visible on the seating, the spindle must be ground.

If gap **G1** exceeds the maximum allowable value *T22-18*, or the burn-off **F1** exceeds the maximum allowable burn-off *T22-17*, the spindle must not be ground.

Instead the spindle must be reconditioned. Contact MAN Diesel & Turbo for advice on reconditioning.

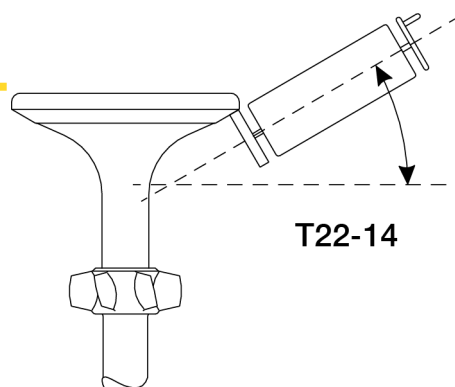
20. Grind the spindle

If it is necessary to grind the seating, proceed as follows:

NOTICE

The valve spindle grinding machine is an optional tool.

If it proves necessary to grind the seating surface and the tool is not available, please contact an authorized MAN Diesel & Turbo repair shop.



Mount and secure the spindle in the grinding machine. Using a dial gauge, check that the spindle is correctly centred.

Adjust the grinding head to achieve the correct grinding angle *T22-14*.

NOTICE

As the grinding angle is very important to the operation of the exhaust valve, make absolutely sure to adjust the grinding head correctly.

For use of the grinding machine, see separate instructions from the grinding machine manufacturer.

During grinding, measure gap **G1** frequently. The max. grinding of the spindle must not be exceeded.

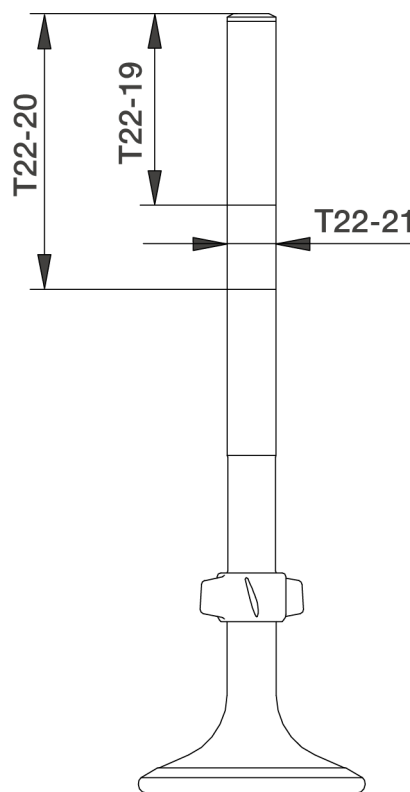
If the max. grinding limit is reached, and burn marks are still visible on the seating of the spindle, contact MAN Diesel & Turbo for advice on reconditioning.

Clean the spindle.

21. Measure spindle stem In connection with evaluation of the spindle, the spindle stem should be measured.

Check the spindle stem for wear in the area *T22-19* to *T22-20* measured from the top of the spindle.

If the stem diameter is less than *T22-21*, or the hard facing layer is worn away, contact MAN Diesel & Turbo for advice.



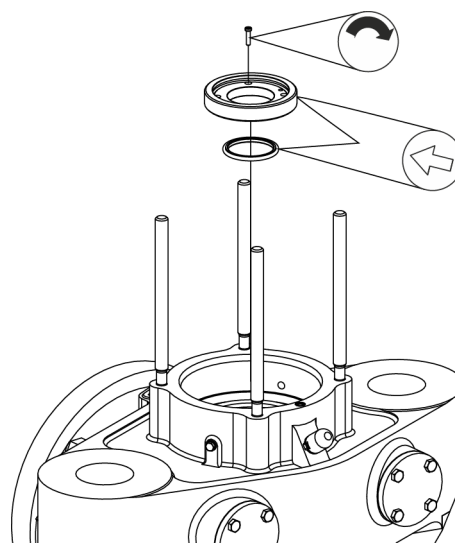
2265-0201-0001O15

22. Renew sealing rings Check that the top of the spindle bushing and the face on the housing is clean.

Mount new sealing rings on the spindle bushing.

Mount new O-rings.

Mount the spring disc on top of the spindle guide.



2265-0201-0017O22

23. Mount the spindle

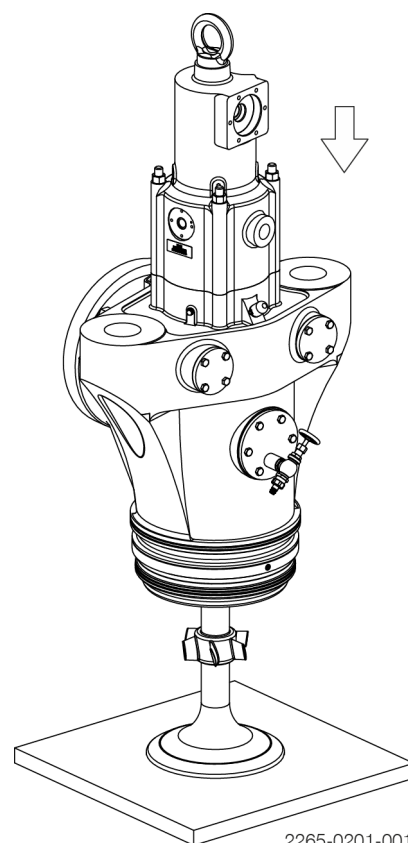
Lubricate the inside of the bushing in the spindle guide with plenty of lubricating oil.

Use the oil cylinder as a lifting tool for the exhaust valve housing.

Carefully land the exhaust valve housing with the bottom piece on the exhaust valve spindle.

Take care not to damage the sealing ring in the spindle bushing.

Remove the oil cylinder.



2265-0201-0017O24

24. Inspect air cylinder

Remove the protective cap from the safety valve mounted on the air cylinder/valve housing. Dismount the safety valve.

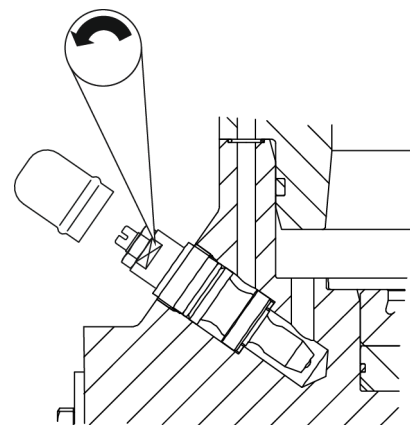
Unscrew the plug for the bore to the spindle stem bushing.

Blow through all bores in the air cylinder/valve housing.

Check the bottom of the air cylinder for possible coke, remove visible coke deposits.

Visually check the running surface for scores and abnormal wear.

Mount a new or overhauled safety valve. For overhaul of the safety valve, see next step.



2265-0201-0017O25

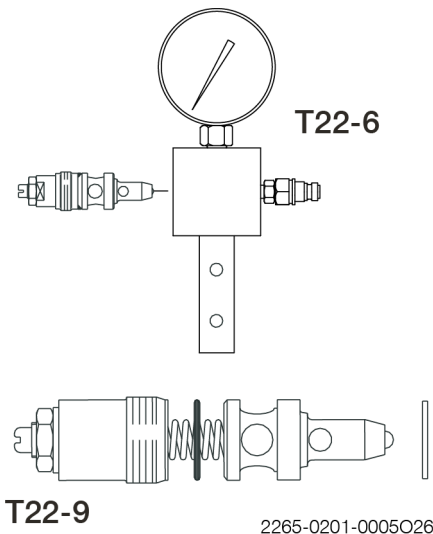
25. Overhaul safety valve Place the safety valve in the pressure testing device. Connect the testing device with the high pressure pump by means of a hose.

Check the opening pressure *T22-6*.

If the opening pressure is not correct, loosen the lock nut and, using a screwdriver, adjust the safety valve until the correct pressure is indicated. Tighten the lock nut and test the opening pressure once more.

Mount a new gasket on the safety valve. Install the safety valve on the air cylinder/valve housing. When screwing in the safety valve, do only use the machined faces on the valve housing. Tighten to the specified torque *T22-9*.

Mount the protective cap.



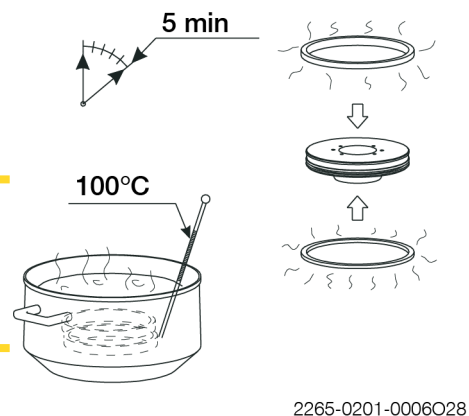
Exhaust Valve • Overhaul

26. Check air piston seals Check the Teflon guide ring and Teflon sealing ring for wear, if it is necessary to replace the sealing rings on the air piston, cut them and remove them.

NOTICE

Be careful not to damage the edges of the ring grooves in the piston.

Before mounting, heat the new Teflon rings in 100°C hot water for at least five minutes.



NOTICE

When mounting the Teflon rings, be careful not to damage the running surfaces.

Mount new O-rings in the inside grooves of the air piston.

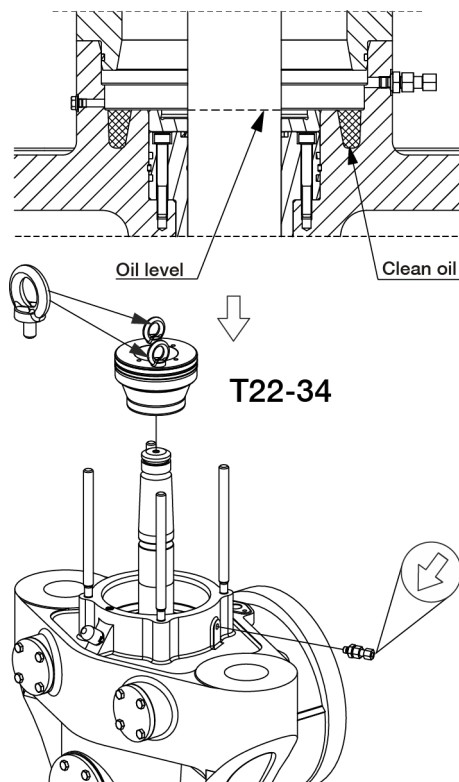
Work Card
2265-0201-0043

27. Mount air piston

Fill the bottom of the air cylinder up to the drain hole with clean lubricating oil.

Lower the air piston over the valve spindle down into the air cylinder.

Mount the non-return valve for spring air.



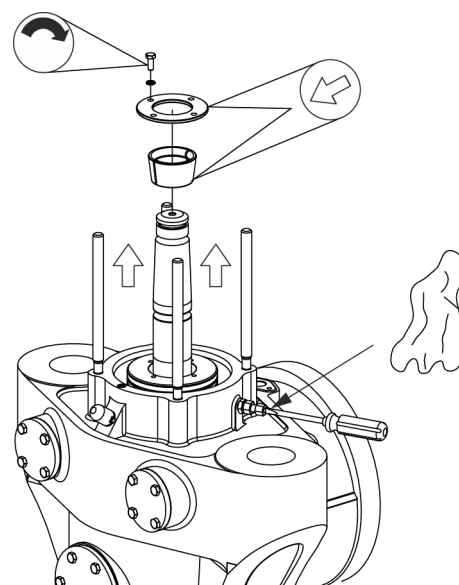
2265-0201-0017029

28. Mount locking ring

Mount the two-part conical locking ring.

Mount the flange on top of the air piston and. Tighten the bolts.

On valve models where the bolts are designed for securing, secure the bolts.
See work card 7665-0501.



2265-0201-0017030

29. Clean throttle valve and orifice plug

Unscrew the plug screws for the throttle valve and orifice plug.

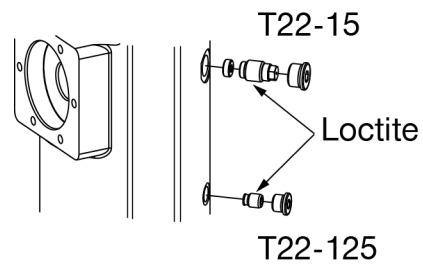
Remove and discard the sealing discs from the bores of the oil cylinder.

Unscrew and clean the orifice plug.

Disassemble, clean and re-assemble the throttle valve. When re-assembling secure the lock nut of the throttle valve with a thin layer of Loctite 243 or similar.

Clean the bores in the oil cylinder.

Mount the throttle valve and orifice plug with a new sealing discs. Tighten to the torque stated in *data*.



2265-0201-0006031

NOTICE

The throttle valve and orifice plug must be secured with a thin layer of Loctite 243 or similar applied to the threads.

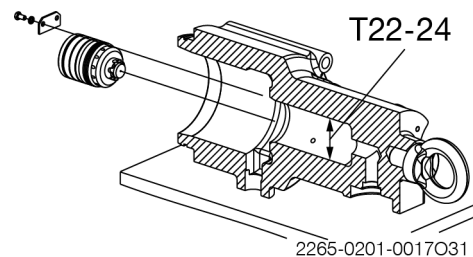
Mount the plug screws.

30. Clean and inspect oil cylinder

Place the oil cylinder in a horizontal position. Remove the flange and take out the piston.

Clean the oil cylinder and inspect the bore of the oil cylinder for scoring and check its measurements.

If the diameter of the oil cylinder exceeds *T22-24*, send the complete oil cylinder to an authorised MAN Diesel & Turbo workshop for overhaul.



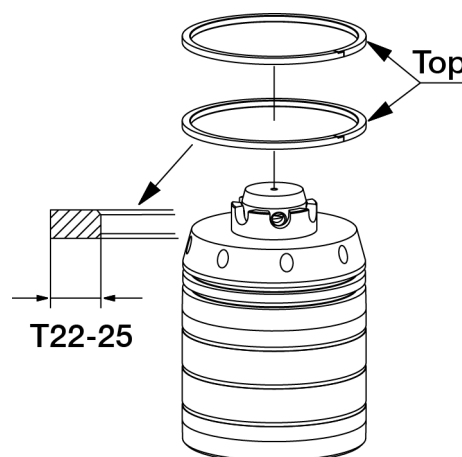
2265-0201-0017031

31. Renew piston rings

Remove the piston rings from the oil piston and check them for wear.

If the thickness of the rings has worn down to the minimum, *see data*, discard the rings and mount new ones.

Check that the **TOP** mark on the piston rings faces upwards.



2265-0201-0003O26

32. Measure oil piston damper

Mount the piston on top of the spindle and check the mesh of the damper piston by measuring the height of the damper relative to the oil cylinder.

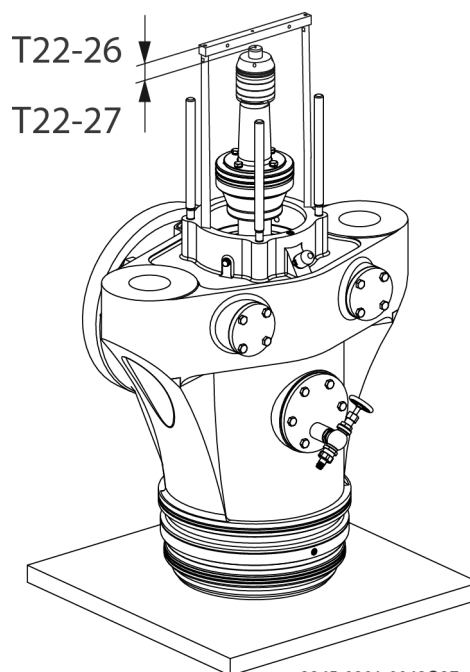
Connect compressed air to the air spring, in order to keep the valve closed, and to keep the air cylinder in close contact with the valve housing.

Place the measuring tool on the air cylinder across the piston.

Check the mesh of the damper piston by checking the distance from the upper edge of the crossbar to the top of the damper piston. *See data*.

If the measurement is outside the value stated in data, an adjustment must be made by changing the disc in the damper piston.

Spare discs in thickness steps of 0.5 mm can be ordered.



2265-0201-0043O27

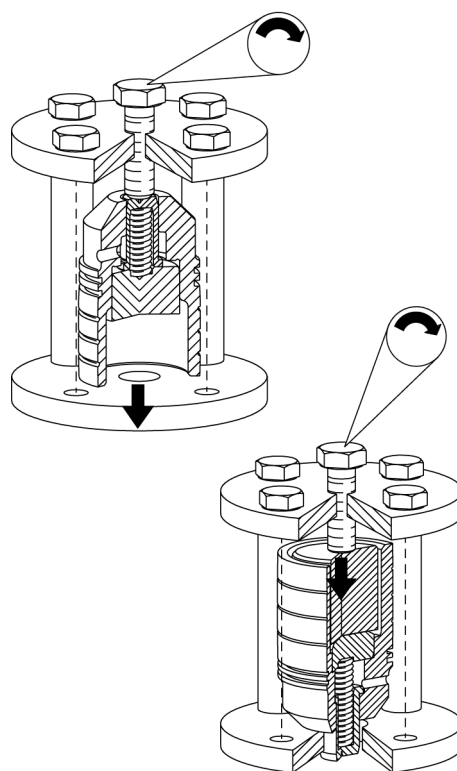
33. Adjust oil piston damper

Place the piston in the special tool.
Press out the damper piston and the disc using the centre screw.

Inspect the spring and the piston. A thicker disc decreases the mesh and a thinner disc increases the mesh.

Assemble the damper piston with the new disc in the special tool. Place the piston upside down in the tool and press the disc into place in the piston.

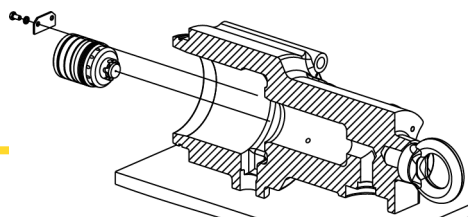
Check the mesh once more.



2265-0201-0005O34

34. Assemble oil cylinder

Mount the piston and the flange in the oil cylinder. Tighten and lock the screws.



2265-0201-0017O35

NOTICE

Locking device

For correct mounting of the locking device,
see work card 7665-0501.

Mount a new O-ring for the oil cylinder.

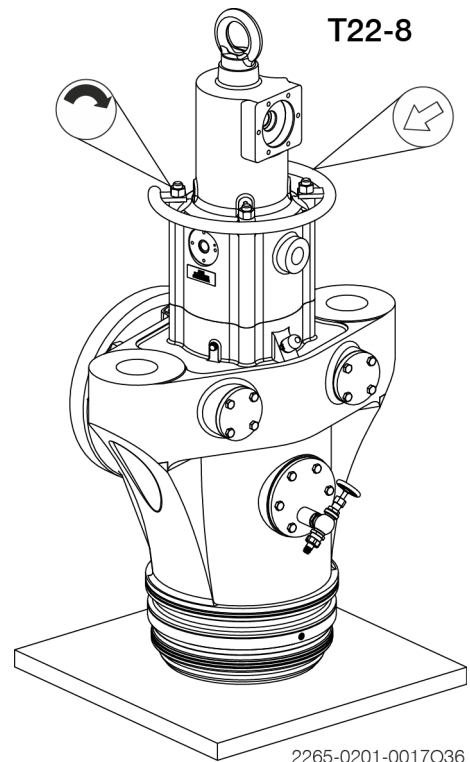
Return the oil cylinder to an upright position.

35. Mount oil cylinder

Mount the overhauled oil cylinder on top of the air cylinder.

Mount and tighten the nuts and, depending on valve model, the handrail.
See data.

T22-8



2265-0201-0017036

1. Check before mounting

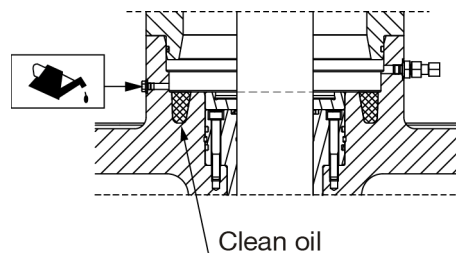
Before mounting an overhauled exhaust valve in the engine, it is recommended that the valve is checked and prepared as follows:

Check the oil level in the bottom of the air cylinder. If necessary, fill with oil as illustrated.

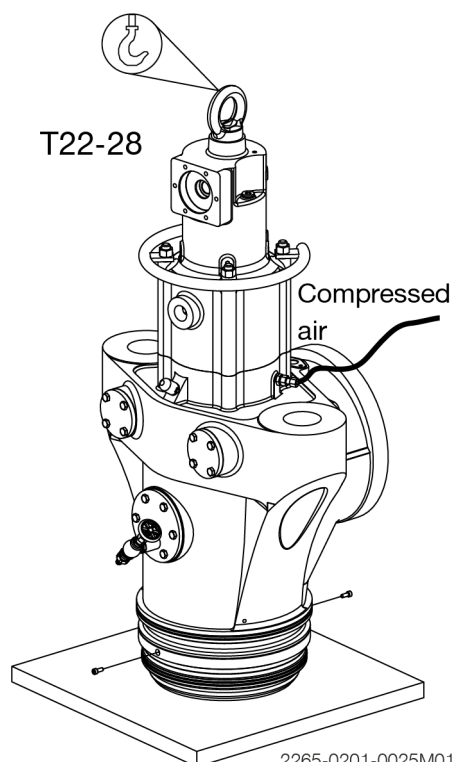
Connect compressed air to the air cylinder to close the valve.

Lift the valve with the engine room crane.

The valve must be able to stay closed for a minimum of 15 minutes or according to the drop-down test.
See checking procedure.



T22-28



2265-0201-0025M01

NOTICE

If the air cylinder is mounted with new sealing rings, the time the valve is closed may be considerably shorter than 15 minutes. The drop-down test should not be carried out until after a running-in period of 500 hours on valves with new sealing rings.

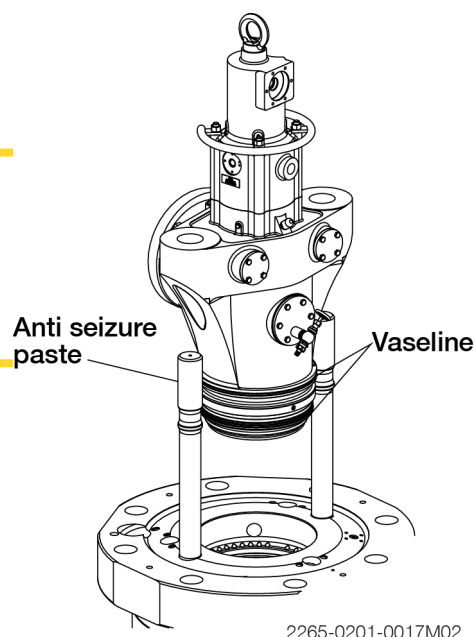
Check that the valve is mounted with new sealing rings in the grooves on the bottom piece.

2. Land exhaust valve Lubricate the sealing rings with Vaseline and the threads of the studs with anti-seizure paste.

NOTICE

Before mounting the valve on the engine, connect 7 bar working air to the air cylinder to keep the exhaust valve closed during the mounting process.

Position the valve in the cylinder cover bore, guiding it in accordance with the exhaust flanges. Depending on model either the guide pin on the exhaust side of the exhaust valve or the water connection on the manoeuvring side must fit.

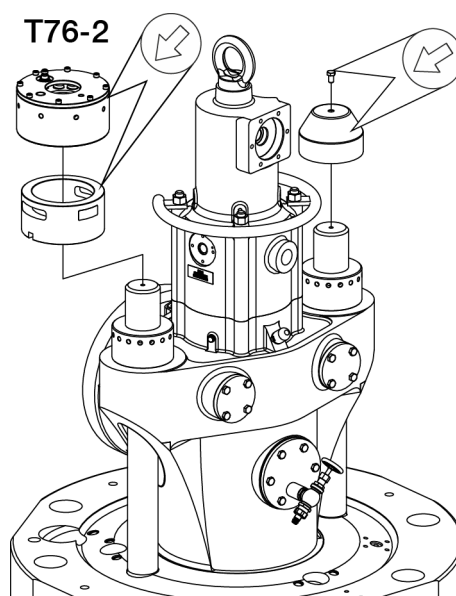
**NOTICE**

When lowering do not damage the thread of the studs.

3. Tighten the nuts Mount and tighten the nuts, *see data*.

For use of the hydraulic tools, see work card 7665-0101.

Mount the protective caps on the exhaust valve studs.



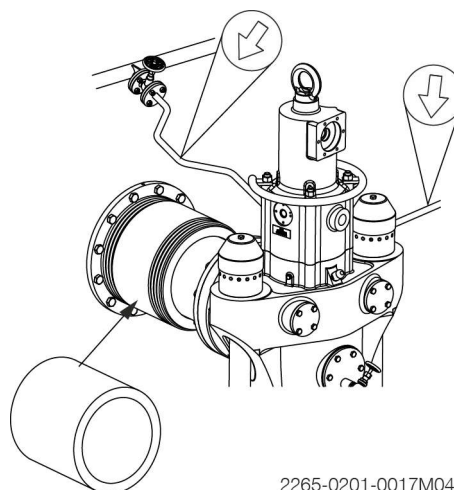
4. Mount the pipe connections

Connect the intermediate pipe to the exhaust valve.

Mount and tighten the screws to the exhaust valve housing.

Mount the insulation and plate jacket for the intermediate pipe.

Mount the cooling water connections for the exhaust valve and the air pipe for the air spring.



2265-0201-0017M04

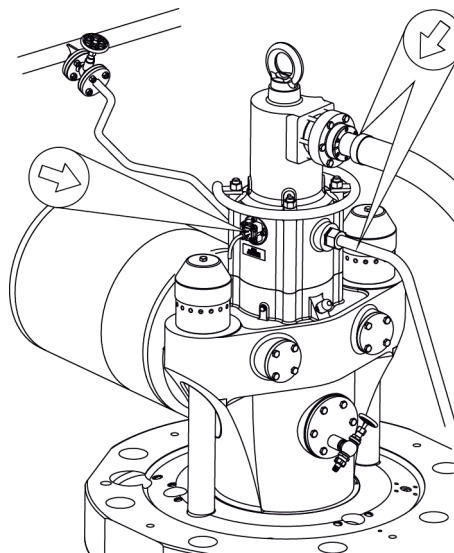
5. Mount the oil pipe connections

Mount the high-pressure pipe for the hydraulic valve actuator.
See work card 2265-0101.

Mount the drain oil pipe to the exhaust valve.

Check that all pipe connections are properly tightened.

Mount the valve position sensor.



2265-0201-0017M05

6. Open cooling water supply

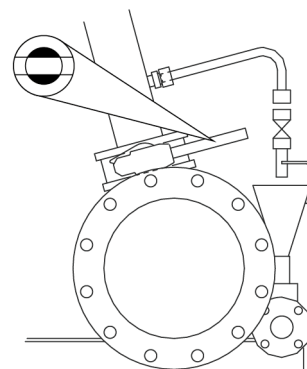
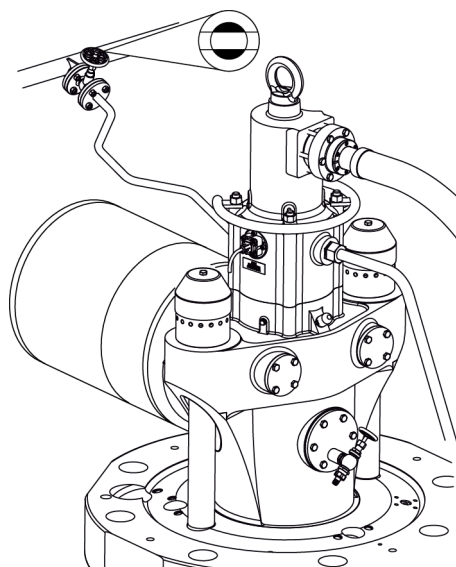
Check that all water connections are mounted and tightened.

Open the cooling water inlet supply, and vent the exhaust valve. Open the cooling water outlet valve.

Open the air supply to the exhaust valve.

Check the tightness of the sealing ring between the bottom piece and the exhaust valve housing.

See checking procedure.



2265-0201-0017M06

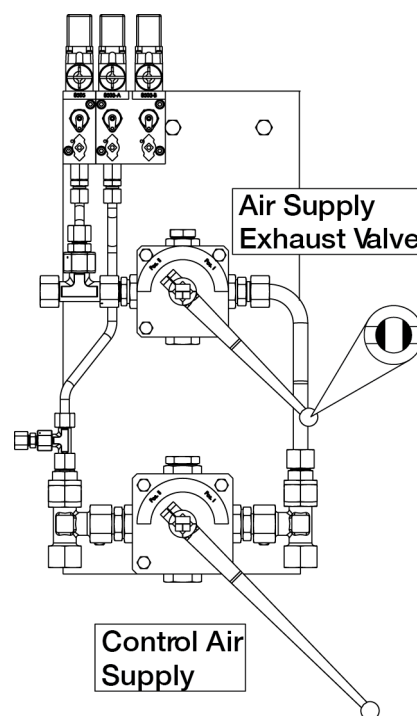
7. Air supply

The air supply to the exhaust valve must always be connected and pressurized before turning on the oil supply to the exhaust valve actuator.

NOTICE

If the lubricating oil pumps have been started before the exhaust valve air springs are pressurised, the valves can move to open position, thus giving starting problems.

To close the exhaust valves as fast as possible, pressurise the air springs, stop the lubrication oil pumps and drain the actuators at the drain screws.



2265-0201-0005M07

Safety Precautions

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Shut off air supply to exhaust valve - Only when stopped lubricating oil pumps
○	Engage turning gear
○	Shut off cooling water
○	Shut off fuel oil
○	Stop lubricating oil supply
○	Lock the turbocharger rotors
○	Shut down hydraulic power supply



Data

Ref.	Description	Value	Unit
T22-40	Starting valve stud, screwing-in torque	140	Nm
T22-41	Fuel valve stud, screwing-in torque	140	Nm
T22-44	Cylinder cover stud, check distance	161 - 162	mm
T22-46	Cylinder cover, complete	1800	kg
T22-47	Cylinder cover without valves	1650	kg
T22-48	Cooling jacket	160	kg
T22-49	Exhaust valve stud	45	kg
T22-50	Cylinder cover stud	80	kg
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
2270-0300	046	Grinding tool for exhaust valve seat
2270-0300	058	Milling and grinding wheel for fuel valve
2270-0300	060	Milling and grinding wheel for starting valve

Plate	Item No.	Description
2270-0300	201	Handle for sundry types
2270-0315	-	Cylinder cover hydraulic tools
2270-0350	-	Cylinder cover lifting tools
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	131	9-way distributor block, complete
7670-0200	-	Torque spanners



Check engine blocking

Check that the engine is stopped and blocked according to the safety precautions.
See data.

1. Shut off the oil supply

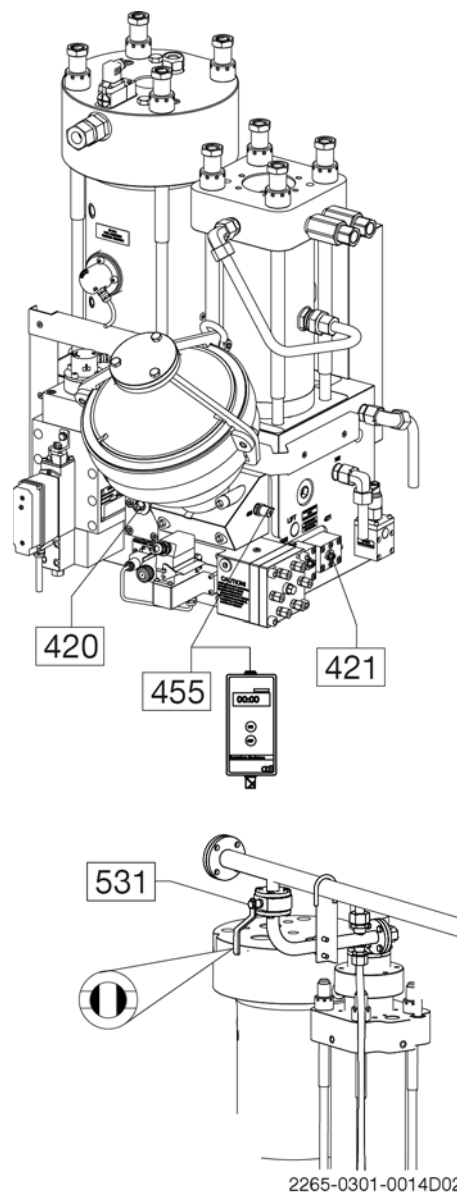
Close the fuel oil supply for the unit concerned.

Mount a pressure gauge in minimess point No. **455**. Check the pressure.

Close valve **420** and open valve **421** on the hydraulic block.

Check that the hydraulic cylinder unit is pressure free.

Close valve **531** for hydraulic operation of the exhaust valve.



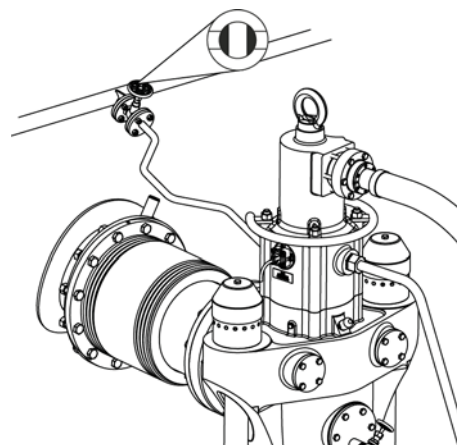
2. Shut off the water supply

Close the water outlet above the exhaust valve.

Shut off the water supply placed on the exhaust side below the exhaust gas receiver.

Open the drain next to the inlet valve.

Open the venting cock next to the outlet valve.



2265-0301-0017D03

3. Disconnect the oil pipes

Remove the hydraulic high pressure pipe for the exhaust valve.

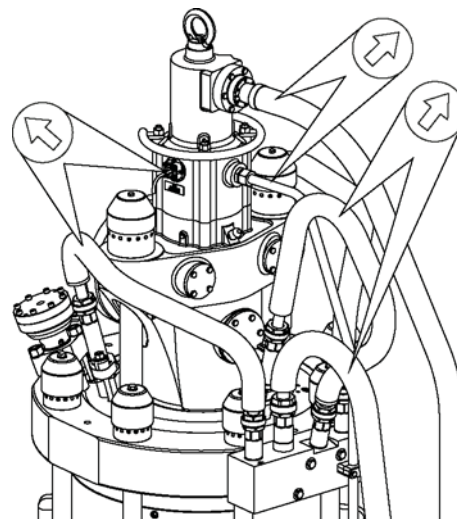
See work card 2265-0101.

Unscrew the drain pipe for the exhaust valve.

Remove the fuel oil high pressure pipes.
See work card 4265-0101.

Disconnect the pipes for return fuel oil from the fuel valves.

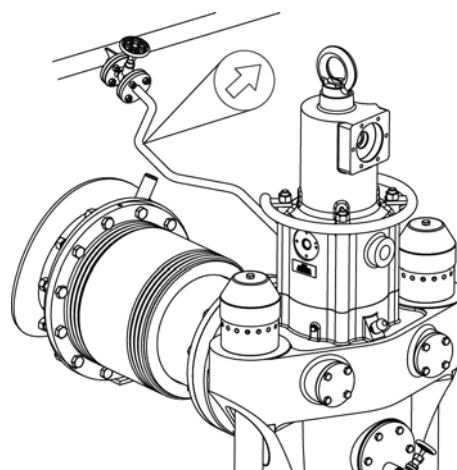
Disconnect the plug for the electrical exhaust valve sensor.



2265-0301-0017D04

4. Disconnect the water pipes

Unscrew and remove the water outlet pipes.



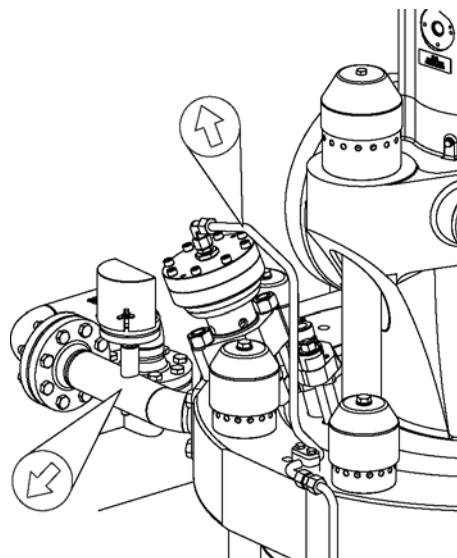
2265-0301-0017D05

5. Disconnect the starting air pipe

Unscrew and remove the control air pipe for the starting air valve.

Unscrew and remove the air pipe for the starting valve.

Unscrew and remove the air supply to the exhaust valve air spring.



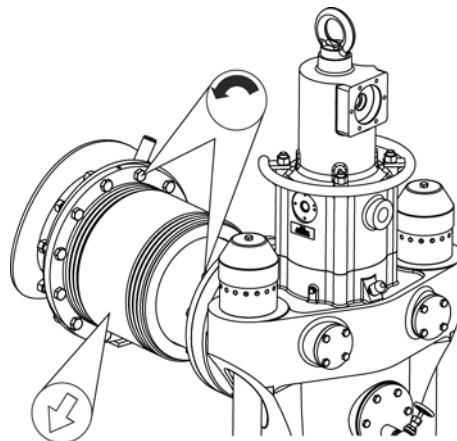
2265-0301-0017D06

6. Disconnect the exhaust gas compensator

Remove the protective jacket enclosing the insulation for the intermediate pipe or compensator. Remove the insulation.

Remove the bolts in the flange between the intermediate pipe and the exhaust receiver.

Remove the bolts in the flange between the intermediate pipe and the exhaust valve. Remove the intermediate pipe.



2265-0301-0017D07

7. Cylinder cover loosening

Remove the protective caps from the cylinder cover nuts.

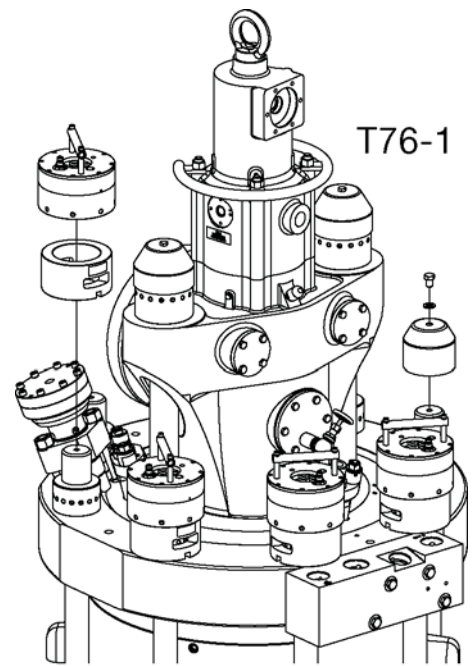
Mount the spacer ring.

Mount the hydraulic jacks.

Loosen and remove the cylinder cover nuts.

See data.

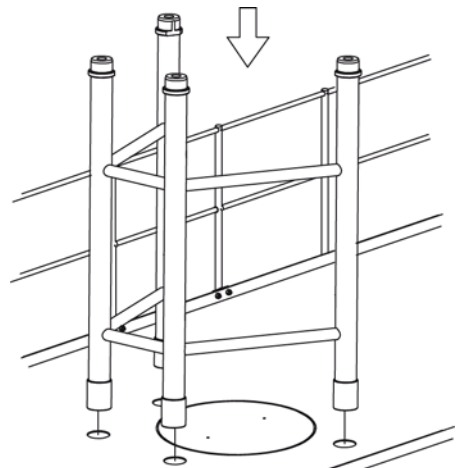
For use of hydraulic tools, see work card 7665-0101.



2265-0301-0017D08

8. Cylinder cover supporting tool

Mount the cylinder cover supporting tool in the holes on the uppermost platform.

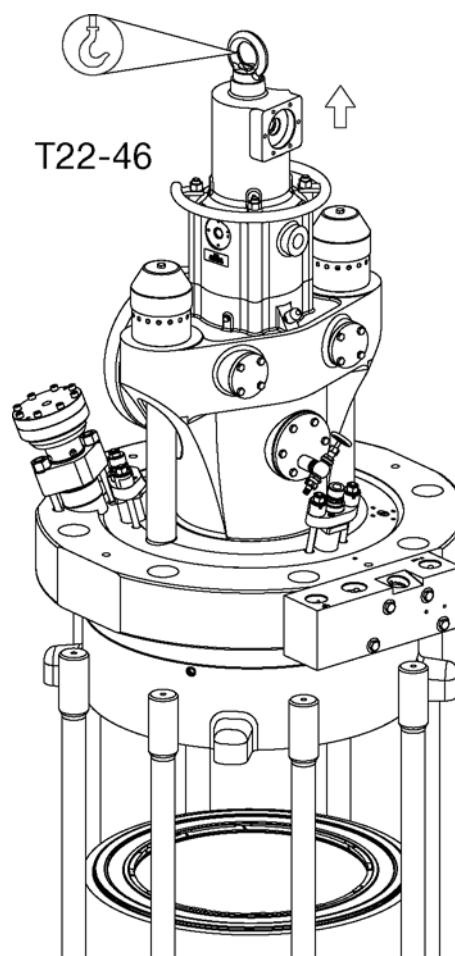


2265-0301-0002D09

9. Cylinder cover lifting Hook on the engine room crane to the lifting attachment on top of the exhaust valve.

Check that all cylinder cover connections have been loosened and removed.

Lift away the complete cylinder cover.



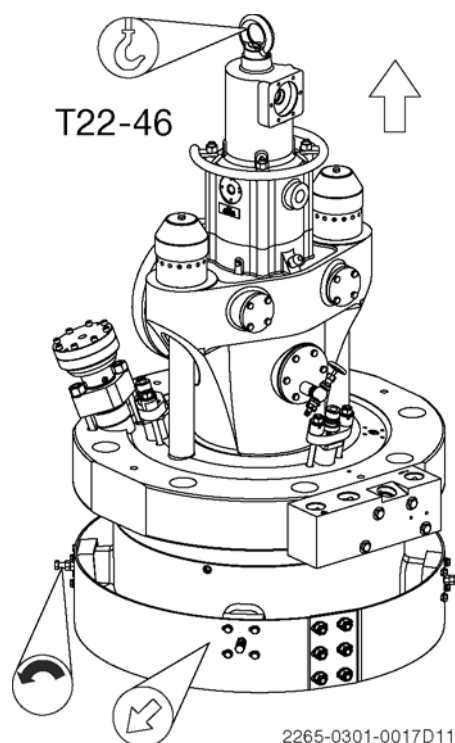
2265-0301-0017D10

10. Remove the protective shield

If the cylinder is equipped with a protective shield the shield must be removed before landing the cylinder cover.

To remove the shield:

- loosen the four screws
- lift up the shield approx. 100 mm
- turn the shield approx. 30 degrees relative to the cylinder cover
- lower the shield away from the cylinder cover.



2265-0301-0017D11

11. Cylinder cover landing

Land the cylinder cover on the cylinder cover support tool.

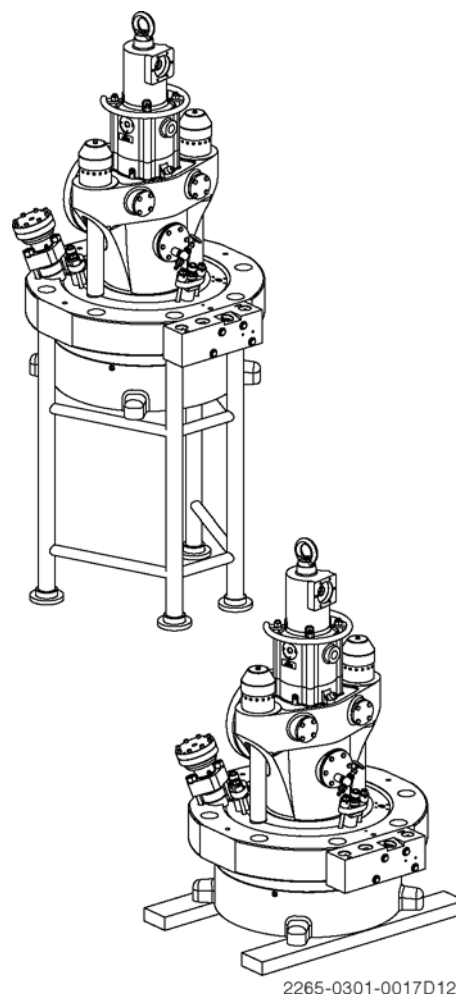
If the cylinder cover is to be overhauled it is recommended instead to land the cylinder cover on a couple of wooden planks.

NOTICE

The cylinder cover supporting tool should only be used when the ship is in port.

CAUTION**Crushing hazard**

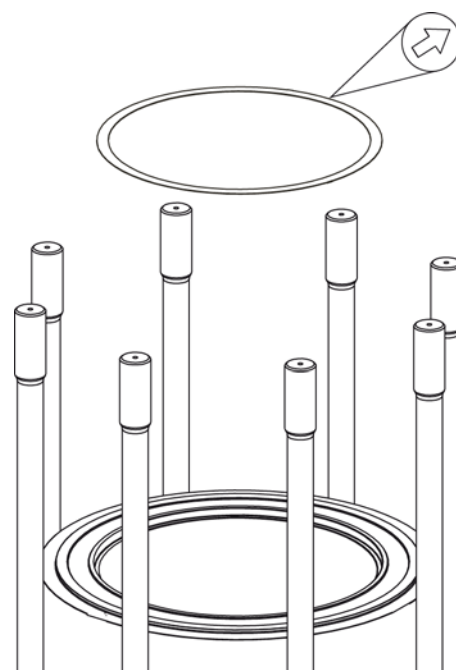
Keep clear during landing of the cylinder cover.



2265-0301-0017D12

12. Remove gasket

Remove and discard the gasket (mild steel ring) ring between the cylinder cover and cylinder liner.

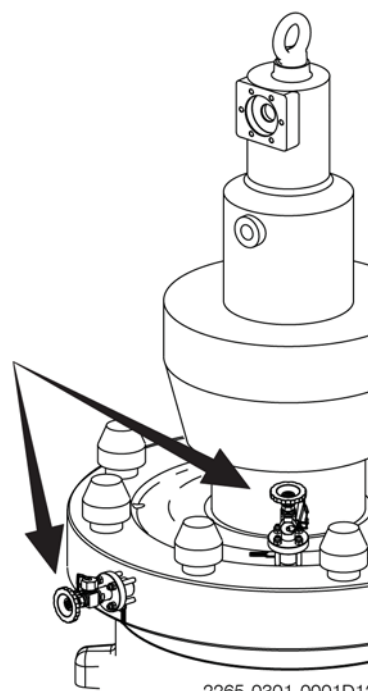


2265-0301-0014D13

13. The PMI sensor

The sensor can be mounted at the side or top of the cylinder cover.

The PMI sensor can be dismantled and then allowed to dangle by its cable connection. The cable connection is fastened to the cylinder liner and connected to a pressure transducer at the other end.



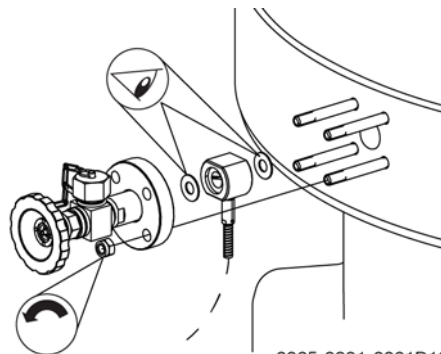
2265-0301-0001D12

14. Copper packings

There are two copper packings. Inspect the packings for blow-by or heat deformation. The Packings can be kept in place by copper grease, if they are not to be removed.

NOTICE**Packing quality**

Use only the correctly specified copper packings when replacement is necessary.



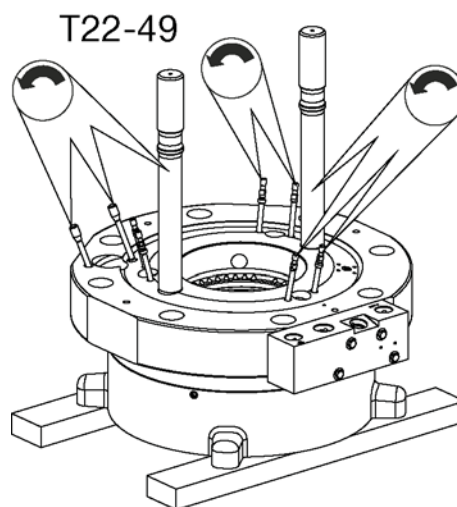
2265-0301-0001D13

15. Inspection of sensor

Check the sensor for damage or any heat deformation. If damaged, it should be replaced.

1. Dismantle valves and pipes
Dismantle all valves and pipes from the cylinder cover.
See work cards 3465-0201, 2265-0201 and 4265-0201.

Remove all studs on top of the cylinder cover.



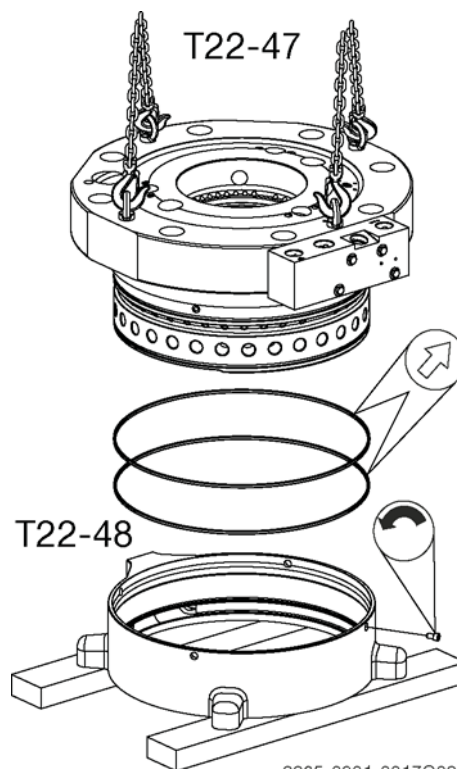
2265-0301-0017O01

2. Remove the cooling water jacket
Mount four eye bolts and the lifting chains as shown in the sketch.

Remove the four screws which secure the cooling jacket to the cylinder cover.

Lift the cylinder cover free of the cooling jacket and land it on a couple of planks.

Remove and discard the O-rings from the cover, and carefully clean the cooling jacket and the cylinder cover.



2265-0301-0017O02

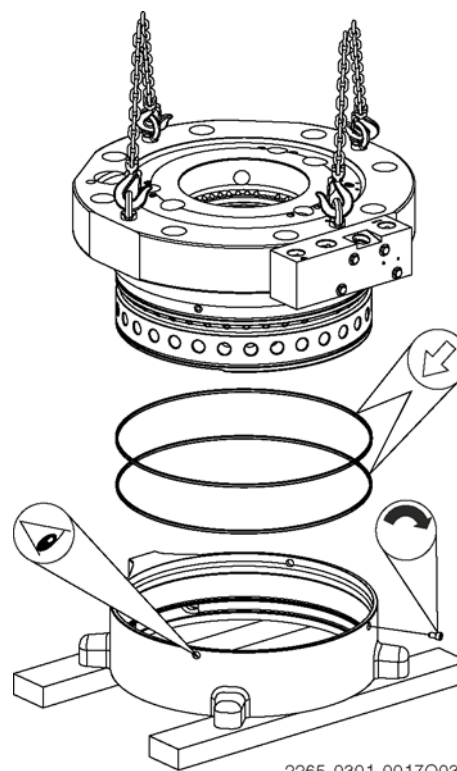
3. Mount the cooling water jacket

Provide the cylinder cover with new O-rings, well lubricated with Vaseline.

Lift the cylinder cover and guide the jacket/ cover into position, using the guide pin as a reference (manoeuvring side).

Mount and tighten the screws for the cooling jacket.

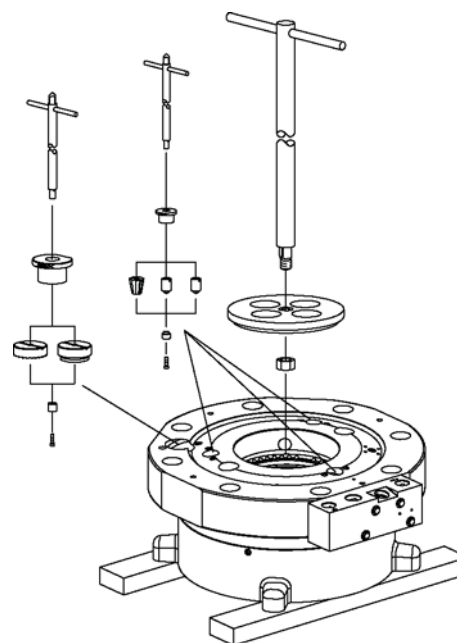
Lubricate the threads with 'Never Seize' or molybdenum disulphide (MoS_2).



2265-0301-0017O03

4. Seat reconditioning tools

The tools for reconditioning of the valve seats are found on the 'Cylinder Cover Tool Panel'.
See plate 2270-0300.



2265-0301-0017O04

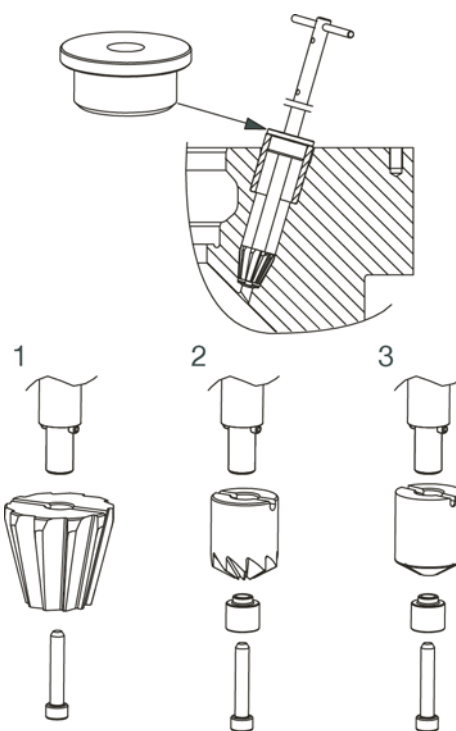
5. Fuel valve bore

The tool consists of a common spindle with a handle, a guide, a carbon cutter, a seating face cutter and a grinding mandrel.

Clean the fuel valve bores using the carbon cutter. If required, recondition the fuel valve seating with the appropriate cutter.

Grind the seating with the grinding mandrel and a grinding compound (e.g. Carborundum No. 200).

After the milling/grinding, clean the bore and seating carefully, and check that the seating is not damaged.



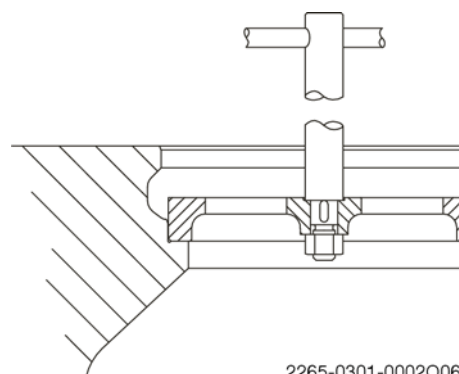
2265-0301-0002005

6. Exhaust valve bore

The tool consists of a spindle with a handle and a grinding disc.

After cleaning the valve bore and seating, grind the seating with the grinding disc and a grinding compound (e.g. Carborundum No. 200).

After the grinding, clean the bore and seating carefully, and check that the seating is not damaged.

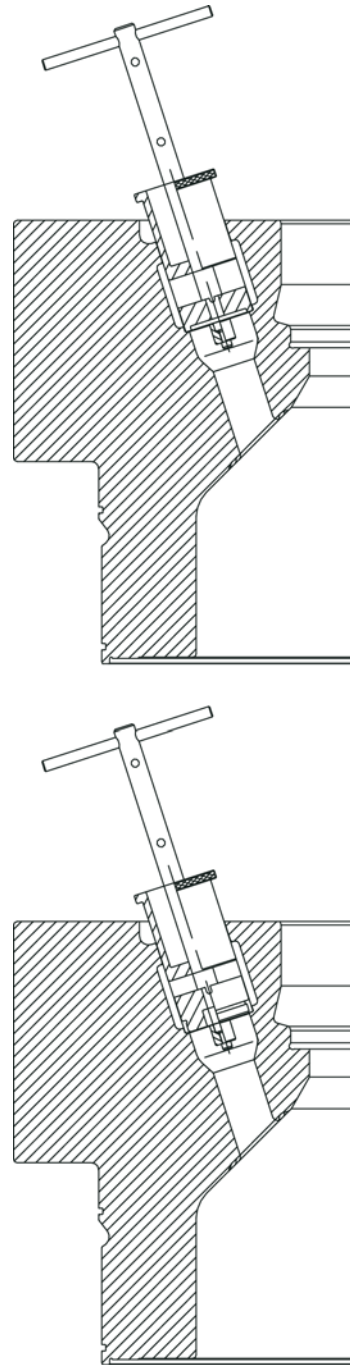


2265-0301-0002006

7. Starting valve bore The tool consists of a guide, a cutter, and a grinding disc.

Recondition the starting valve bore and seating in the same way as described for the fuel valve bore.

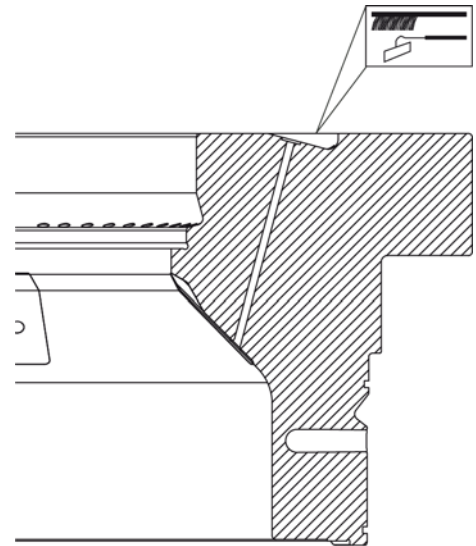
When replacing the valves on a cylinder cover while it is mounted on the engine, recondition the valve bores/seating as described here, however, without removing the studs.



2265-0301-0002O07

8. Indicator - safety valve bore

Clean the bores for safety valve/indicator cock.



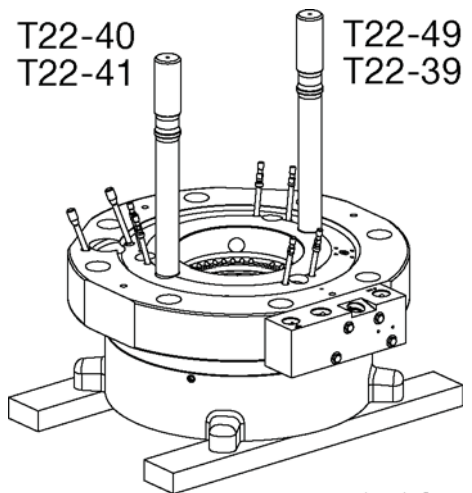
2265-0301-0002Q08

9. Mounting of studs

Lubricate the threads with 'Never Seize' or molybdenum disulphide (MoS_2) and mount the valve studs.

Tighten up the studs in accordance with the screwing-in torque stated.
See data.

Fill up the grooves between the valve studs and the bores for the valve studs with Permatex to prevent water or oil from entering the bores during operation of the engine.



2265-0301-0017O09

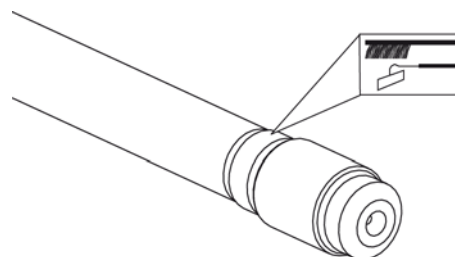
10. Mounting of valves

Install the valves on the cylinder cover, *see work cards 3465-0201, 2265-0201 and 4265-0201.*

1. Clean the studs

If a cylinder cover stud has been removed, it must be re-mounted before landing the cylinder cover.

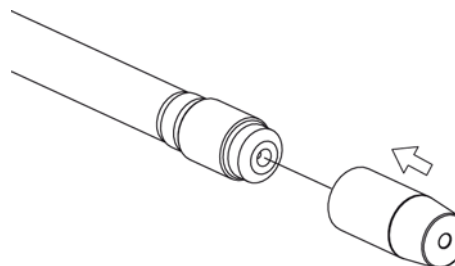
Clean the sealing face for the sealing ring.



2265-0301-0002M01

2. Mount the cone for sealing ring

Mount the cone on the bottom end thread of the stud.



2265-0301-0002M02

3. Heat the sealing rings

Before mounting new sealing rings on the cylinder cover stud, **heat them to 70-100°C**, preferably in oil, for at least five minutes.

**NOTICE**

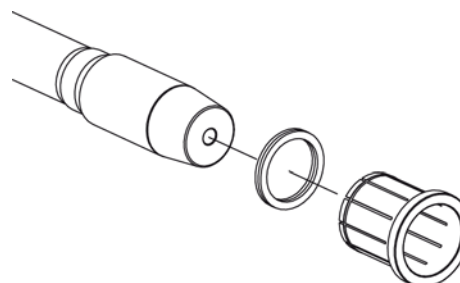
Take care not to exceed the temperature limits.



2265-0301-0002M03

4. Mount the sealing ring

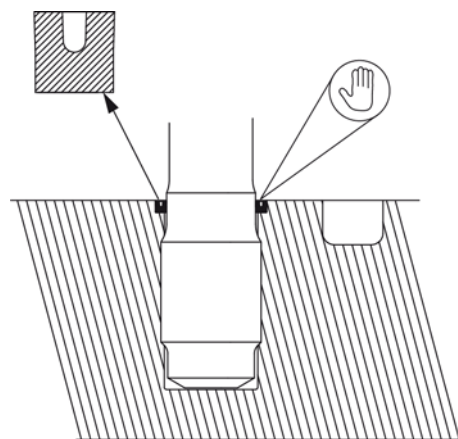
Place the sealing ring on the cone as shown in the sketch. Lubricate the cone with oil. Push on the sealing ring with the pusher. Remove the cone and pusher.



2265-0301-0002M04

5. Sealing ring

Screw the stud into the cylinder frame. Screw back the stud $\frac{1}{4}$ revolution. By hand push the sealing ring into the groove in the top of the cylinder frame (see the sketch).



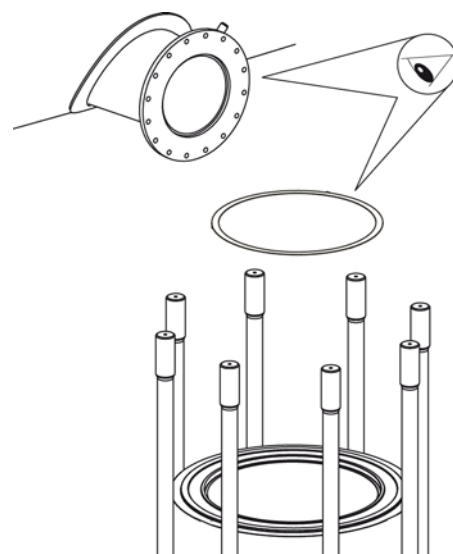
2265-0301-0002M05

6. Gaskets

Check that the liner sealing surface is clean.

Place a new gasket (mild steel ring) on top of the cylinder liner.

If necessary mount a new "Klinger" gasket in the groove of the flange of the intermediate pipe.



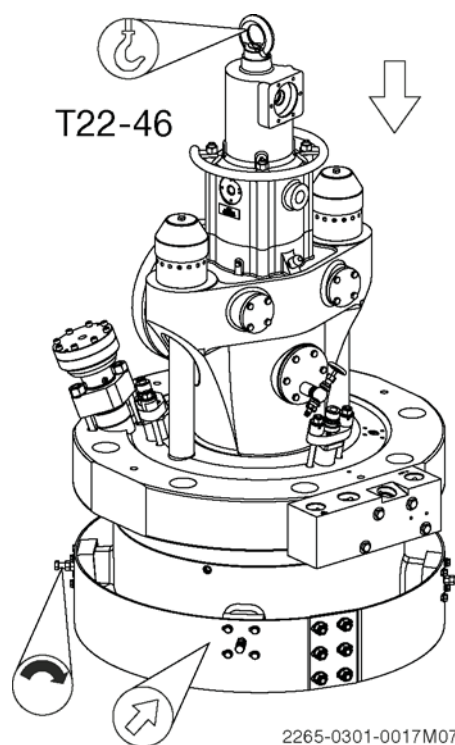
2265-0301-0014M06

NOTICE

Do not apply any kind of lubricant to the gasket (mild steel ring).

7. Protective Shield

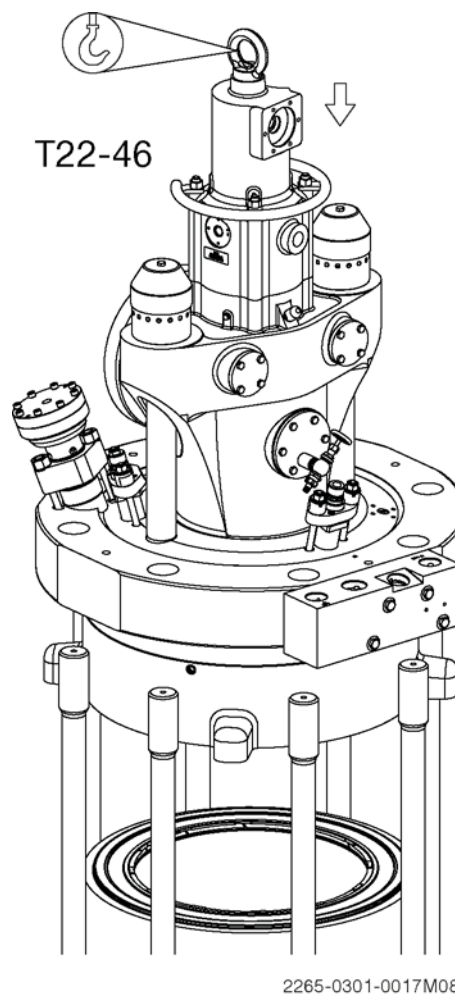
If the cylinder liner is equipped with a protective shield, this must be mounted on the cylinder cover before the cylinder cover is mounted on the cylinder liner.



8. Cylinder cover landing

Carefully wipe the cylinder cover contact surface facing the cylinder liner, while the cover is resting on the support.

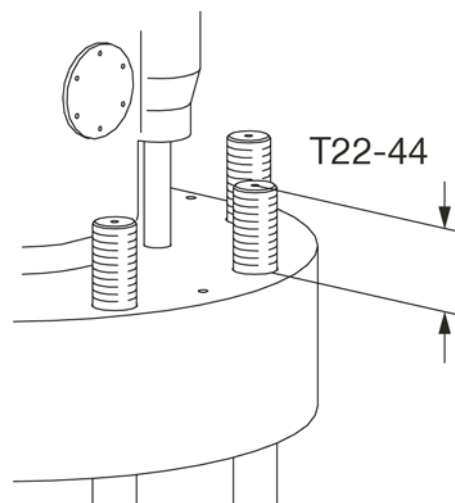
Lift the cylinder cover by means of the crane and lower it **carefully** into position. During the landing, **carefully** check that the cooling water connecting pipes engage correctly with the holes in the cooling jacket.

**Crushing hazard**

Keep clear during landing of the cylinder cover.

9. Cylinder cover stud - check distance
- If the cylinder cover studs have been removed and reinstalled, check the distance the stud is protruding from the cylinder cover.

If necessary, adjust to the distance T22-44 by turning the stud.



2265-0301-0002M09

10. Cylinder cover tightening

Mount and tighten the cylinder cover nuts.

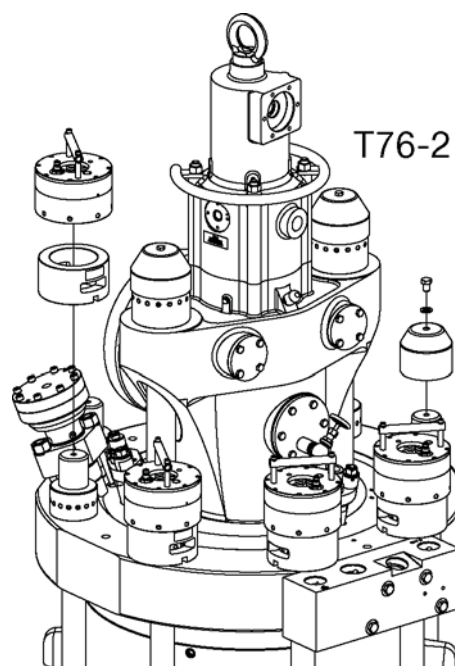
Screw the jacks onto the studs.

Continue turning until the jacks are completely compressed.

Unscrew the jacks 1/8 turn and tighten the nuts.

For operation of hydraulic jacks, see work card 7665-0101.

Mount the protective caps on the cylinder cover studs.



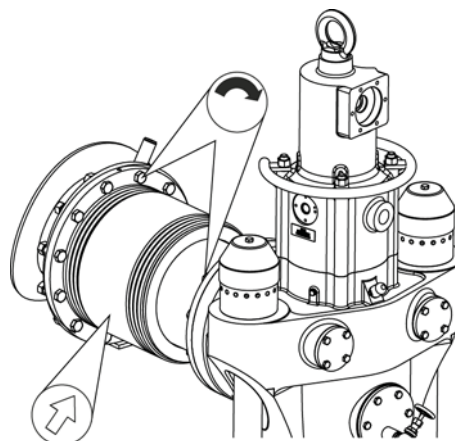
2265-0301-0017M10

11. Mount the exhaust gas compensator

Mount the intermediate pipe. Mount the bolts in the flange between the intermediate pipe and the exhaust valve. Mount the bolts in the flange between the intermediate pipe and the exhaust receiver.

NOTICE

Lubricate the bolts with "Never Seize" or molybdenum disulphide (MoS₂)



2265-0301-0017M11

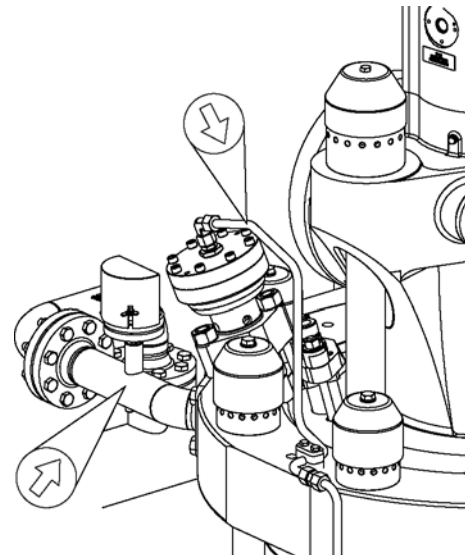
Mount the insulation. Mount the protective jacket enclosing the insulation.

12. Connect the starting air pipe

Connect and tighten the air pipe for the starting valve.

Connect and tighten the control air pipe for the starting air valve.

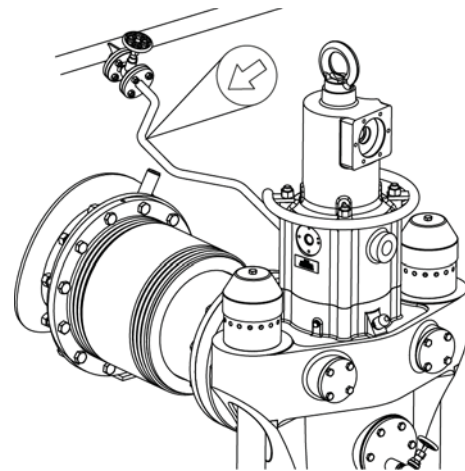
Connect the air supply pipe for the exhaust valve air spring.



2265-0301-0017M12

13. Connect the water pipes

Mount and tighten the water outlet pipes.



2265-0301-0017M13

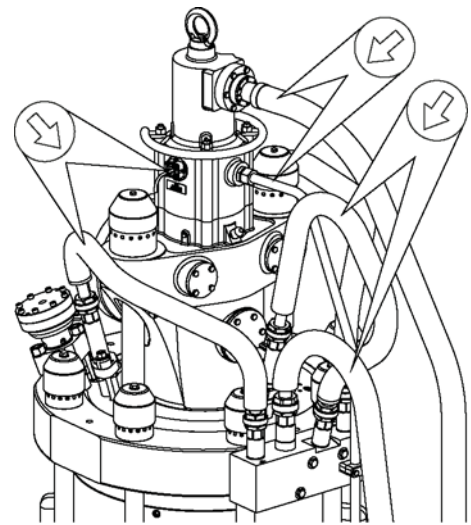
14. Connect the oil pipes Mount the hydraulic high pressure pipe for the exhaust valve.
See work card 2265-0101.

Connect the drain pipe for the exhaust valve.

Connect the fuel oil high pressure pipes.
See work card 4265-0101.

Connect the pipes for return fuel oil from the fuel valves.

Connect the plug for the electrical exhaust valve sensor.



2265-0301-0017M14

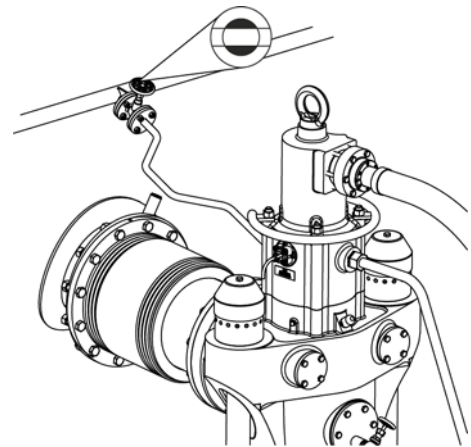
15. Close the drain and open the water supply Close the venting cock next to the outlet valve.

Close the drain next to the inlet valve.

Slowly open the water supply valve, placed next to the cylinder liner cooling water jacket on the exhaust side.

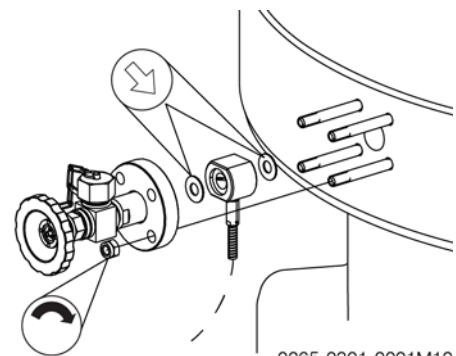
Vent the unit by releasing air through the venting cock next to the outlet valve.

When the venting is finished, close the venting cock. Open the water outlet valve on the exhaust side.



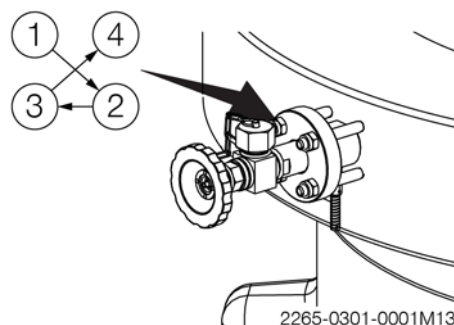
2265-0301-0017M15

16. Preparing to mount the sensor Make sure that the copper packings are in place. Some copper paste should be applied to ensure an air-tight seal as well as to hold the packings in place.

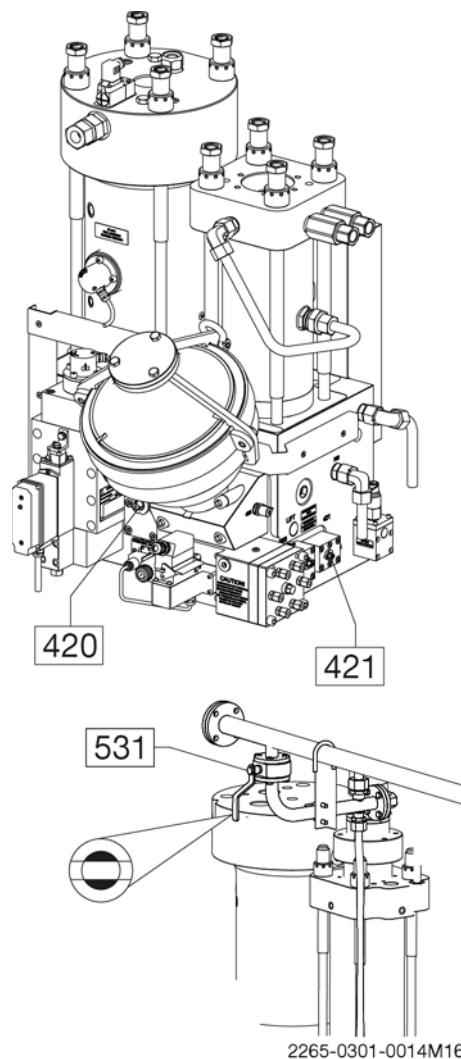


2265-0301-0001M12

17. Mounting the sensor The sensor should be tightened cross-wise, in order to ensure tightness. Check, and be vigilant, for possible air leakage.



18. Open the oil supply Open the fuel oil supply for the unit concerned.
- Open valve **531** for hydraulic operation of the exhaust valve.
- Close valve **421** and open valve **420** on the hydraulic block.



Safety Precautions

for detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off safety air supply - Not ME Engines
☐	Shut off control air supply
☐	Shut off air supply to exhaust valve - Only when stopped lubricating oil pumps
☐	Engage turning gear
☐	Shut off cooling water
☐	Shut off fuel oil
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply



Data

Ref.	Description	Value	Unit
T22-44	Cylinder cover stud, check distance	161-162	mm
T22-53	Test pressure	7	bar
T22-56	Piston rod/crown stud, screwing-in torque	100	Nm
T22-57	Piston skirt, tightening torque	190	Nm
T22-58	Cooling oil pipe, tightening torque	80	Nm
T22-59	Lifting tool, tightening torque	150	Nm
T22-62	Piston ring new, radial width	20.2	mm
T22-64	Groove No.1, max. vertical height	14.7	mm
T22-65	Groove Nos. 2, 3 and 4, max. vertical height	11.7	mm
T22-66	Piston top, max. permissible burn-away	16	mm
T22-67	Piston ring new, height of ring No. 1	13.9	mm
T22-68	Piston rings new, height of ring Nos. 2, 3 and 4	10.9	mm
T22-69	CPR ring CL groove, min. depth / POP ring, max. width of leakage groove	1.3 / N.A.	mm
T22-71	Minimum ring gap, ring No. 1 (new ring in new liner)	4.1	mm
T22-72	Minimum ring gap, ring Nos. 2, 3 and 4 (new ring in new liner)	3	mm
T22-73	Vertical clearance, new parts	0.43	mm
T22-74	Vertical clearance, worn parts, max.	0.92	mm
T22-78	Piston complete	1500	kg
T22-79	Piston crown	300	kg
T22-80	Piston rod	1000	kg
T22-81	Piston skirt	120	kg
T22-82	Piston cooling pipe	40	kg

Ref.	Description	Value	Unit
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1470-0300	124	Rubber cover for croshead
2270-0400	040	Lifting for piston rod foot
2270-0400	075	Template for piston top
2270-0400	099	Cover for stuffing box hole
2270-0400	110	Pressure test tool for piston
2270-0400	134	Piston ring expander
2270-0430	-	Piston guide tool
2270-0440	-	Hydraulic jack
2270-0440	-	Hydraulic jack support
2270-0470	-	Piston support tool
2270-0480	-	Piston lifting tool
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	118	5-way distributor block
7670-0200	-	Torque spanners
7670-0410	066	Slide caliper

NOTICE

For detailed information on scavenge port inspection, see description 2245-0100.

**WARNING**

ALWAYS bring the turning gear switch into the scavenge air receiver during inspection.

- Block the starting air supply to the main starting valve.
- Open the indicator valves.
- The access cover to the scavenge air receiver must be locked and secured in **open position** during the inspection.
- Bring in bottles with drinking water for consumption in the scavenge air receiver.
- Take care when moving around in the receiver and bring proper lighting.
- Pockets for thermometers are placed in head level. Hard hat is also recommended. Remember to take breaks to replenish fluid lost from sweating, especially in hot climates.

1. Inspection - how to

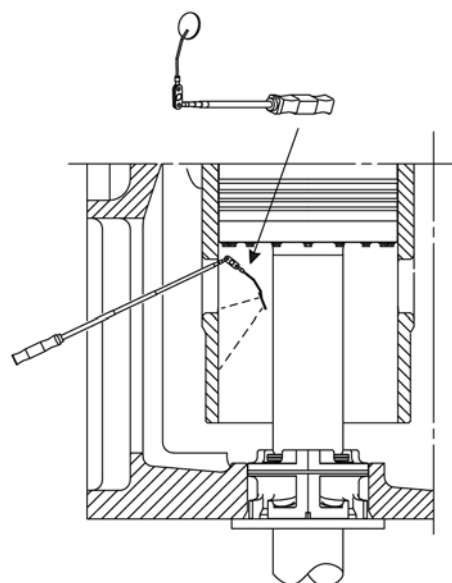
The scavenge port inspection is carried out from the scavenge air receiver. Before entering the receiver, open the access cover and secure it in open position. An additional view of the rings is possible through the cleaning cover on the manoeuvring side.

NOTICE

To detect possible leakages from the piston or cylinder cover, keep the cooling water and cooling oil circulating during the scavenge port inspection.

Turn the engine at least $\frac{1}{2}$ a revolution, and begin with a unit arriving downwards, just above the scavenge air ports. Inspect the piston rod and the lower part of the cylinder wall.

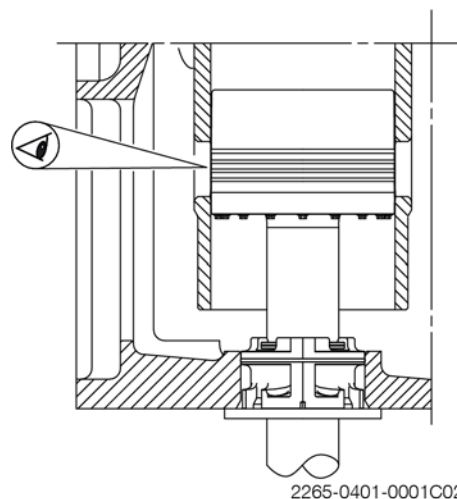
While the piston is passing downwards, inspect the piston skirt, all the piston rings, the ring lands and the piston top.



2265-0401-0001C01

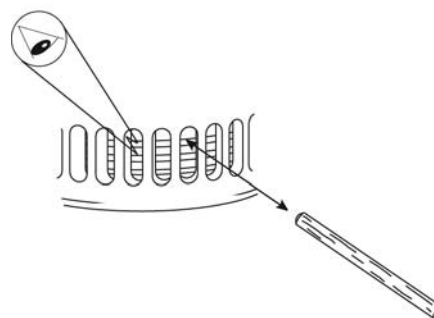
2. Ring inspection

Inspect the rings, one at a time, and note down the results.



3. Ring tension

Check the tension of the piston rings, by pressing against them with a wooden stick. It is not possible to move a ring in good condition.



4. Ring grooves

Measure the total clearance between the piston ring and the ring groove. The total clearance must not exceed the value stated *in data*.

NOTICE

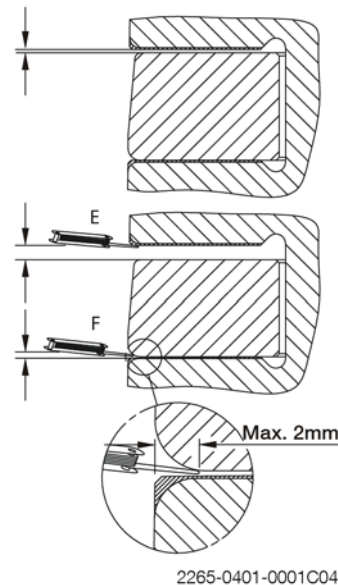
In *Data*, the piston rings are given numbers. Note that the lowest number refers to the piston ring closest to the top of the piston crown.

Measure the clearance at the bottom **E** and top **F** of the piston ring groove.

Total clearance = **E** + **F**.

T22-73

T22-74

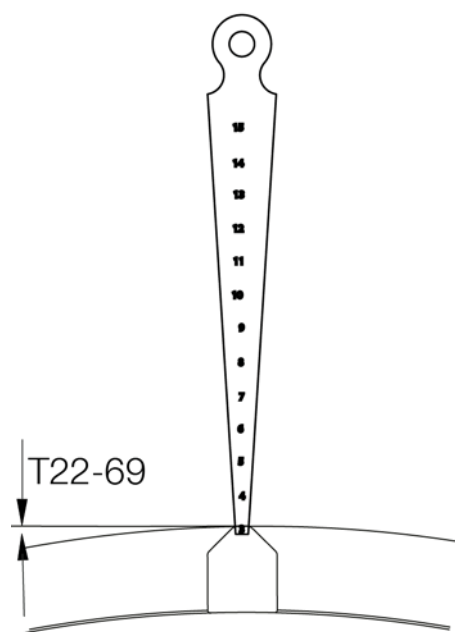


5. For engines with CPR-POP ring (Port-On- Plane) installed:

To measure the wear of the ring, the width of the leakage passage can be measured using a feeler-gauge-type measuring tool.

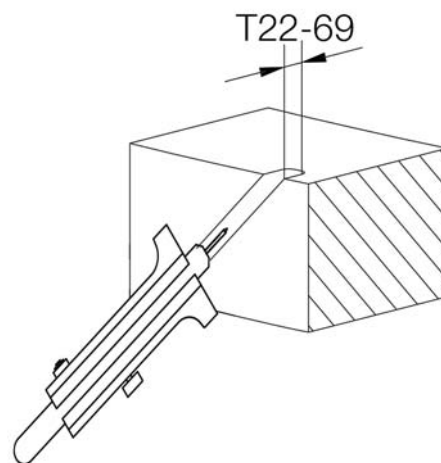
The opening is 3 mm from the beginning, and the milled passage is designed in such a way that for every 1 mm the ring is worn radially, the gap opens 2 mm.

For maximum allowable width of the leakage gap, see data T22- 69.



6. For engines with CPR-CL ring installed:

If possible, measure the depth of the pressure relief grooves with a calliper. The piston rings must be replaced if the radial depth of the grooves has worn down to less than stated in *data T22-69*.



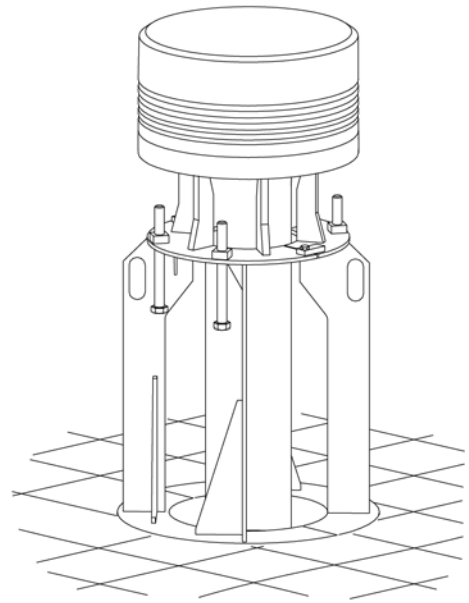
7. Piston support

Remove the piston from the cylinder and place it on the piston support.
See description 2245-0100.

NOTICE

It is recommended to replace all the piston rings whenever a piston is removed from the engine.

If however, the piston rings have not been in service so long, it is acceptable to let them remain in place.



2265-0401-0001C07

8. Free ring gap

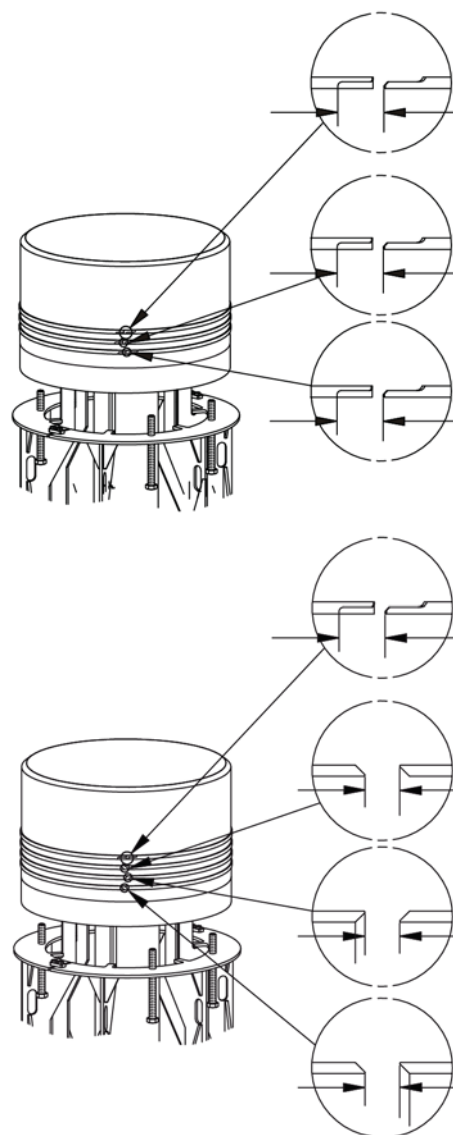
Before dismantling the piston rings, measure the free ring gap of all the piston rings. Measured values should be noted in cylinder condition report.

For dismantling the piston rings, see overhaul procedure.

NOTICE

Some pistons are equipped with four piston ring grooves, but only three piston rings are provided.

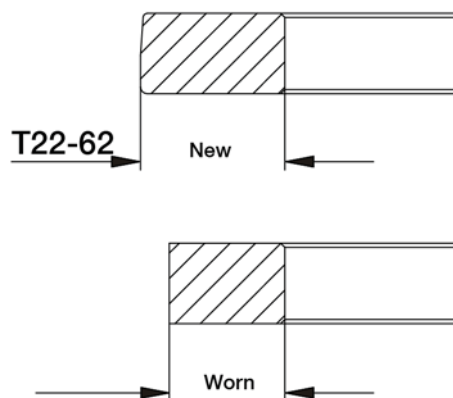
In these cases only the three uppermost grooves are to be used.



2265-0401-0001C18

9. Radial ring width

Measure the radial width of the rings. Note down the results in cylinder condition report.



2265-0401-0001C11

10. Ring grooves

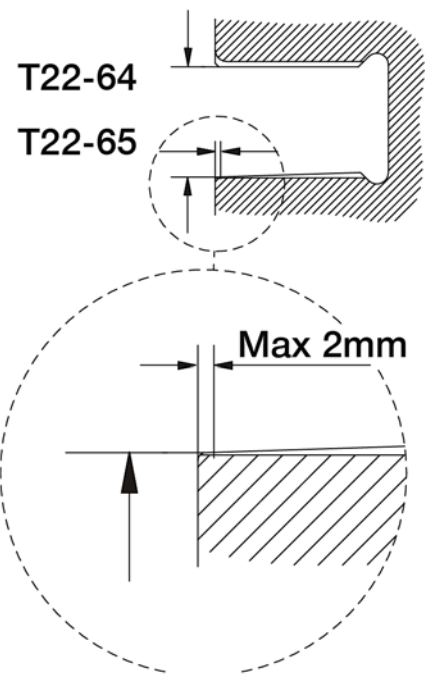
Clean the ring grooves and check them for burn marks or other deformation.

Measure the ring grooves with a calliper gauge, *see data T22-64 and T22-65.*

Clearance in piston ring grooves:

The maximum vertical height in a worn ring groove **must not** exceed the value stated *in data*. The groove is also worn out if there is no chromium layer.

If the ring grooves are worn out, the piston crown must be reconditioned, contact MAN Diesel & Turbo for advice.



2265-0401-0001C12

11. Piston crown top

Clean the piston crown and check the burn-away by means of the template.

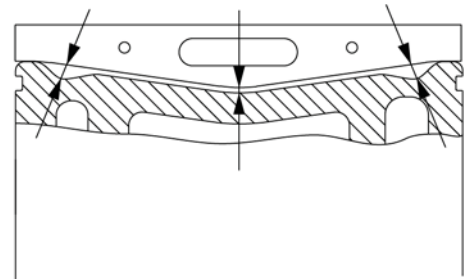
For maximum permissible burn-away value, see data.

Check the burn-away on the whole circumference of the piston crown top.

If the burn-away exceeds the values given *in data*, contact MAN Diesel & Turbo for advice.

Note down the results for later reference.

T22-66

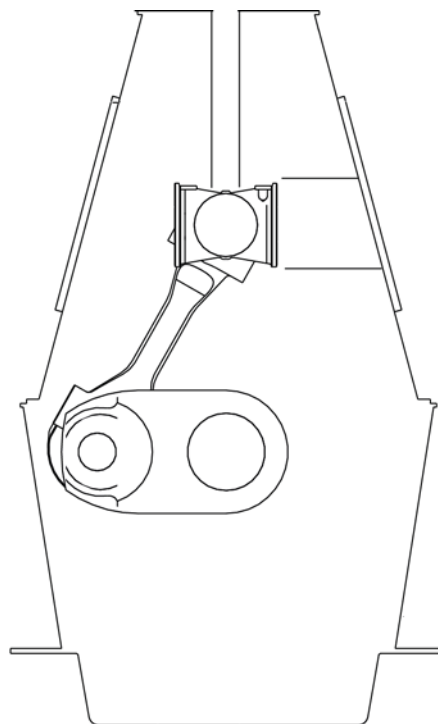


2265-0401-0001C13

**WARNING****Observe safety precautions, before entering the crankcase.***See description 0545-0100.***1. Access**

Open the crankcase door to the cylinder concerned.

Turn the crosshead down far enough to give access to the piston rod stuffing box and the piston rod/crosshead connection.



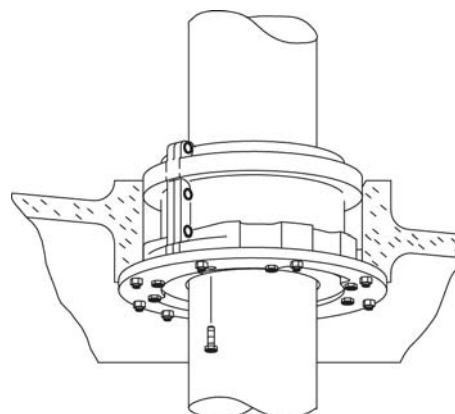
2265-0401-0001D01

2. Stuffing box

Release the stuffing box by removing the innermost screws from the stuffing box flange.

On engine models where the drain pipe is connected directly to the stuffing box:

Disconnect the stuffing box drain pipe.



2265-0401-0002D02

NOTICE

Do not remove the outermost screws from the flange.

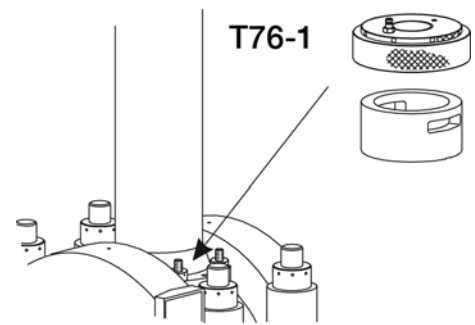
Piston • Dismantling

Work Card
 2265-0401-0018

3. Loosen the piston rod-crosshead connection

Loosen and remove the hydraulic nuts.
See data.

For operation of hydraulic tools, see work card 7665-0101.



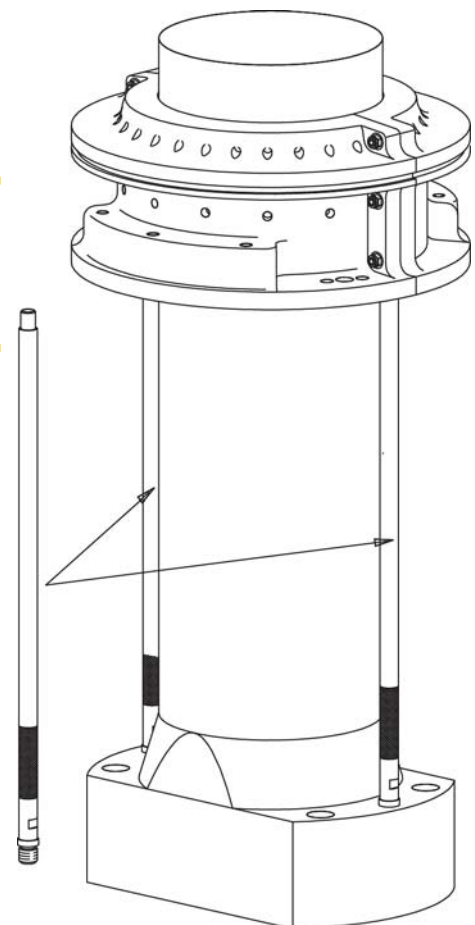
2265-0401-0024D03

4. Stuffing box distance pieces

Mount the two distance pieces on the piston rod foot to protect the lower scraper ring and to guide the stuffing box.

NOTICE

Design and length of distance pieces may vary.



2265-0401-0002D04

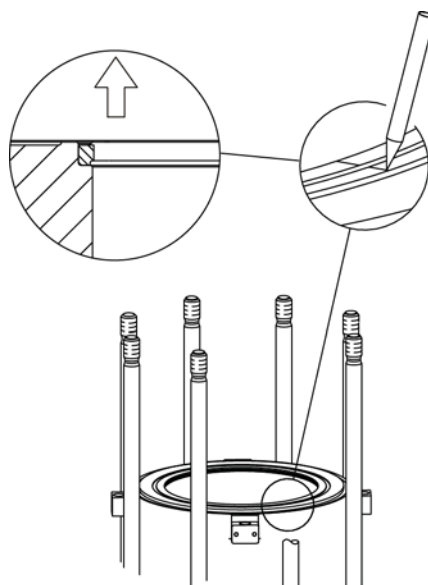
5. Cylinder cover

Remove the cylinder cover.
See work card 2265-0301.

Make a scratch mark in liner and piston cleaning ring to ensure correct re-mounting. Remove the piston cleaning ring.

Carefully remove any wear ridges at the top of the cylinder liner.
See work card 2265-0601.

If necessary, remove the aftmost access platform for the unit concerned. On some engine installations, this will be necessary to give room for the piston rod foot.



2265-0401-0007D05

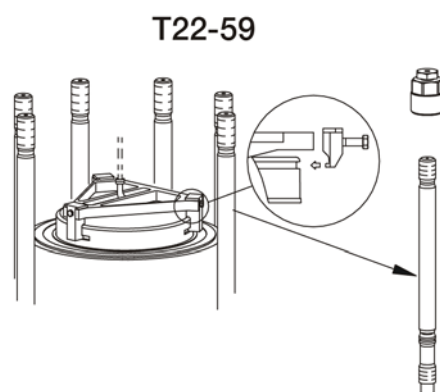
6. Piston lifting tool

Turn the piston to TDC. The top of the piston is now free of the cylinder liner.

Clean the lifting groove of the piston crown and mount the lifting tool.

NOTICE

Make sure to mount the lifting tool correctly, so that the claws of the lifting tool enter the lifting grooves of the piston crown.



2265-0401-0001D06

If the engine isn't equipped with long distance pieces, remove one or two cylinder cover studs, using a stud setter.

7. Piston lift

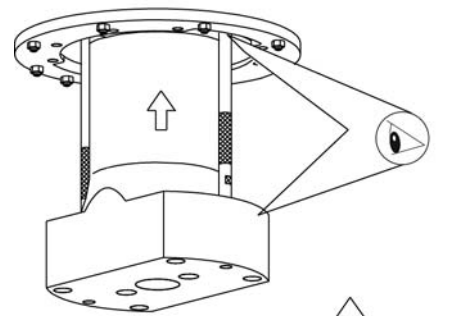
Lift the piston out of the cylinder liner and guide the piston rod foot through the stuffing box flange.

If the engine is equipped with long distance pieces for the stuffing box, the piston rod foot can pass between two cylinder cover studs.

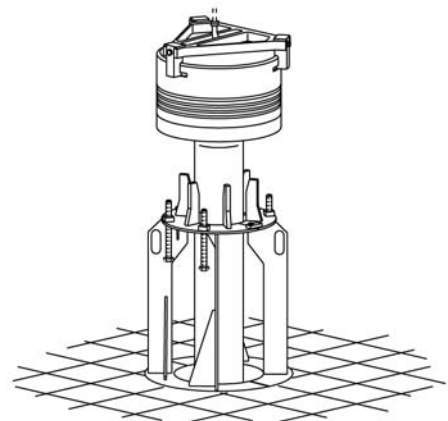
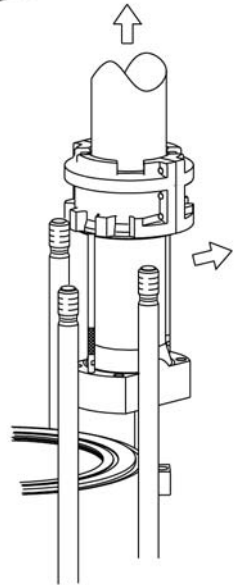
Place the two halves of the support around one of the openings in the platform. Lower the piston rod foot and stuffing box through the opening in the platform. Secure the two support halves with screws and lower the piston on the support. Check the piston is resting on the piston rod flange.

NOTICE

The piston and the piston support, should not be placed on the gallery during engine operation.



T22-78



2265-0401-0001D07

8. Limited Lifting height

If the piston rod foot can not be lifted clear of the liner top with the standard lifting tool, contact MAN Diesel & Turbo for instructions for tilted lift.

9. Protect the crosshead bearing

Place a cover over the opening for the piston rod stuffing box in the bottom of the cylinder unit.

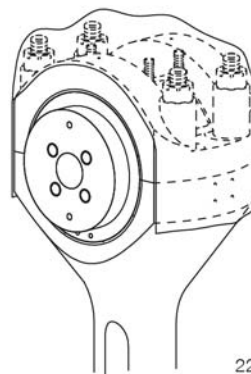
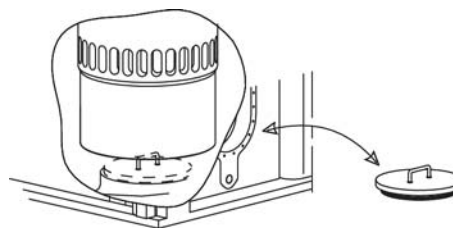
Turn the crosshead down far enough to permit mounting of the protective rubber cover on the crosshead bearing cap. The protective rubber cover is found on the 'connecting rod and crosshead' tool panel.

See plate 1470-0300.

The covers must remain in place to protect the crosshead bearing journal from impurities until the piston is remounted.

Clean, measure and recondition the cylinder liner.

See work card 2265-0601.



2265-0401-0002D08

1. Piston support

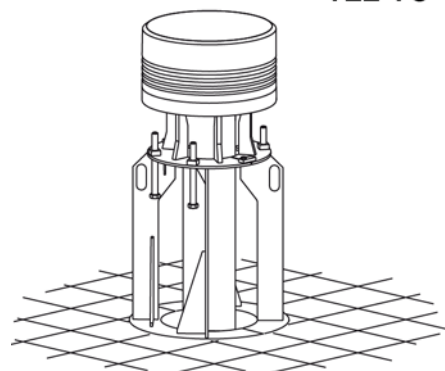
Place the piston in the support and remove the piston lifting tool.

Clean the piston top and the piston rings.

Check the free ring gap and the burn-off on the piston top.

Remove the stuffing box.
See work card 2265-0501.

T22-78



2265-0401-0001001

2. Piston ring dismantling

Remove the piston rings by means of the ring expanders. If the engine is equipped with two ring expanders, and four piston rings the short ring expander is for the uppermost (CPR-POP) ring.

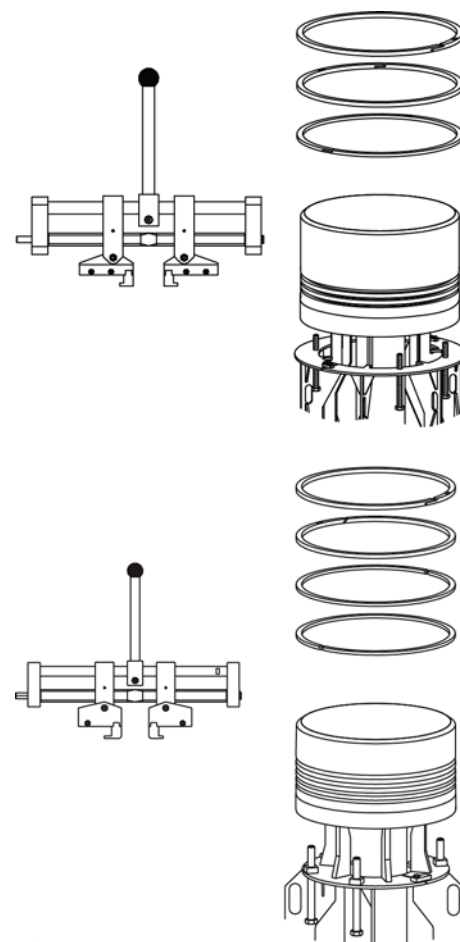
NOTICE

Some pistons are equipped with four piston ring grooves, but only three piston rings are provided.

In these cases only the three uppermost grooves are to be used.

First remove the uppermost ring, then ring number two, three and four if installed.

Clean and inspect the rings and the ring grooves.
See checking procedure.



2265-0401-0001002

3. Piston crown dismantling

Loosen and remove the hydraulic nuts between the rod and the piston crown.
See data.

For operation of hydraulic tools, see work card 7665-0101.

Lift the piston crown and skirt clear of the piston rod.



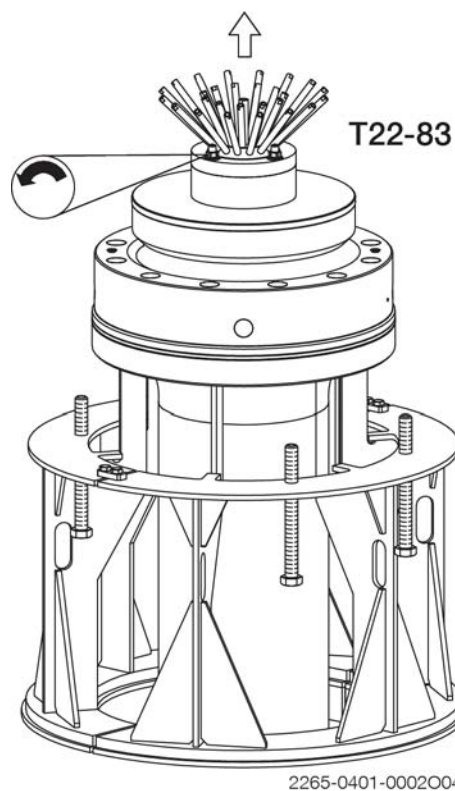
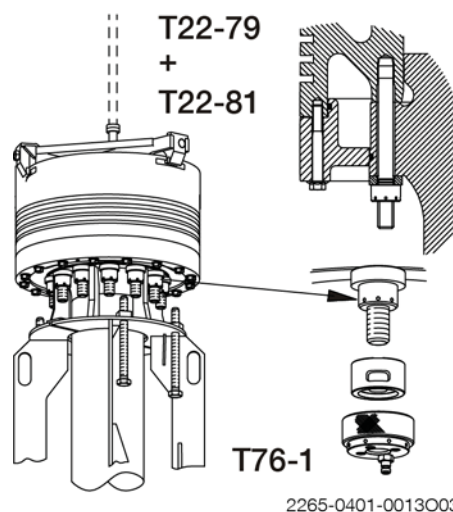
WARNING

Safe working load (SWL)

Always use lifting gear with sufficient SWL.
See data.

4. Cooling insert

Unscrew and remove the nuts for the cooling insert. Remove the cooling insert,. Clean and inspect the cooling insert.



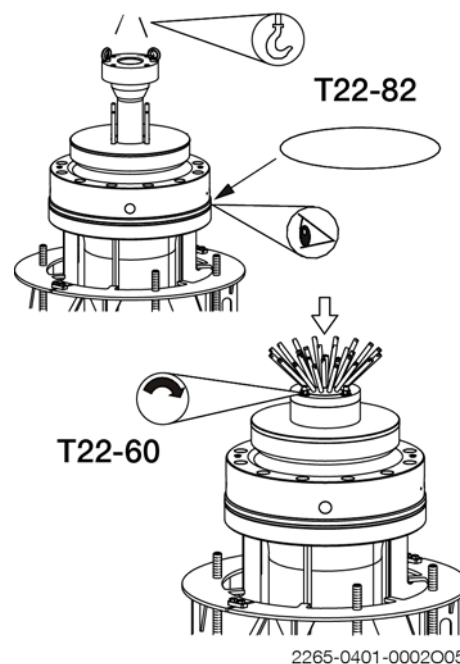
5. Piston rod and cooling pipe

Screw on the eye bolts and lift out the cooling oil pipe.

Clean and inspect the cooling oil pipe and the piston rod, then reinsert the cooling oil pipe. Remount the cooling insert and tighten the nuts as specified.
See data.

Check that the surfaces of the O-ring groove are clean and smooth.
See data.

Mount a new O-ring on the piston rod flange.



2265-0401-0002005

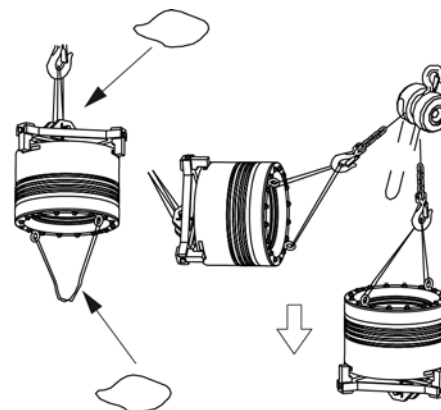
6. Piston crown turning

Unhook the crane from the piston lifting tool, and connect the lifting tool and the crane hook by means of a wire rope. Lift up the piston crown.

Mount two eye bolts in the piston skirt and a wire rope between the bolts as shown in the sketch.

Install a tackle in a suitable place with sufficient space below for the piston crown. Attach the tackle to the wire rope on the piston crown and carefully turn the piston crown upside down. Use both cranes if the engine room is equipped with two cranes.

Land the piston lifting tool and the piston crown on a sufficient support of wood pieces. Loosen the piston lifting tool and lift the piston crown clear of the tool.



2265-0401-0001005

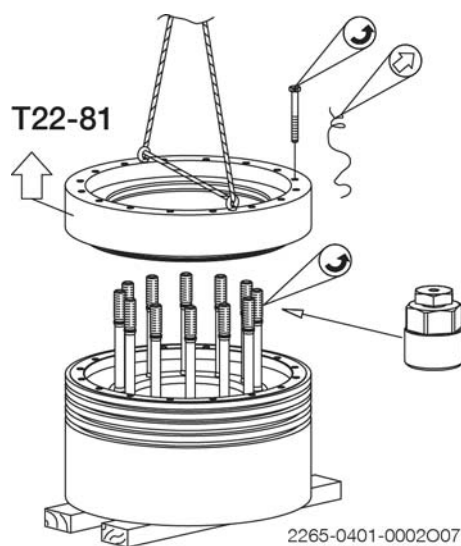
7. Piston crown dismantling and cleaning

Place the piston crown with skirt on a wooden support as shown.

Remove the locking wire and the screws in the skirt. If necessary use two dismantling screws to pull the skirt out of the piston crown. Mount two eye bolts in the skirt. Lift the skirt and land it on a couple of planks.

Discard the sealing ring on the piston skirt.

Thoroughly clean and inspect all parts of the crown and skirt. If coke deposits are found in the cooling spaces of the piston crown, they should be washed clean with Carbon Remover or a similar cleaning fluid. When all coke deposits have been dissolved, clean and inspect the piston crown again.



NOTICE

Coke deposits reduce heat transfer from the piston crown to the cooling oil. The deposits must be removed as a routine procedure when a piston is overhauled.

If the piston crown is renewed, remove the piston crown studs using a stud setter.

8. Piston crown assembly

Mount the piston crown studs in a new or overhauled piston crown, lubricate the threads on the studs with molybdenum disulphide (MoS_2).

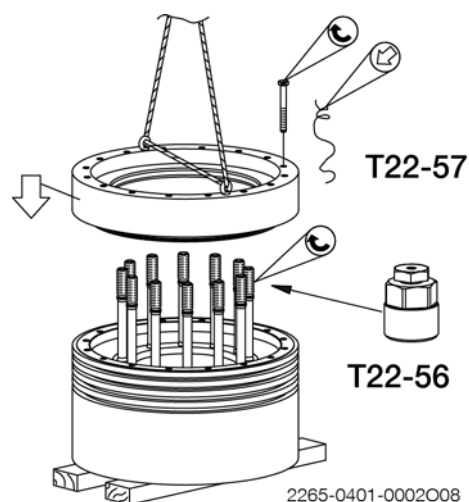
Tighten the studs to the specified torque using a stud setter.
See data T22-56.

Mount a new O-ring on the piston skirt, check that the surfaces of the O-ring groove is clean and smooth, coat the ring with lubricating oil before mounting.

Mount the piston skirt on the piston crown.

Tighten the screws to the specified torque.
See data T22-57.

Lock the screws with locking wire.
See work card 7665-0501.



9. Piston crown and skirt mounting

Lubricate the O-ring on the piston rod flange with lubricating oil.

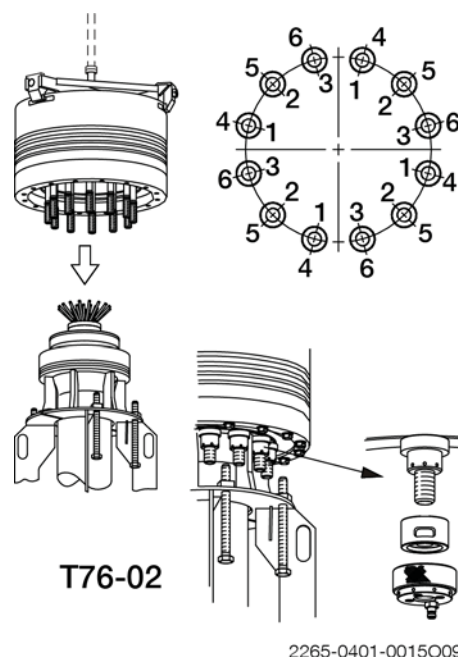
NOTICE

Take care not to damage the pipes of the cooling insert when landing the piston crown on the piston rod.

Land the overhauled piston crown and skirt on the piston rod.

Mount and tighten the hydraulic nuts on the piston crown studs.

When tightening the hydraulic nuts follow the tightening sequence. All the nuts must be tightened twice to full tightening pressure.
See data.



10. Sealing ring and pressure test

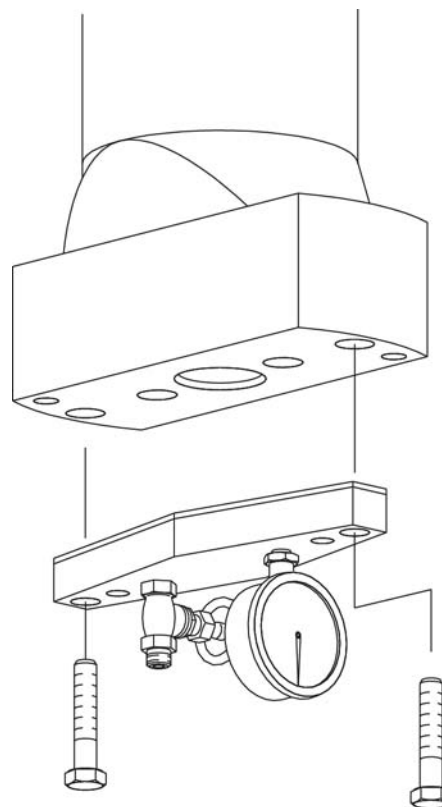
According to current class rules, the piston must be pressure tested hydraulically. It is possible to carry out a test of the sealing rings with compressed air before filling the piston with oil. The sealing ring test can also be carried out when the piston is resting in the support tool.

11. Sealing ring test

Mount the pressure-testing tool on the piston rod foot. Connect compressed air to the testing tool and fill the piston to 4-5 bar. Close the valve on the testing tool and remove the air connection. The piston must now hold the pressure for minimum 30 minutes.

Spray a little soap water on to the surface joints between piston rod/crown/skirt and around the bolt heads to detect leaks.

Dry off all soap water.



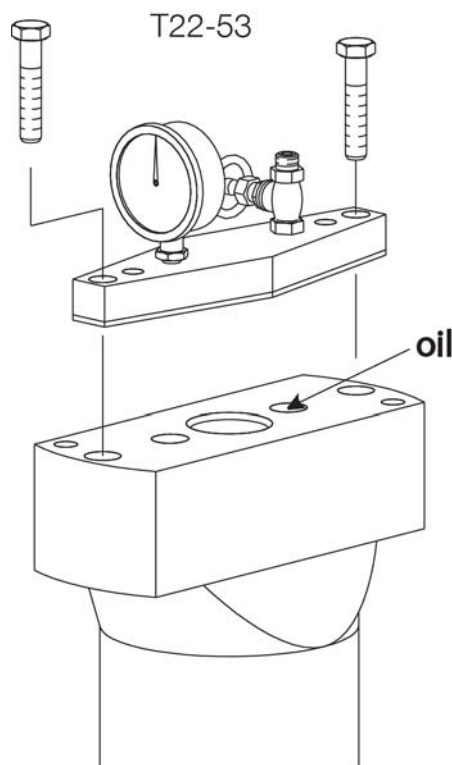
2265-0401-0001O09

12. Pressure test

For this test, the piston must be turned upside down (*see next step to turn a complete piston*).

Fill the piston and piston rod with lubricating oil. Mount the pressure-testing tool on the piston rod foot. Pressure-test the piston at the pressure stated *in data*. Check the contact surfaces of the piston and the sealing rings for tightness. Check that there are no cracks in the piston crown.

Turn the piston upside up and drain out the piston oil.



2265-0401-0001O10

13. Piston turning

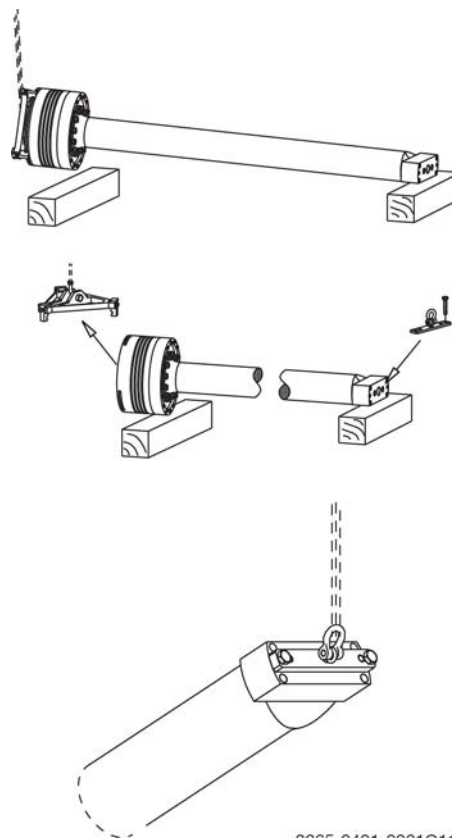
Lift the piston with the normal lifting tool. Lower the piston rod foot until it is close to the platform. Land the foot on a wooden block.

Lower the piston crown to the platform and land it on a wooden block in such a way that it is possible to remove the lifting tool.

Attach the lifting bracket to the bottom of the piston rod foot. Hook the crane on to the lifting bracket. Lift the piston rod foot clear of the wooden block. Keep lifting until the piston rod is in a vertical position.

NOTICE

During the lift, follow with the crane to keep the crane positioned vertically above the lifting point. The stuffing box must be removed.



2265-0401-0001011

14. Piston completion

When mounting the piston rings, use the ring expanders to prevent unintended deformation of the rings.

NOTICE

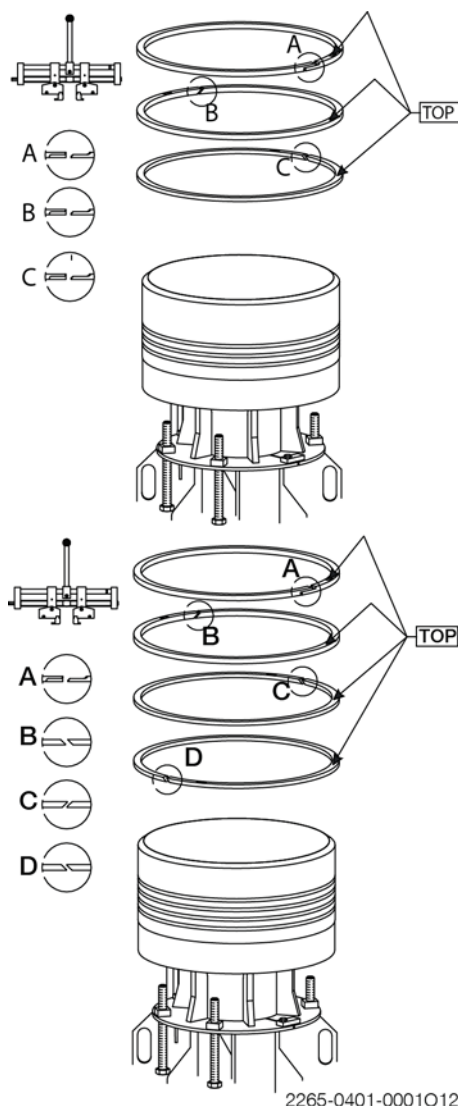
Some pistons are equipped with four piston ring grooves, but only three piston rings are provided.

In these cases only the three uppermost grooves are to be used.

Mount the new piston rings. If equipped with CPR-CL alternately right-hand and left-hand cuts, but always with the ring gaps staggered 180° and with the TOP mark upwards.

Do not expand the rings more than necessary. The uppermost ring (CPR-POP) must be mounted with the short ring expander, if the engine is equipped with four piston rings.

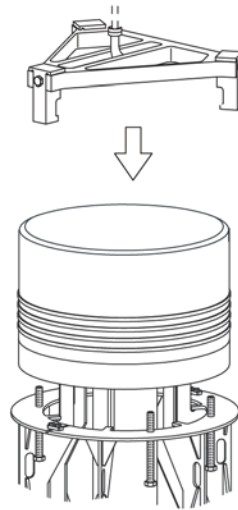
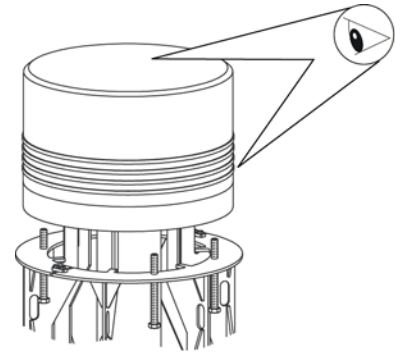
Mount the piston rod stuffing box.
See work card 2265-0501.



2265-0401-0001012

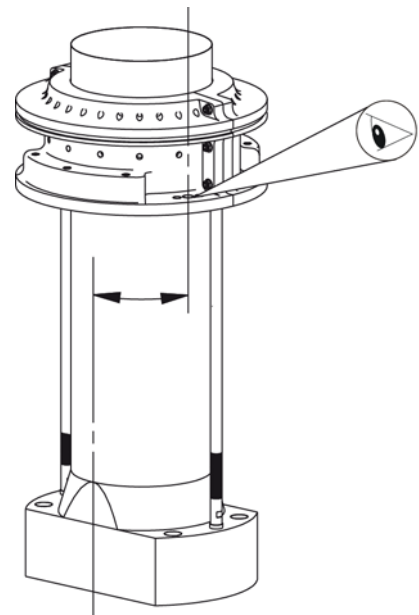
1. Preparation of piston If not already done, check the piston rings and piston crown.
See checking procedure.

Mount the lifting tool on the piston crown.
See data T22-59.



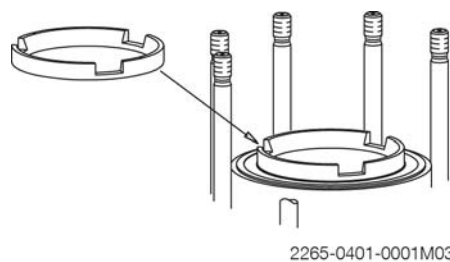
2265-0401-0001M01

2. Stuffing box position Ensure that the stuffing box is correctly positioned over the distance pieces mounted on the piston rod foot. Both the holes for the flange and the drain hole for the drain pipe must be positioned correctly.



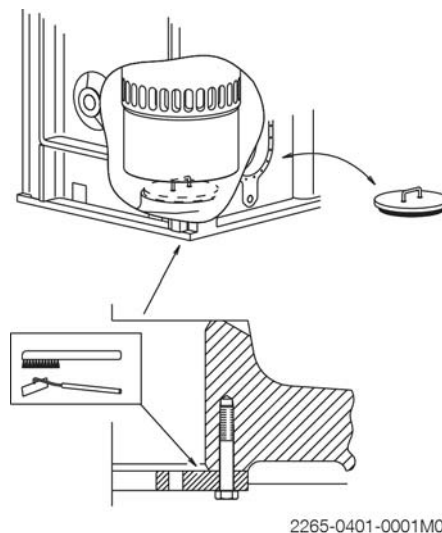
2265-0401-0001M02

3. **Mount the guide ring** Mount the guide ring in the top of the cylinder liner. The cut outs for the lifting tool must be turned to fit the piston lifting tool.

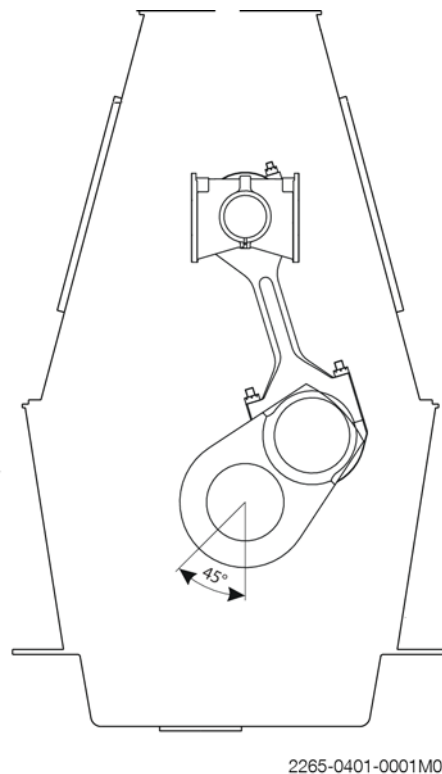


4. **Stuffing box cover** Remove the cover from the piston rod stuffing box opening in the bottom of the cylinder unit.

Clean the stuffing box flange.



5. **Crosshead position** Turn the crosshead to a position 45° from TDC (crank web pointing towards exhaust side).

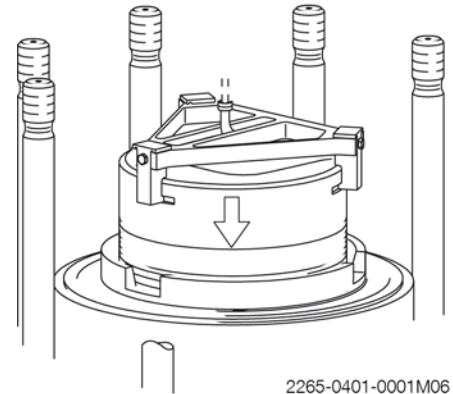


6. Mounting of piston

Coat the O-rings of the stuffing box and the piston rod with oil. Coat the piston rings and cylinder liner with cylinder lubricating oil.

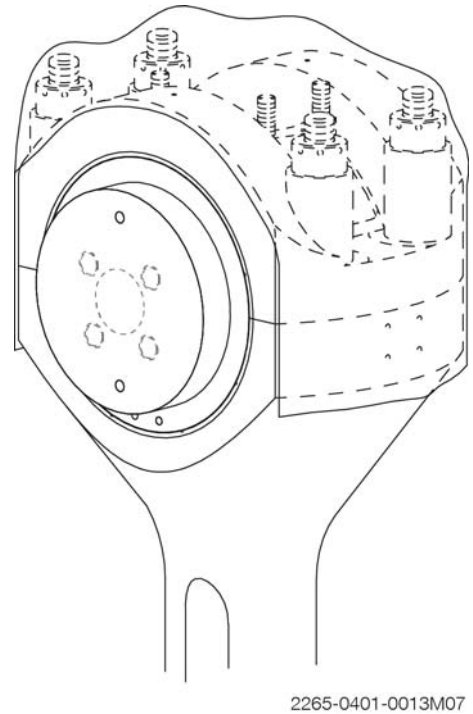
Lower the piston into the cylinder liner – while guiding the piston rod foot through the cut-out in the stuffing box flange – until the piston rings are inside the liner.

T22-78



7. Protective cover

Remove the protective rubber cover from the crosshead.



8. **Crosshead alignment** Turn the crosshead almost to TDC. If necessary, mount the hydraulic nuts on the studs and screw down until the nuts are flush with the top of the studs.

Turn the crosshead upwards until the piston rod foot lands on the nuts, thereby turning the crosshead until the face is parallel to the piston rod foot.

Lower the crosshead just enough to enable removal of the nuts. Turn the crosshead upwards until the piston rod lands on the crosshead. When mounting the piston on the crosshead, make sure that the piston rod foot does not damage the threads of the studs. Ensure that the guide ring in the crosshead fits correctly in the centre hole of the piston rod.

Unscrew the lifting tool and remove the lifting tool and the guide ring for piston rings.

9. Stuffing box

Turn down and land the stuffing box on the stuffing box flange. Check that the holes in the stuffing box and stuffing box flange are correctly centered.

Tighten the piston rod stuffing box by means of the screws through the inner holes in the stuffing box flange.

For data, see work card 2265-0501.

On engine models where the drain pipe is connected directly to the stuffing box:

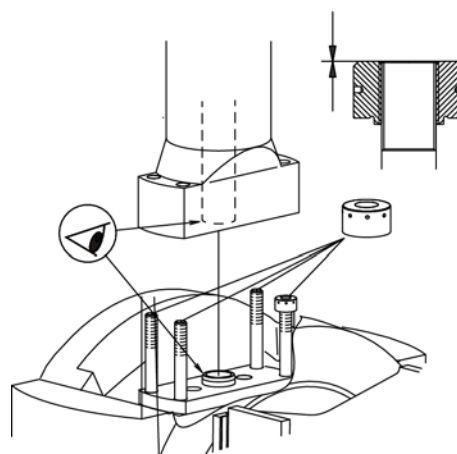
Mount the stuffing box drain pipe.

Remove the distance pieces from the piston rod foot.

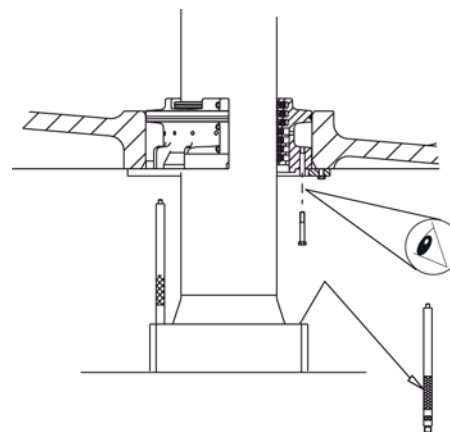
10. Tightening of the piston rod-crosshead connection

Mount and tighten the piston rod nuts with the hydraulic jacks.
See data.

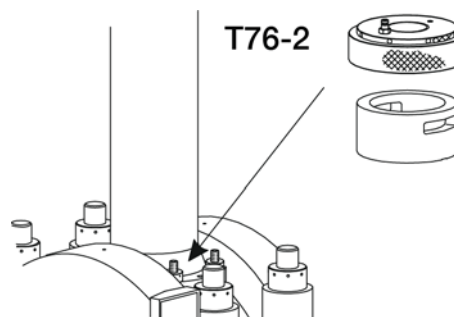
For operation of hydraulic tools, see work card 7665-0101.



2265-0401-0013M08

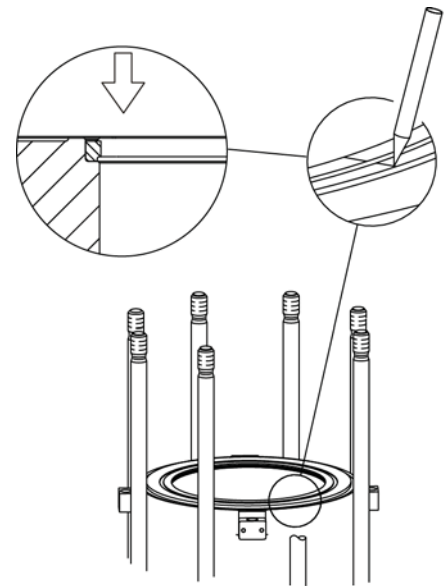


2265-0401-0001M09



2265-0401-0024M10

11. Piston cleaning ring Mount the piston cleaning ring in accordance with the scratch mark. If the PC-ring is damaged (broken or cracked), it must be replaced by another ring. See work card 2265-0601.



2265-0401-0007M11

12. Cylinder cover Mount the cylinder cover. See work card 2265-0301.
13. Running-in Smear the piston rod with molybdenum disulphide, and turn the crankshaft a couple of revolutions.
- At the first opportunity, start the engine and keep it running for about 15 minutes at a speed corresponding to "Dead Slow" Ahead.
- Then stop the engine and inspect the piston rod and stuffing box.

Safety**Precautions**

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Shut off air supply to exhaust valve - Only when stopped lubricating oil pumps
○	Engage turning gear
○	Shut off cooling water
○	Shut off fuel oil
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T22-86	Stuffing box flange, outer screws tightening torque	80	Nm
T22-87	Stuffing box flange, inner screws tightening torque	80	Nm
T22-88	Stuffing box halves, tightening torque	80	Nm
T22-89	Stuffing box halves fitted bolts, tightening torque	25	Nm
T22-90	Sealing rings, ring-end clearance	4x6	mm
T22-91	Lowermost rings, ring-end clearance	3x3	mm
T22-92	Sealing ring springs new, free length	688	mm
T22-93	Scraper ring springs new, free length	606	mm
T22-102	Stuffing box complete	70	kg
T22-103	Stuffing box half	35	kg

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1470-0300	112	Rubber cover for croshead
2270-0400	109	Mounting tool for stuffing box spring
2270-0400	122	Worktable for stuffing box

Plate	Item No.	Description
7670-0200	-	Torque spanners
7670-0410	066	Slide caliper



NOTICE

It is important for the proper operational performance of the stuffing box that it is not covered in sludge.

A dirty stuffing box indicates that the scavenge air box is not cleaned regularly and sufficiently. This could damage the stuffing box and the piston rod, and pollute the system oil.

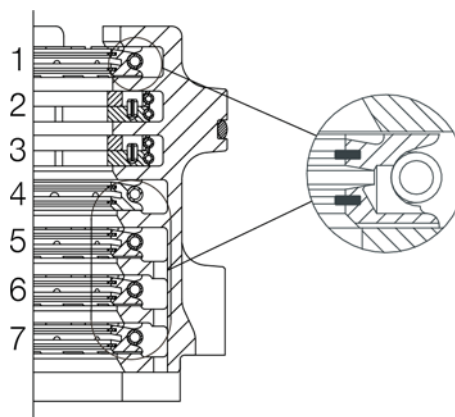
1. Scraper rings

Dismantle the piston rod stuffing box.
See dismantling procedure.

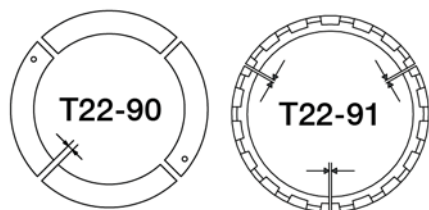
Check the end clearances of the scraper rings.

The ring end clearance stated *in data* applies to new rings.

As a general guide, it is recommended – depending on the overhauling intervals and one's own experience – to replace sealing rings and scraper rings when the specified clearance value *T22-91* has been halved.

**NOTICE**

Scraper ring no. 4 is standard type, while scraper rings no. 1, 5, 6 and 7 are Lap Joint type. The end clearances for standard type and Lap Joint type are the same.



2265-0501-0005C01

2. Springs

Garter springs:

Generally, it is recommended to renew the springs when the sealing rings and scraper rings are renewed.

The springs can be checked as follows:

Place the springs on the table, measure L_0 (free length), and compare with *data*. If a spring is extended more than 8% from the value given *in data*, it must be discarded.

T22-92**T22-93**

2265-0501-0001C02

WARNING

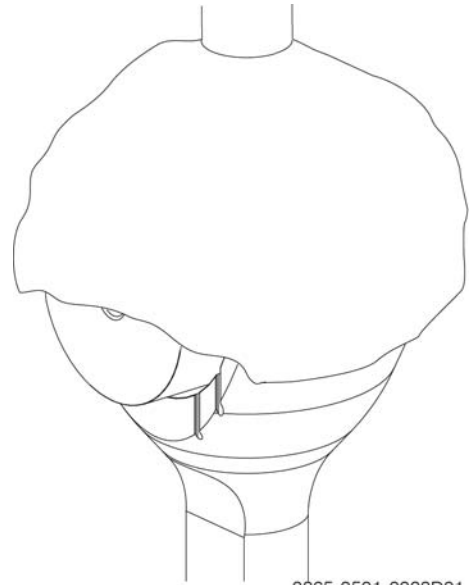
Observe safety precautions when working in the crankcase.
See description 0545-0100.

1. The crosshead

If, in the period between piston overhauls, it becomes necessary to inspect the piston rod stuffing box, proceed as follows:

Turn the crosshead to about 90° from TDC.

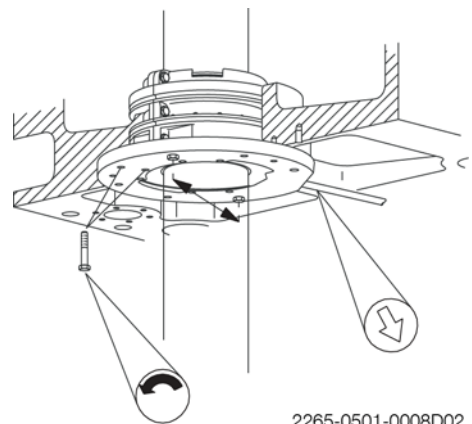
Mount the rubber cover around the piston rod to protect the crosshead bearing from impurities.



2265-0501-0008D01

2. Drain oil pipe

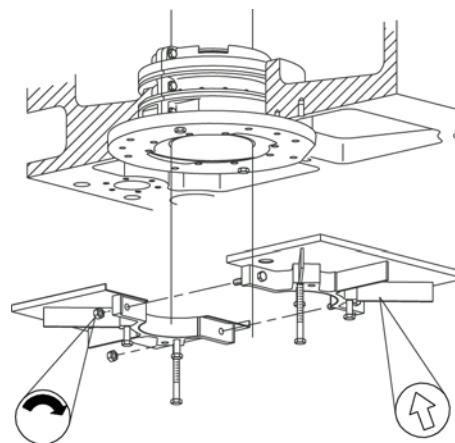
Remove the drain oil pipe and all innermost screws and all outer screws except for two screws placed diametrically opposite in the stuffing box flange, longitudinally to the engine.



2265-0501-0008D02

3. Worktable

Mount the worktable around the piston rod so that the two remaining screws in the stuffing box flange can be loosened through the holes.



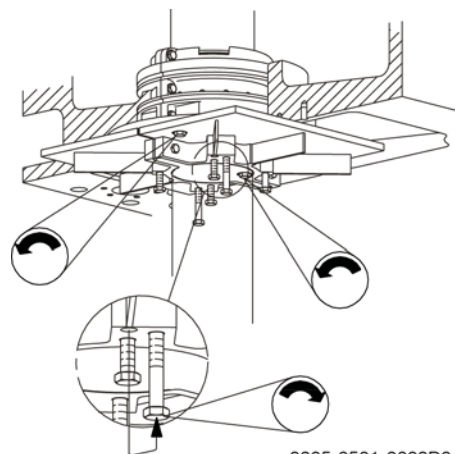
2265-0501-0008D03

4. Screws

Unscrew the two long dismantling screws from the worktable.

Mount them in the stuffing box through the holes in the worktable.

Remove the remaining two screws from the stuffing box.

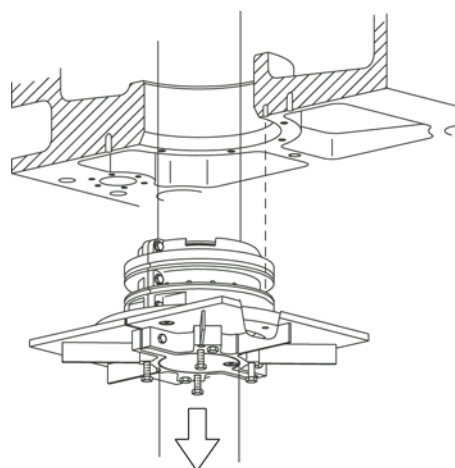


2265-0501-0008D04

5. BDC

Turn the piston to BDC, thereby withdrawing the stuffing box from the cylinder frame bottom.

Remove the two long dismantling screws from the stuffing box and mount them in the worktable.



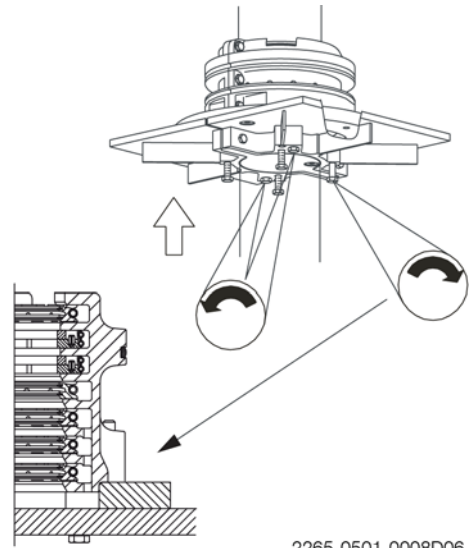
2265-0501-0008D05

6. Stuffing box

Remove the two long dismantling screws from the stuffing box and mount them in the worktable.

By means of the four short screws in the worktable, press the stuffing box out of the flange.

Overhaul the stuffing box.
See overhaul procedure.

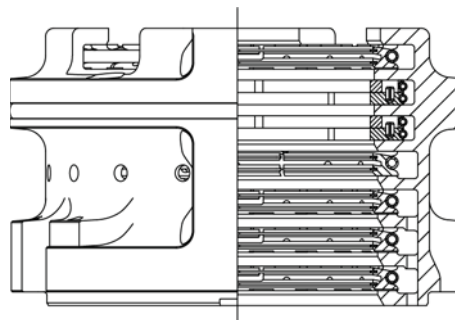


1. Outside the engine

Normally, overhaul of the piston rod stuffing box is carried out by routine methods in connection with the dismantling (pulling) of the pistons.

During such overhauls, the piston rests on a support placed over one of the cut-outs in the top platform.

Work on the stuffing box is then carried out from the platform below.



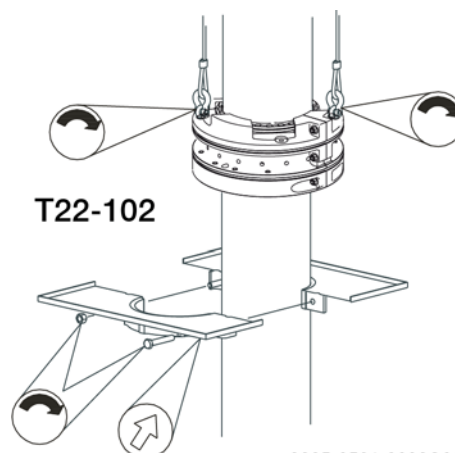
2265-0501-0005001

2. Stuffing box

Mount two eye bolts in the stuffing box flange, and hook on two tackles.

Lift the stuffing box a little up the piston rod, and mount the worktable round the piston rod at a suitable working height.

Land the stuffing box on the worktable, and remove the tackles and eye bolts.

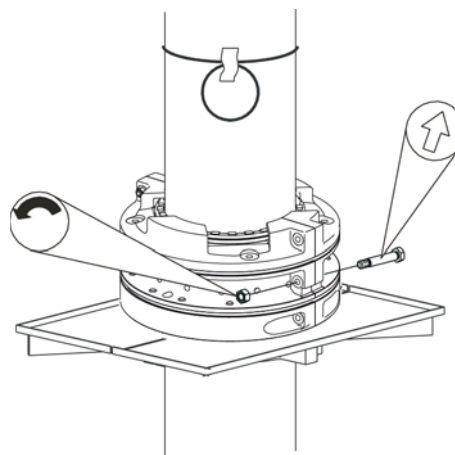


2265-0501-0008002

3. O-rings

Remove the O-ring of the stuffing box. If the O-ring is intact and is to be used again, move it up the piston rod and secure it in this position, for example with tape.

Remove the nuts from the stuffing box assembling bolts.

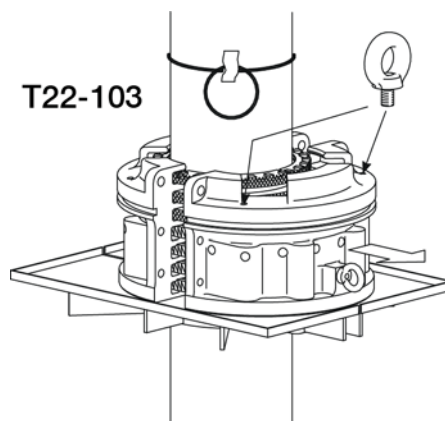


2265-0501-0008003

4. Eye bolts

Remove the six bolts, and pull away one stuffing box half.

Mount two eye bolts on the stuffing box half and remove it from the worktable.



T22-103

2265-0501-0001004

5. Measure vertical clearance of the rings

Using a feeler gauge, measure the vertical clearance of the rings.
See checking procedure.

6. Press down all sealing rings and scraper rings

Remove the remaining stuffing box half and press all sealing rings and scraper rings down against the worktable.

7. Surface inspection

Measure the clearance between the ring segments to determine whether replacement is necessary.
See checking procedure.

Dismantle and stack the rings in the same order as when mounted in the stuffing box.

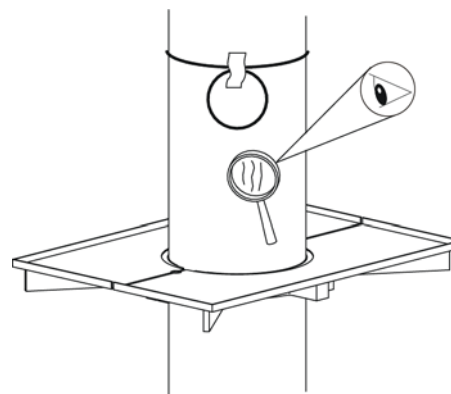
Carefully clean all the ring segments.

Inspect and assess the surface quality of the sealing rings. If their sliding surfaces have scratches or marks, replace the rings.

Check the lengths of the springs.
See checking procedure.

8. Piston rod surface inspection

Inspect the surface of the piston rod. If small longitudinal scratches have occurred (caused by poorly adapted stuffing box rings), smooth the piston rod surface carefully with a fine grained carborundum stone.



2265-0501-0001008

9. Stuffing box housing Clean the halves of the stuffing box housing.

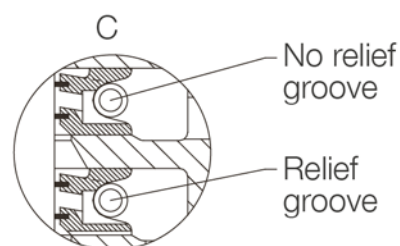
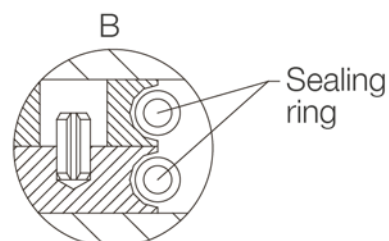
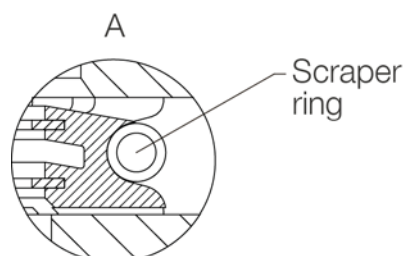
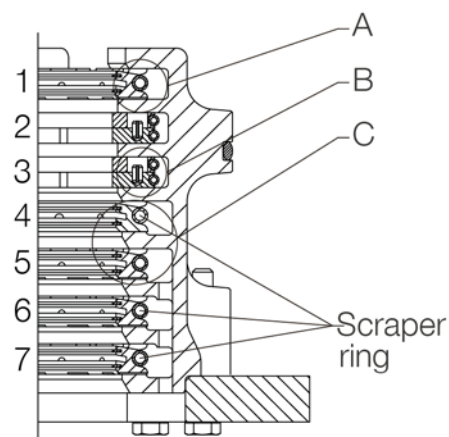
10. Piston rod lubricating Clean the halves of the stuffing box housing.

Lubricate the piston rod (in the area where all the ring units in the stuffing box will be positioned) with molybdenum disulphide (MoS_2)

For correct mounting of the sealing and scraper rings see the sketch.

The scraper ring in groove no. 4 must be standard type without relief grooves on the underside.

The scraper ring in grooves no. 1, 5, 6 and 7 must be lap joint type with relief grooves on the underside.



2265-0501-0005D04

11. Stuffing box ring units

Assemble all the stuffing box ring units around the piston rod, on the worktable, in the following way:

- Place the lowermost scraper ring segments on the worktable.
- Place the spring around the segments.
- Grab the hooks with crossed arms and pull the spring tight. Hook the spring ends together and remove the hooks.

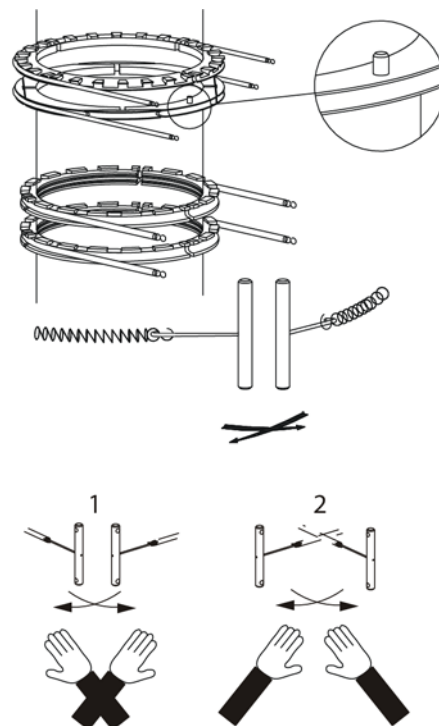
Repeat this procedure for the remaining scraper rings.

On top of the scraper rings, assemble the two sealing ring units (each consisting of a 4-part and an 8-part ring).

Assemble the 8-part sealing ring so that the two guide pins face upwards, place the spring round the segments and, hook the spring ends together.

Assemble the 4-part sealing ring above the 8-part sealing ring. Push the two rings together in such a manner that the guide pins in the lower sealing ring engage with the two holes in the upper sealing ring.

Finally, assemble the uppermost scraper ring (lap joint type)

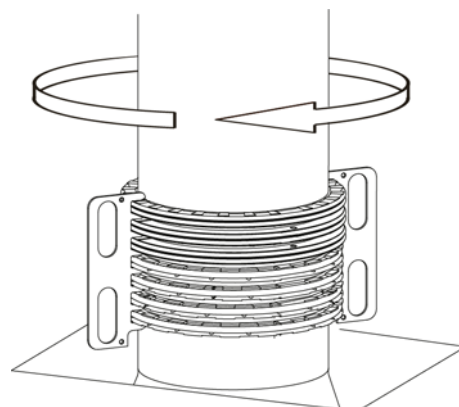


2265-0501-0001O11

12. Gauge tool

Mount all of the scraper rings on the piston rod. Try to position all the rings with an equal distance between them. Use the stuffing box gauge tool to adjust the spacing between the rings.

This is done by carefully inserting the teeth of the gauge tool within the rings and then carefully moving the gauge along the springs.

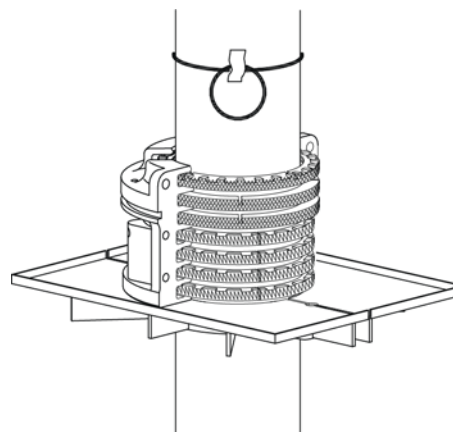


2265-0501-0001O15

13. Mounting the ring units

Use the stuffing box half on the worktable to adjust the height of all the assembled ring units on the piston rod until the ring units are opposite the corresponding grooves in the stuffing box housing.

Subsequently, push the stuffing box half into contact with the piston rod, round the ring units.

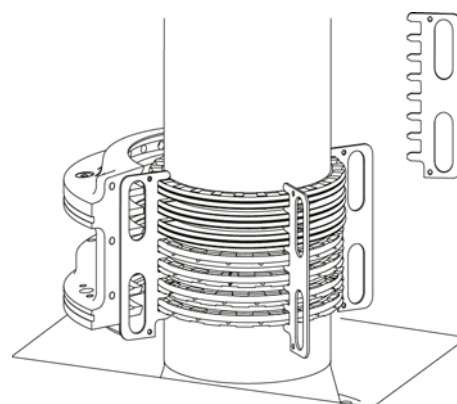


2265-0501-0001O12

14. Adjust the rings

Insert the gauge tool at one end of the stuffing box half and carefully slide it along the entire length of the scraper and sealing rings, thus adjusting the distance between the remaining exposed segment.

Push the stuffing box half into contact with the piston rod, thus enclosing the ring units.



2265-0501-0001O16

15. Bolts

Check the ring clearance again.

Then place the other half of the stuffing box housing on the worktable, pushing it into place round the rings.

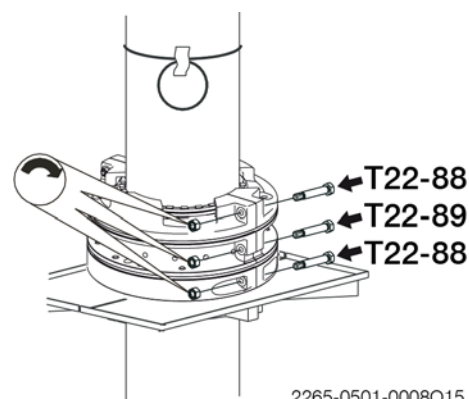
Mount and tighten up the fitted bolts to the torque specified.

See data T22-89.

Tighten the other bolts to the torque specified.

See data T22-88.

Mount the O-ring in the stuffing box groove.

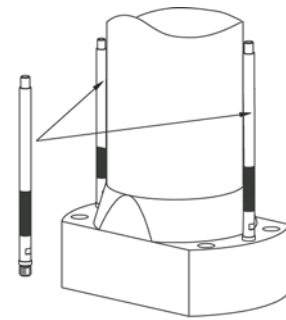


2265-0501-0008O15

16. Distance piece

If not already mounted, mount the stuffing box distance piece to protect the lower scraper ring and to guide the stuffing box.

See work card 2265-0401.



2265-0501-0008O16

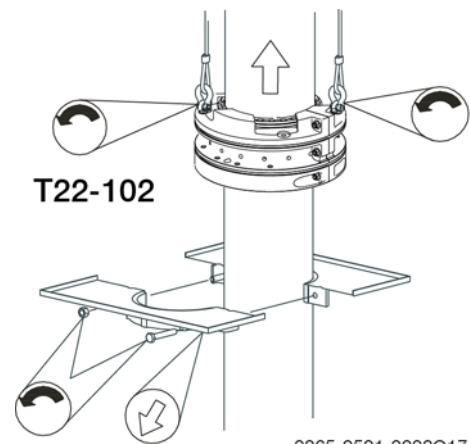
17. Remove the worktable

Mount eye bolts and wire ropes, and lift the stuffing box a little.

If the work is done outside the engine remove the worktable.

Remove the worktable and lower the stuffing box until it rests against the distance pieces on the piston rod foot.

Remove wire ropes and screws.

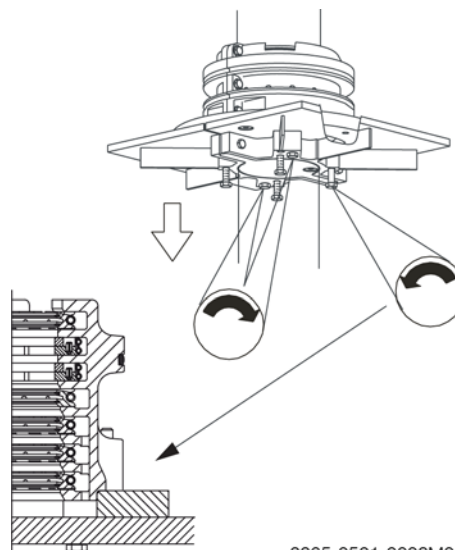


2265-0501-0008O17

1. Stuffing box

Mount the two long screws from the worktable in the stuffing box.

Turn down the short screws so that the stuffing box lands on the flange.



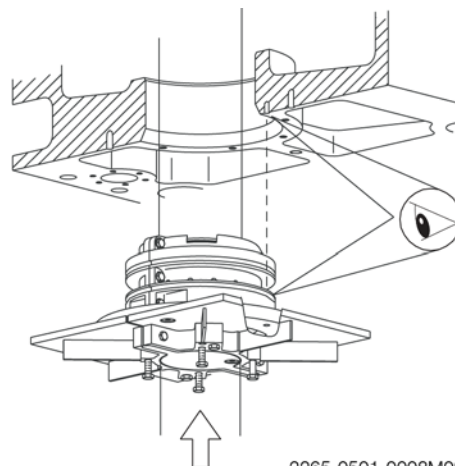
2265-0501-0008M01

2. Turn the piston upwards

Turn the piston upwards until the stuffing box is in place in the cylinder frame.

NOTICE

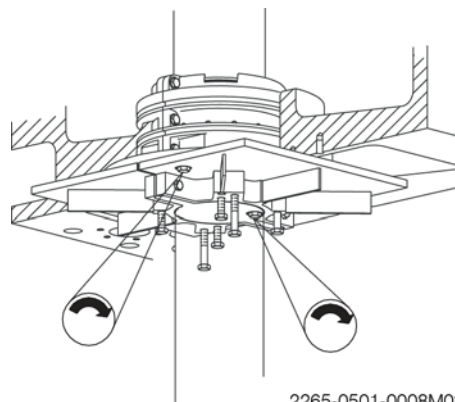
Make sure that the two guide pins in the flange enter the guide holes in the bottom of the cylinder frame.



2265-0501-0008M02

3. Screws

Mount two screws in the flange through the holes in the worktable.

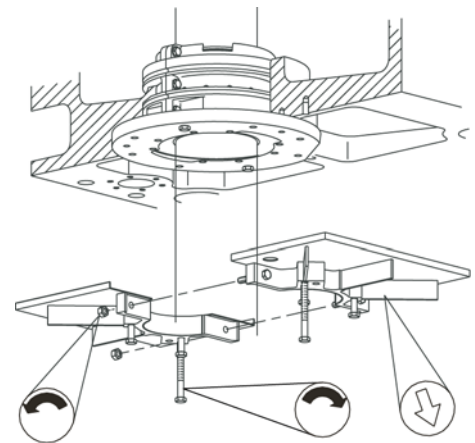


2265-0501-0008M03

4. Remove the worktable

Remove the long screws from the stuffing box and mount them in the worktable.

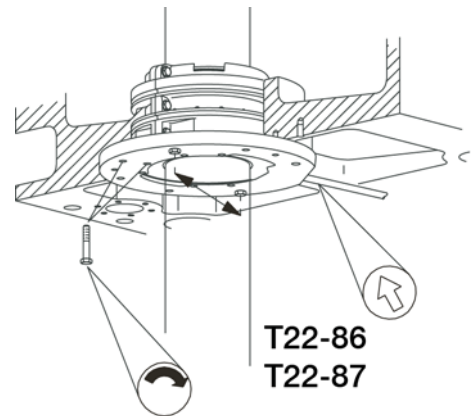
Remove the worktable from the piston rod.



2265-0501-0008M04

5. Mount all screws

Mount and tighten all the inner and outer screws for the stuffing box.
See data.



2265-0501-0008M05

6. Finally

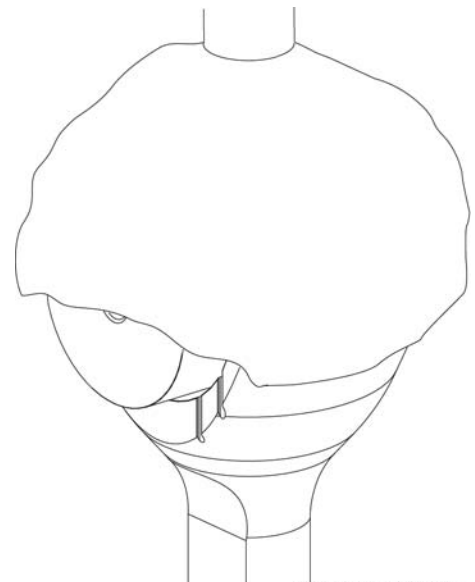
Remove the protecting rubber cover from the piston rod/crosshead.

Smear the piston rod with molybdenum disulphide.

Then turn the crankshaft a couple of revolutions.

Start up the engine and keep it running for about fifteen minutes at a number of revolutions corresponding to very slow or idle speed.

Then stop the engine and inspect the piston rod and stuffing box.



2265-0501-0008D01

Safety**Precautions**

for detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Shut off air supply to exhaust valve - Only with stopped lub. oil pumps
☐	Engage turning gear
☐	Shut off cooling water
☐	Shut off fuel oil
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T22-105	Lifting tool screws, tightening torque	200	Nm
T22-107	Cylinder diameter, new	600	mm
T22-108	Piston cleaning ring inner diameter, new	598.7±0.1	mm
T22-109	Piston cleaning ring radial width, new	13.1	mm
T22-111	Cylinder liner, complete	3700	kg
T22-112	Cooling jacket	160	kg

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
2270-0400	051	Lifting tool for cylinder liner
2270-0610	016	Measuring tool for cylinder liner
2270-0620	010	Wear ridge milling machine
2270-0640	021	Lifting tool for cylinder liner
7670-0200	-	Torque spanners

NOTICE

For information on cylinder liner condition and scavenge port inspection, *See description 2245-0100.*

For information on the condition of the lubrication points and non-return valves, *See work card 3065-0601.*

1. Preparation

Dismount the cylinder cover and the piston.
See work card 2265-0301 and 2265-0401.

2. Taking liner measurements

Position the cylinder liner measuring tool.

For detailed information on taking cylinder wear measurements and assessing liner condition, *See description 2245-0100, item 4.5*

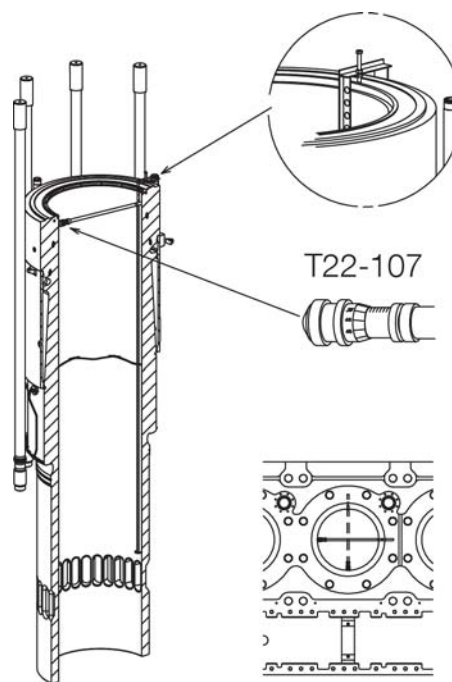
Check and assess the condition of the cylinder liner.

For new cylinder diameter, *See data T22-107.*

**WARNING**

If the piston is removed, mount the stuffing box cover before measuring the liner.

If it is necessary to use a ladder, use one in good condition, with rubber ends and a hook to ensure standstill.



2265-0601-0004C02

3. Piston cleaning (PC) ring

When removing the piston cleaning (PC) ring between the liner and the cylinder cover, make sure to mark the position of the ring to allow fitting of the PC-ring in the same position as it is worn together with the liner.

The PC-ring is to be regarded as an integrated part of the liner and it is intended to follow the service life of the liner.

During inspection of the piston and the liner, the PC-ring must also be inspected.

For the piston cleaning ring measurements, *Data T22-108 and T22-109*

NOTICE

- If the PC-ring is undamaged, re-mount the PC-ring in the cylinder liner in the original position (Scratch marks, made before removal, must align).
- If the PC-ring is broken or cracked and the cylinder liner wear (measured **by the skirt TDC position**, i.e. by the liner measuring point No. 5) is **below** 0.1% of the nominal diameter, replace the PC-ring with a new standard PC-ring.
- If the PC-ring is broken or cracked **and** the cylinder liner wear is **above** 0.1% of the nominal diameter, contact MAN Diesel & Turbo.

When a new cylinder liner is installed, a new PC-ring must also be installed.
When a new liner is ordered, a new PC-ring must also be ordered.

1. Preparations

Dismantle the cylinder cover.
See work card 2265-0301.

Discard the gasket (mild steel ring) from the top of the cylinder liner.

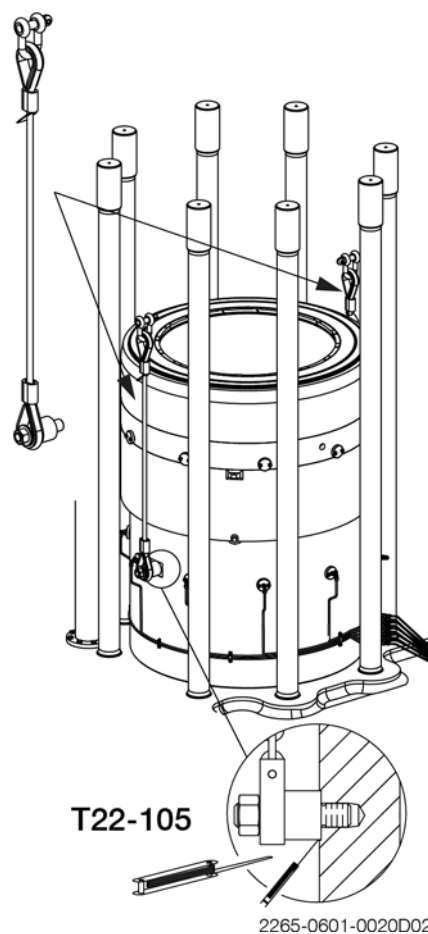
Dismantle the piston cleaning ring and the piston.
See work card 2265-0401.

2. Lifting tools

Screw the lifting tool chain/wire into the cylinder liner and hook the chain/wire to the crossbar.

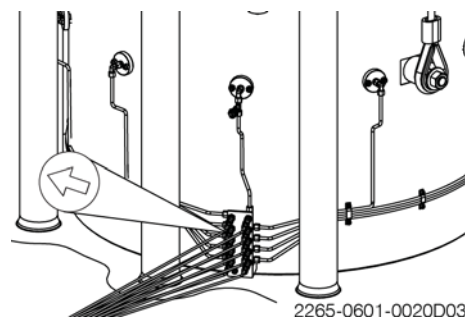
NOTICE

The actual lifting tool can have two designs. In some cases the tool is not made of chain, but can also be made of a single, solid wire. The procedure for use of the two tools is though exactly the same.



3. Lubricator pipes

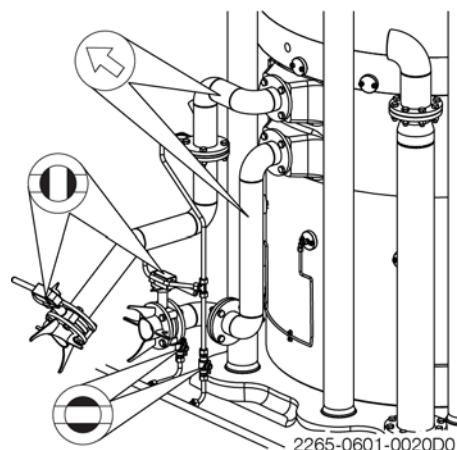
Disconnect the oil pipes leading from the cylinder lubricator to the cylinder liner.



4. Cooling pipes

Close the valves and open the drains as necessary.

Dismount the liner cooling pipes.



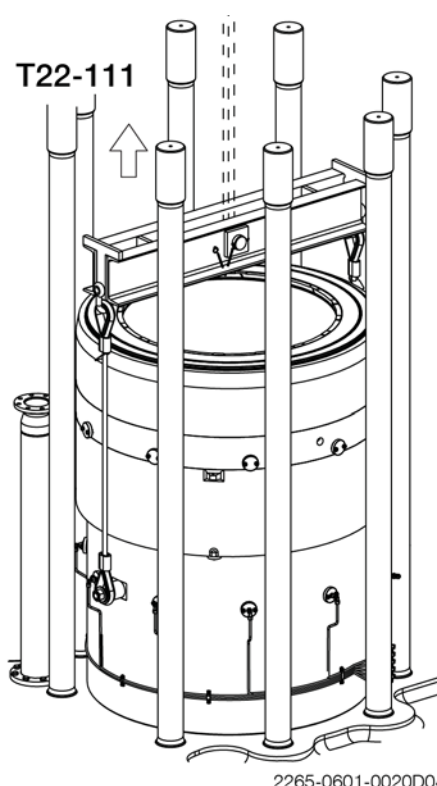
5. Remove the liner

Carefully lift the cylinder liner out of the cylinder frame.

NOTICE**Low lifting height**

Low lifting height in the engine room may require the removal of one or more cylinder cover studs before dismantling the cylinder liner.

Land the cylinder liner vertically on, for instance, a couple of planks.



6. Cylinder frame

Clean the cylinder frame internally, taking special care with the contact surfaces for the cylinder liner at the top of the cylinder frame.

The lifting tools are also used for transporting the cylinder liner.

1. Before removing the cooling jacket
Remove the non-return valves for the cylinder liner lubrication, including the "dummy" valves below the cooling jacket.

If not already done, remove the cylinder liner lifting tool.

Hook the engine room crane on to the crossbar and attach two tackles to the crossbar, as shown.

**WARNING****Safe working load (SWL)**

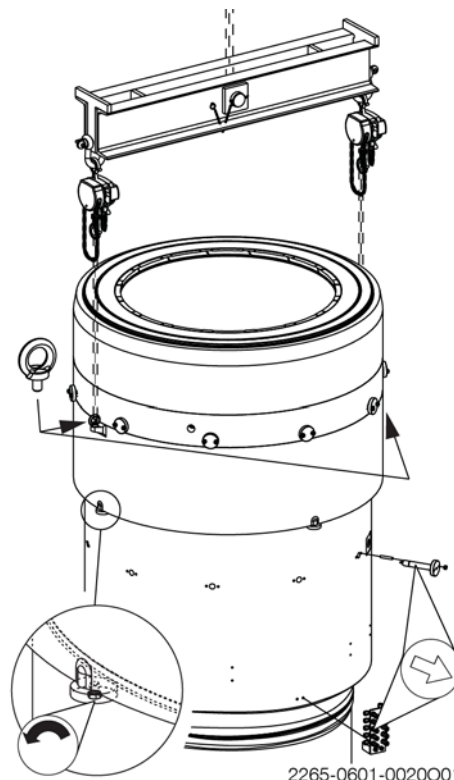
Always use lifting gear with sufficient SWL.
See data.

Mount two lifting eye bolts in the cooling jacket.

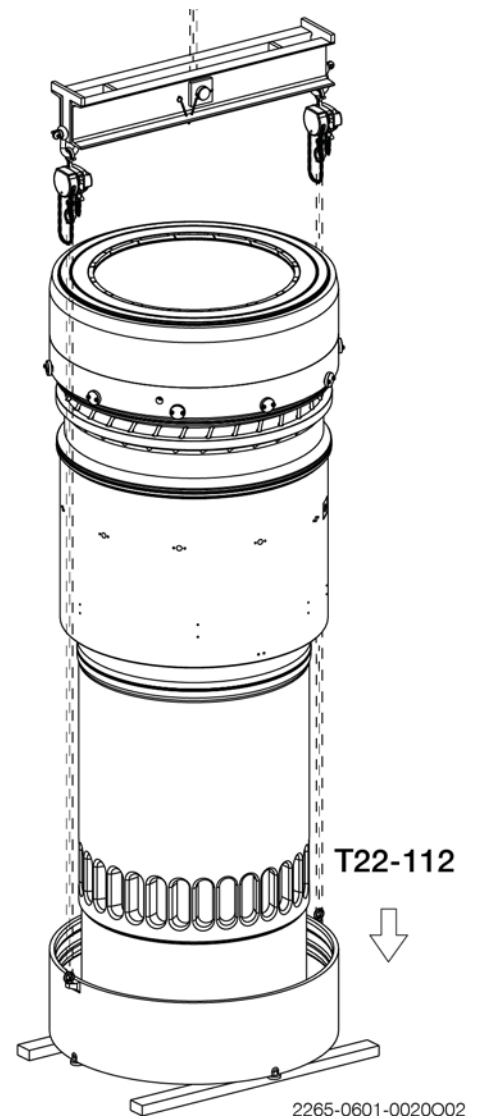
Hook the tackles on to the lifting eye bolts on the cooling jacket and haul tight.

Loosen the screws on the clamps which fix the cooling jacket to the cylinder liner.

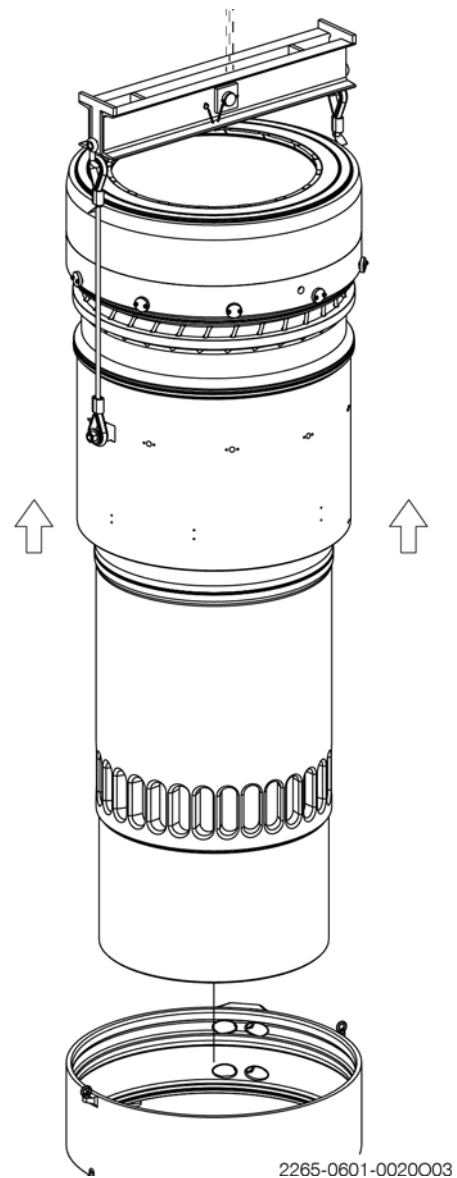
Turn the clamps away from the liner.



2. Remove the cooling jacket
Lower the cooling jacket by means of the tackles and land it on the wooden planks.



3. Moving the cylinder liner from the cooling jacket
- Remove and discard all O-rings.
Re-mount the lifting tool.
- Hook the chains from the lifting crossbar on to the lifting tools.
- Lift the cylinder liner away from the cooling jacket.
- Clean the cooling jacket internally.



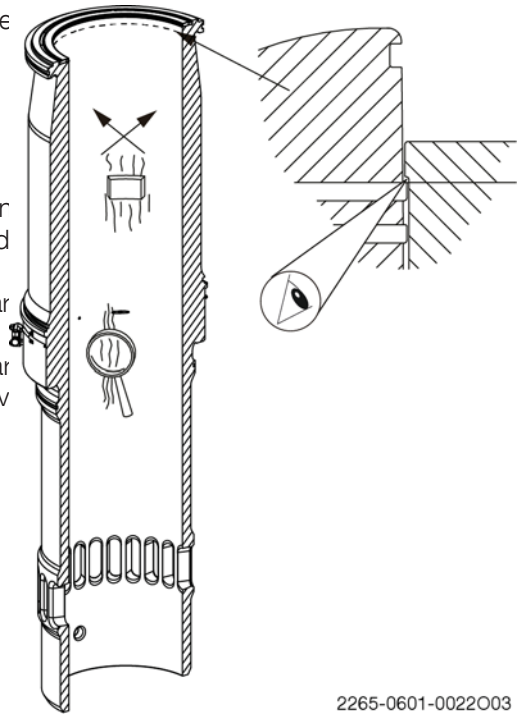
4. Inspect the liner

Check and assess the condition of the cylinder liner.

See description 2245-0100.

Remove any scores or marks on the cylinder liner running surface, by means of a rough grindstone held in the hand

Check in the top of the liner for a wear ridge (where the piston rings reverse direction). If there is any sign of a wear ridge, it is necessary to create a groove by grinding. The groove serves to prevent the build-up of a new wear ridge.

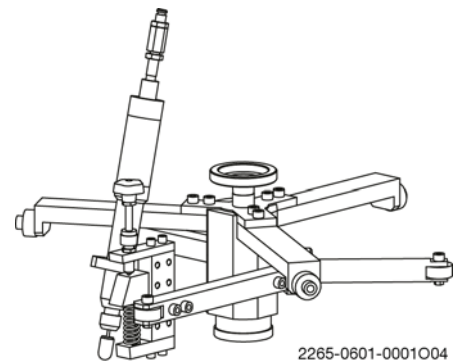


2265-0601-0022003

5. Creating the groove

It is recommended to use a wear ridge milling machine to create the groove.

For use of the milling machine, see supplier's instruction.



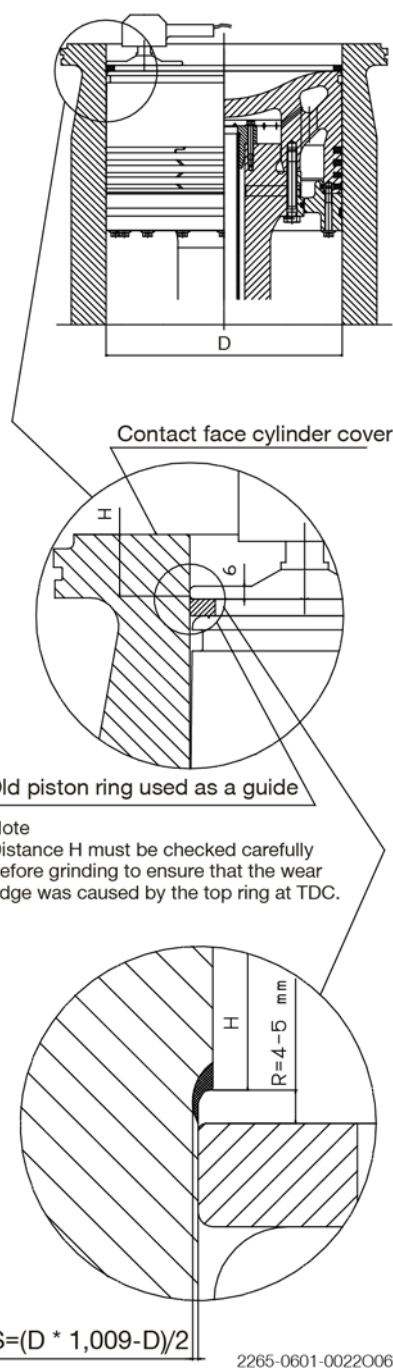
2265-0601-0001004

6. Alternate groove

Alternatively, place an old piston ring on the top of the piston and turn to a position that enables the grinding disc to rest on the old piston ring while removing the wear ridge. Use a grinding disc with a round edge.

NOTICE

It is of utmost importance that the groove is made with a regular rounding as shown in the sketch.

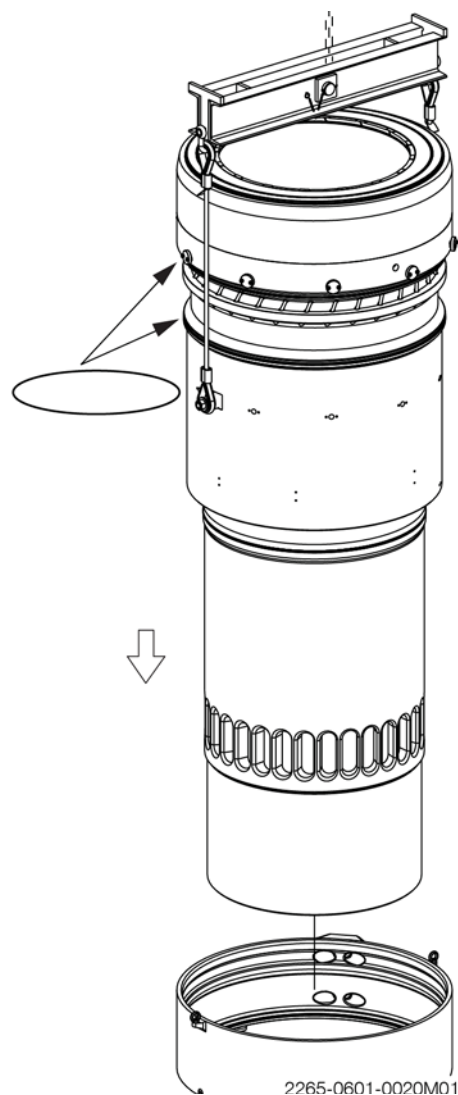


7. Returning the cooling jacket to liner
- Apply a thin layer of grease on the contact surface for the cooling jacket on the liner.

If the lifting tool set-up has been removed, it must now be re-mounted.

Lift the liner a little and mount new O-rings for the cooling jacket.

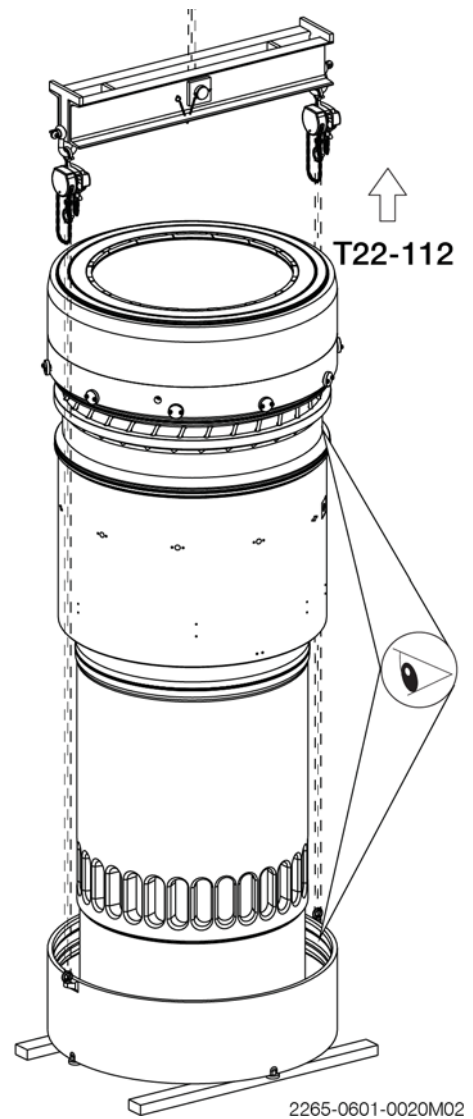
Then place the liner in the cooling jacket.



8. Mount the cooling jacket
Using the crossbar and two tackles, lift the cooling jacket into position.

NOTICE

Make sure that the scratch marks in the manoeuvring side of the cylinder liner and cooling jacket coincide.

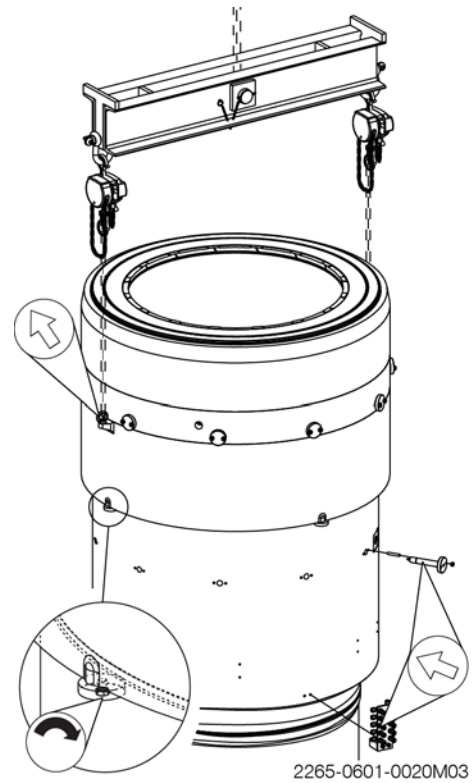


9. Fasten the cooling jacket and mount non return valves.

Turn the clamps into position in the groove of the liner, and tighten the screws.

Remove the tackles and the eye bolts from the cooling jacket.

Mount the non-return valves (and dummy valves) for the cylinder liner lubrication and connect the piping.

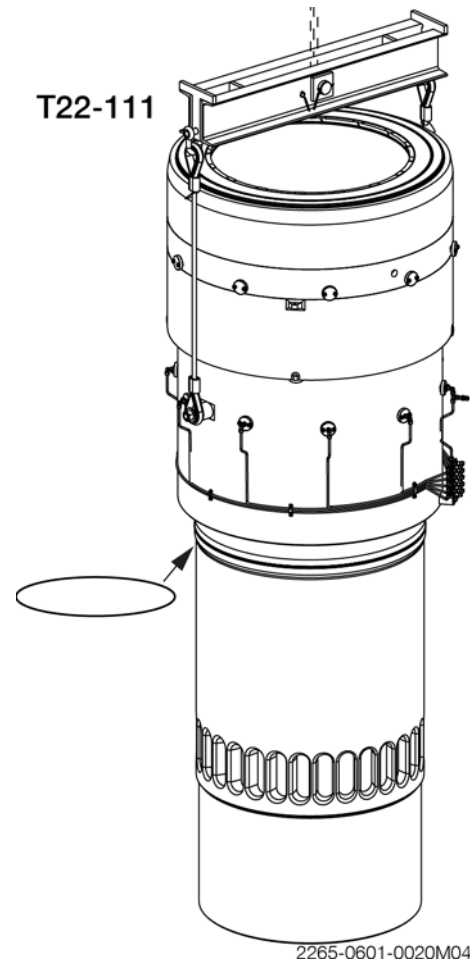


1. Prepare for lift

Mount the lifting tool on the cylinder liner.
For lifting tool screws tightening torque,
See data T22-105.

Hook the chains from the lifting crossbar
on to the lifting tools, and lift the jacket/
liner assembly.

Mount the lowermost O-ring and apply a
little lubricating oil on the ring.

T22-111

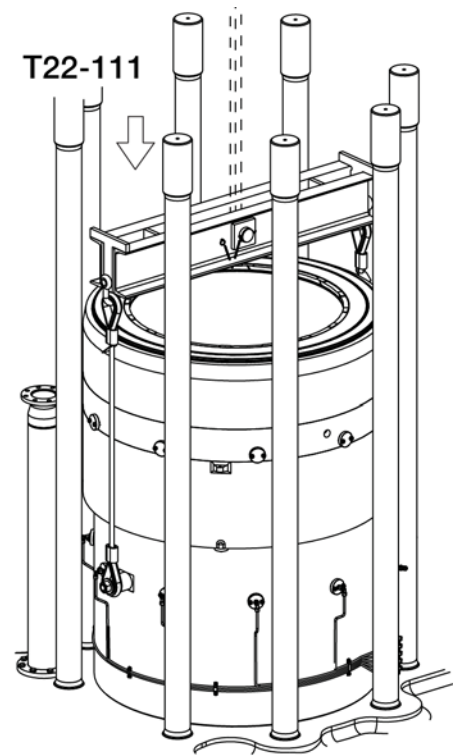
2. Mount the liner

Check that the joint surfaces on the cylinder frame and cylinder liner are completely clean.

Coat the joint surfaces with Permatex or a similar liquid sealing compound.

Mount the cylinder liner in the cylinder frame.

Unscrew and remove the lifting tools.



2265-0601-0020M05

3. Studs

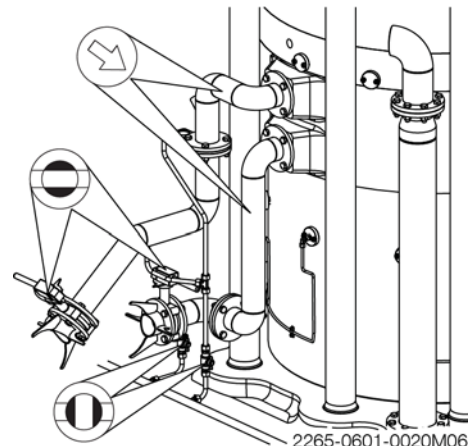
If one or more cylinder cover studs have been removed during the dismantling of the cylinder cover, remount the studs using the stud setter.

See work card 2265-0301.

4. Cooling pipes

Mount the cooling pipes and mount new gaskets between the cooling water pipes and the cooling jacket.

Close the drain and open the valves



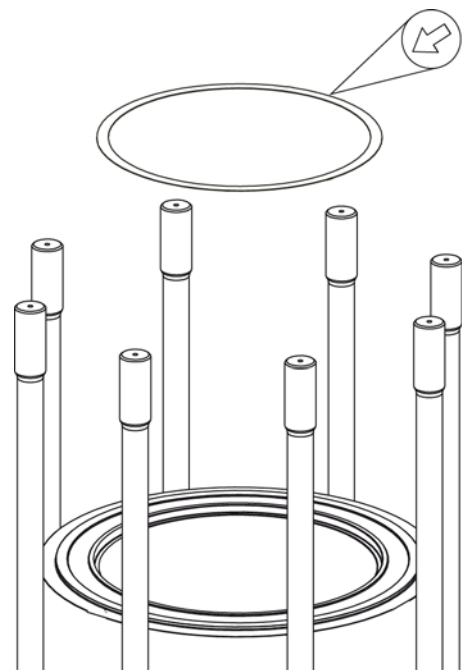
2265-0601-0020M06

5. Mount the piston and cylinder cover
Lubricate the inside of the cylinder liner with cylinder lubricating oil and mount the piston and the piston cleaning ring.
See work card 2265-0401.

Mount the gasket (mild steel ring) and the cylinder cover.
See work card 2265-0301.

NOTICE

Do not apply any kind of lubricant to the gasket (mild steel ring).



2265-0601-0017M06

6. Lubricator pipes

Connect and tighten the oil pipes for the cylinder lubrication.

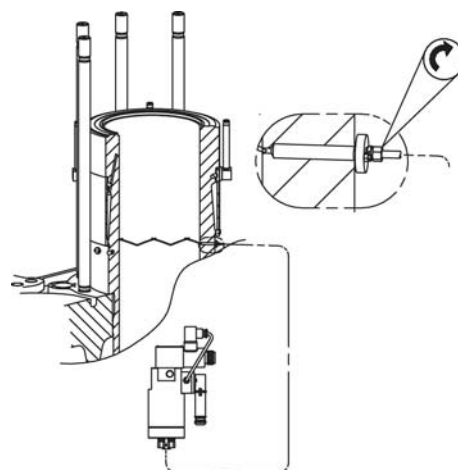
Activate the Lubricator test sequence on the MOP for the pertaining cylinder.

See description 6645-0260 'Cylinder Lubricators'.

Vent the cylinder lubricating system by loosening the unions at the non-return valves until oil, without air bubbles, comes out from the pipes.

**Oil spray risk**

Use eye protection when venting the pipes.



2265-0601-0002M05

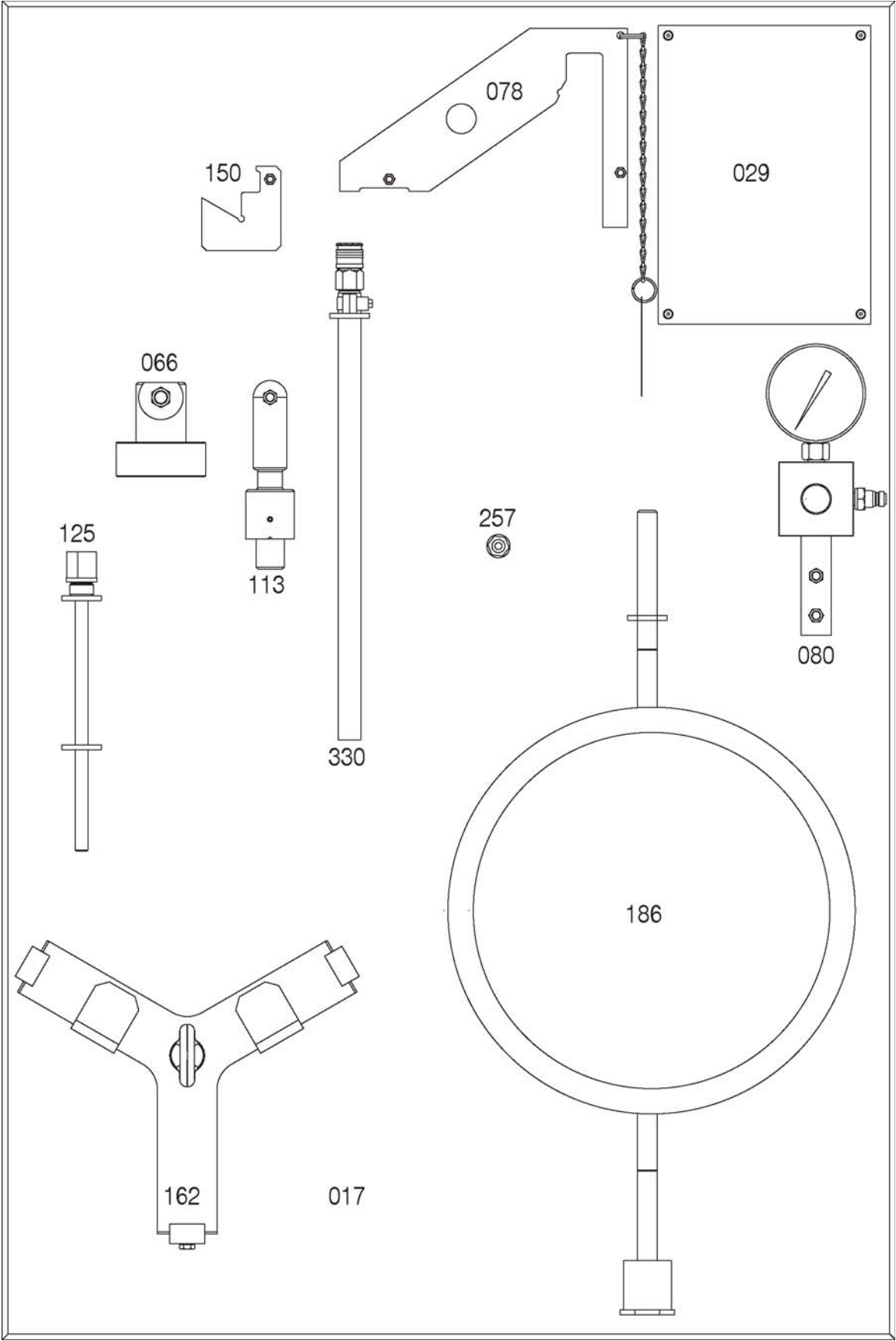
Tighten the unions.

Check that there is no leakage from the system.

Check that each individual lubricating point functions correctly by making a scavenge port inspection. Check that oil comes from each lubricator point.

See work card 3065-0601.

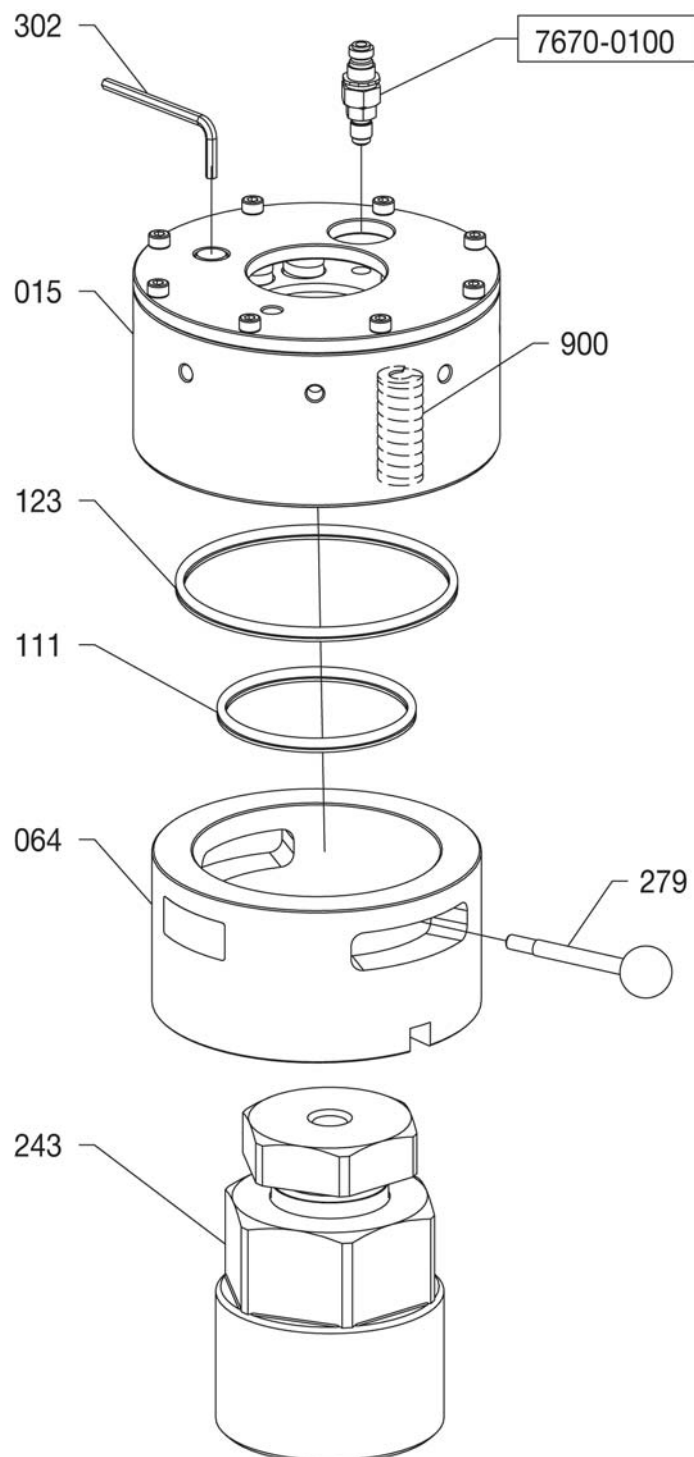
Stop the Lubricator test sequence on the MOP.



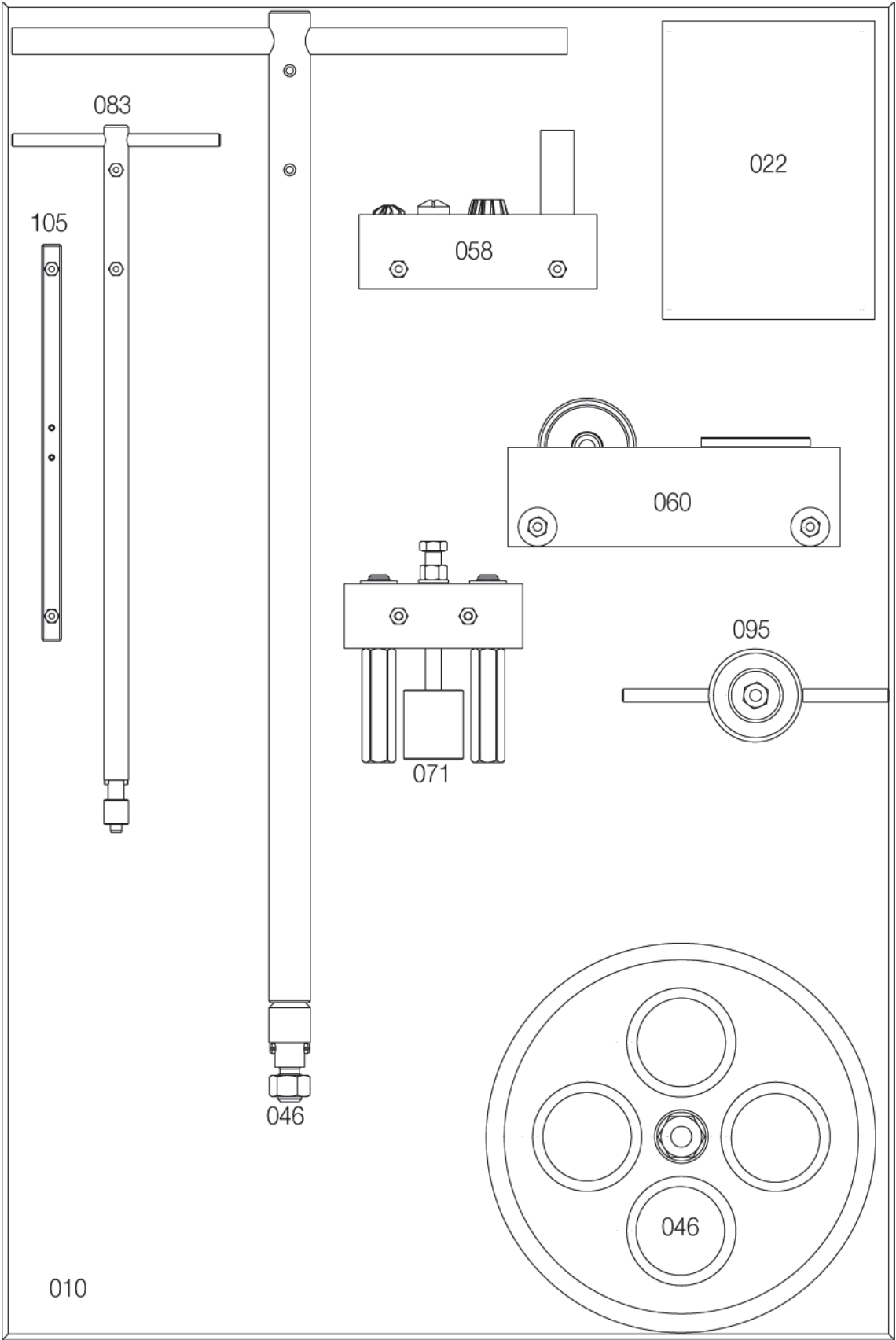
Exhaust Valve Panel Tools

Plate
2270-0200-0042

Item No.	Qty	Item Designation
017	-	Tools on panel
029	-	Name plate
066	-	Lifting tool for exhaust valve
078	-	Gauge for exhaust valve spindle
080	-	Test equipment for exhaust valve
113	-	Grinding tool for high pressure pipe
125	-	Tool for emergency opening of exhaust valve
150	-	Gauge for exhaust valve bottom piece
162	-	Lifting tool for exhaust valve
186	-	Grinding ring for exhaust valve bottom piece
257	-	Coupling
330	-	Hose with 1 coupling



Item No.	Qty	Item Designation
015	-	Hydraulic jack, complete
064	-	Support for hydraulic jack
111	-	Sealing and back up ring
123	-	Sealing and back up ring
243	-	Stud setter
279	-	Ball handle
302	-	Hex key
900	-	Spring

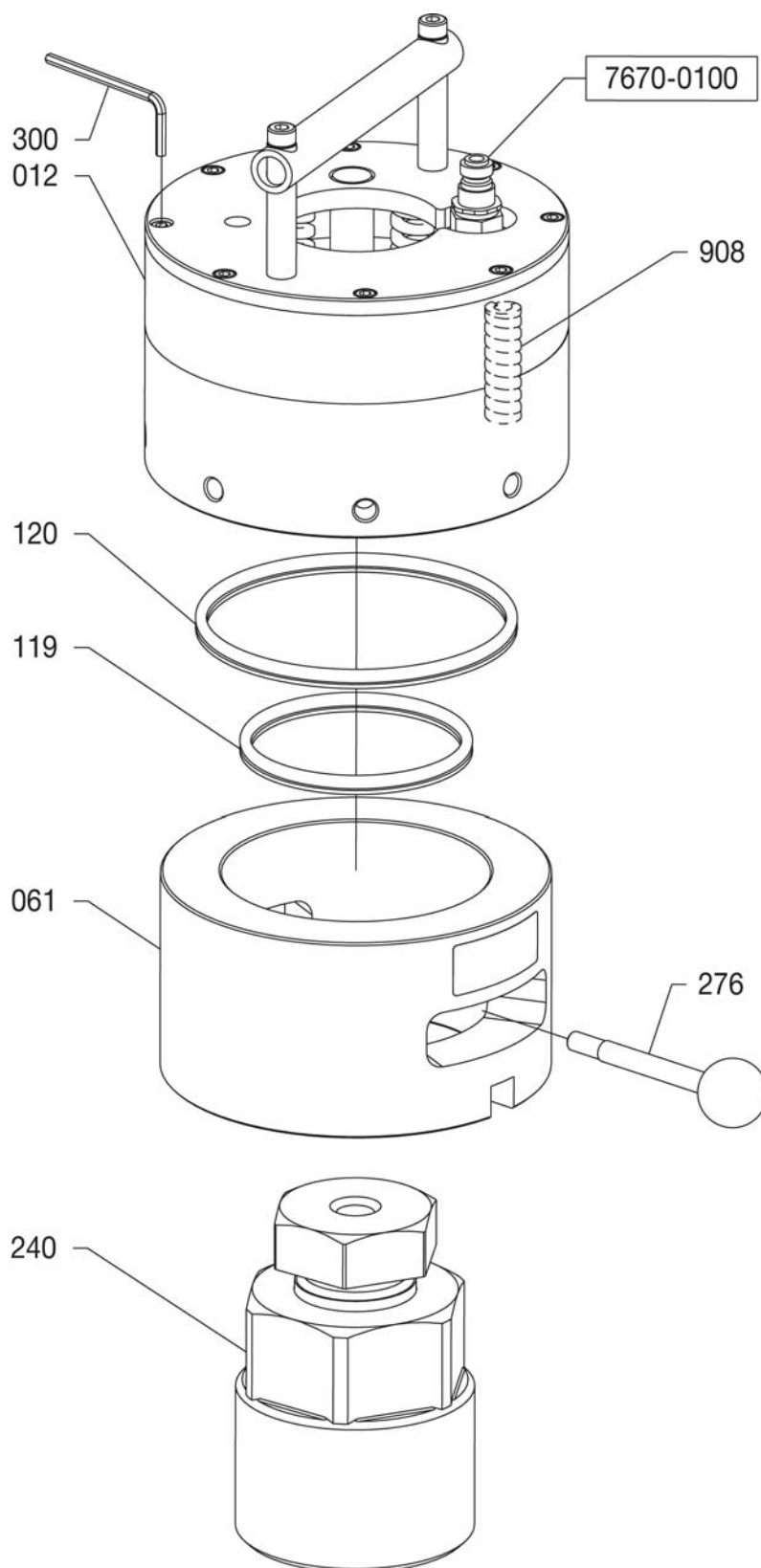


Cylinder Cover Panel Tools

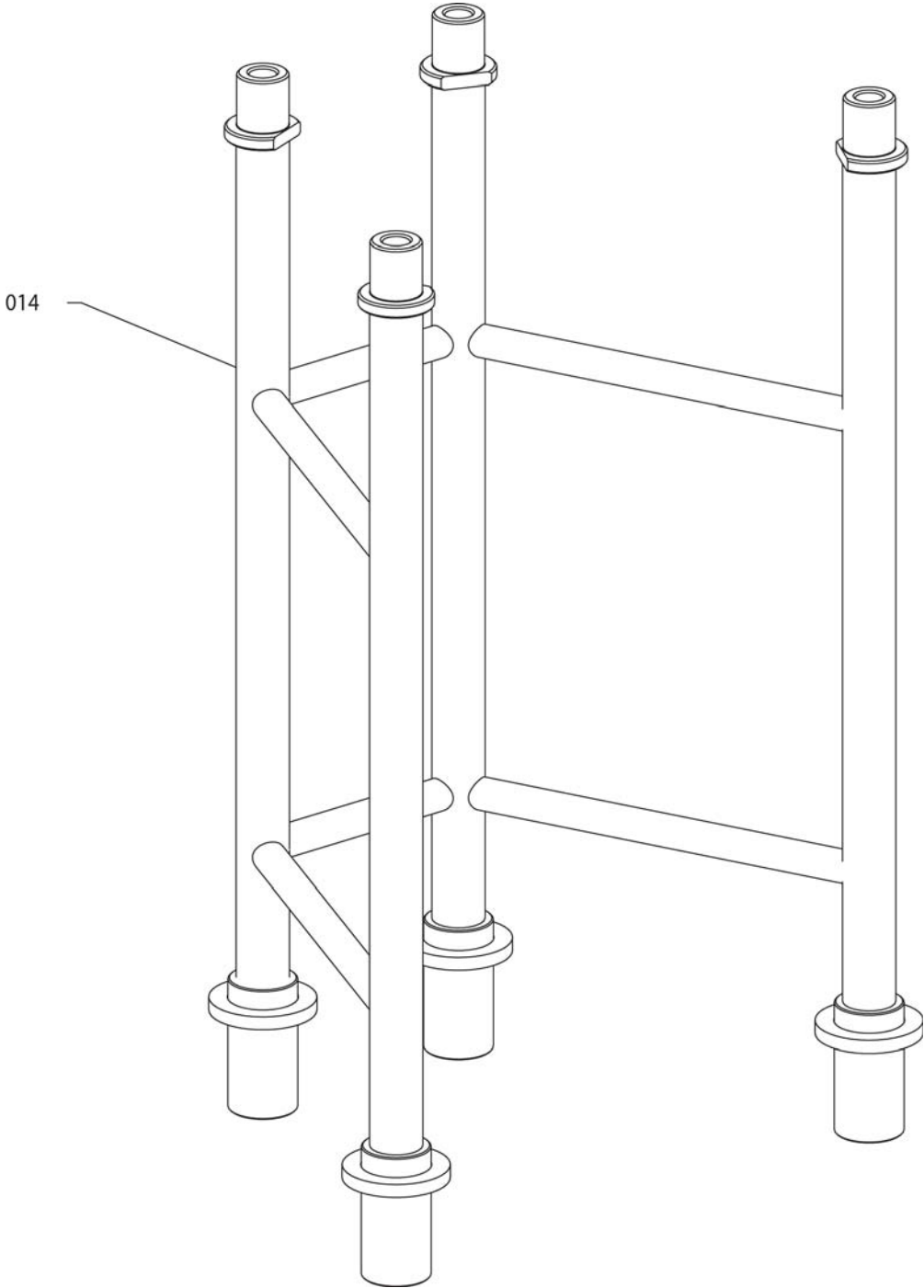
Plate

2270-0300-0014

Item No.	Qty	Item Designation
010	-	Panel for tools
022	-	Name plate
046	-	Grinding tool for exhaust valve seat
058	-	Milling and grinding wheel for fuel valve
060	-	Milling and grinding wheel for starting valve
071	-	Dismantling lever for fuel valve
083	-	Handle, sundry types
095	-	Grinding ring for starting valve
105	-	Pin wrench for starting valve



Item No.	Qty	Item Designation
012	-	Hydraulic jack,complete
061	-	Support for hydraulic jack
119	-	Sealing and back-up ring
120	-	Sealing and back-up ring
240	-	Stud setter
276	-	Ball handle
300	-	Hex key
908	-	Spring



Cylinder Cover Support Tools

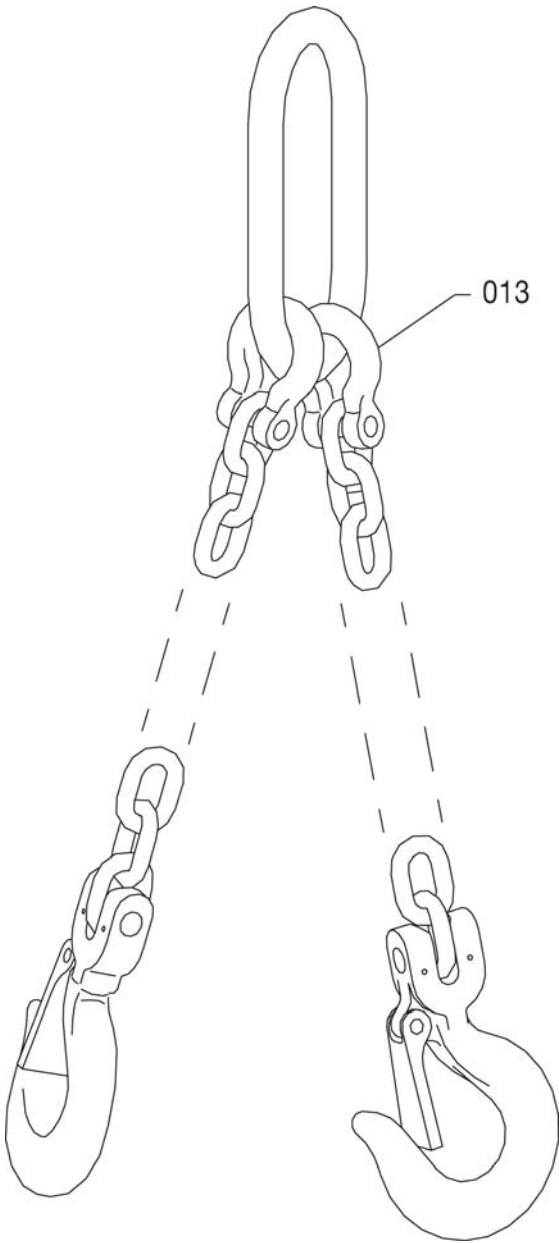
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2270-0330-0005

Cylinder Cover Support Tools

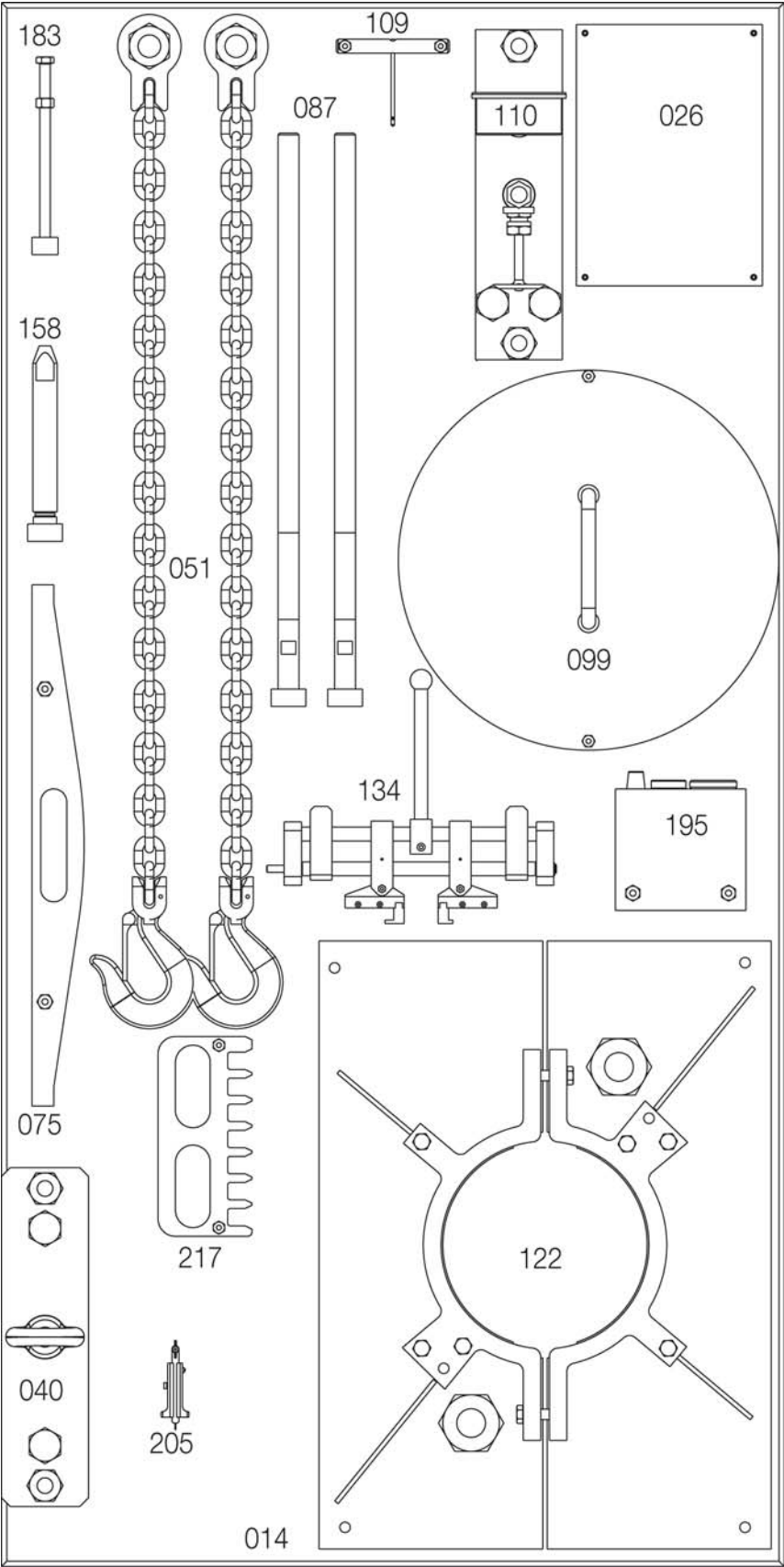
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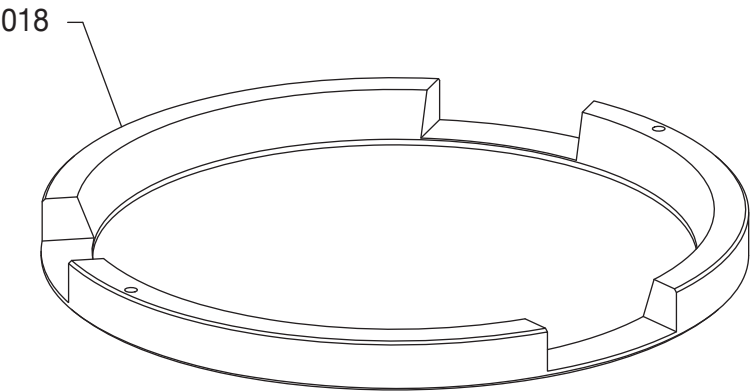


Piston Panel Tools

Plate

2270-0400-0035

Item No.	Qty	Item Designation
014	-	Panel for tools
026	-	Name plate
040	-	Lifting tool for piston rod foot
051	-	Lifting tool for cylinder liner
075	-	Template for piston top
087	-	Distance piece for stuffing box
099	-	Cover for stuffing box hole
109	-	Mounting tool for stuffing box spring
110	-	Pressure test tool for piston
122	-	Worktable for stuffing box
134	-	Piston ring expander
158	-	Guide screw for piston crown
183	-	Pulling tool for stuffing box
195	-	Pushing tool for seals
205	-	Slide caliper
217	-	Gauge stuffing box

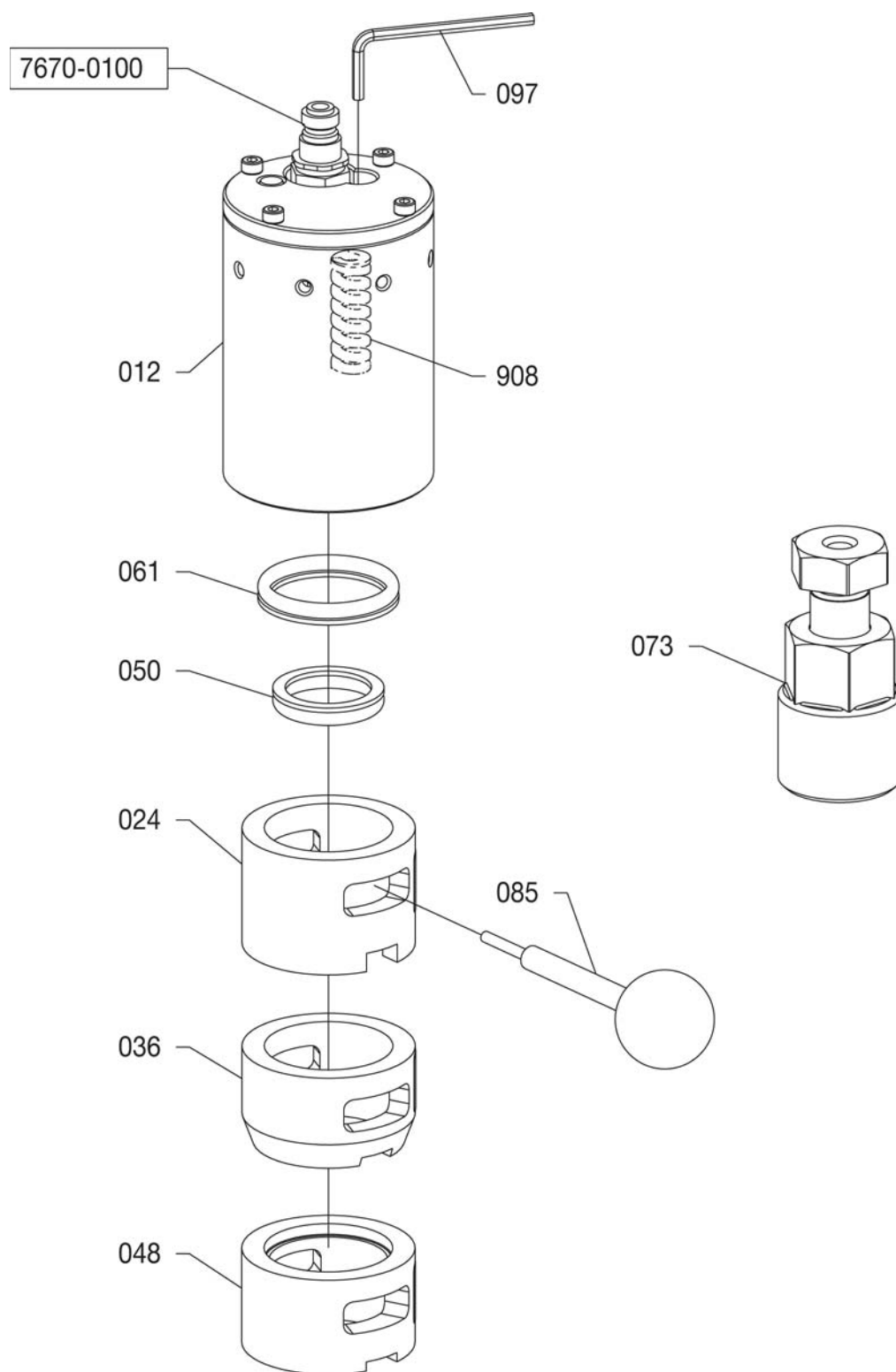


Piston Guide Tool

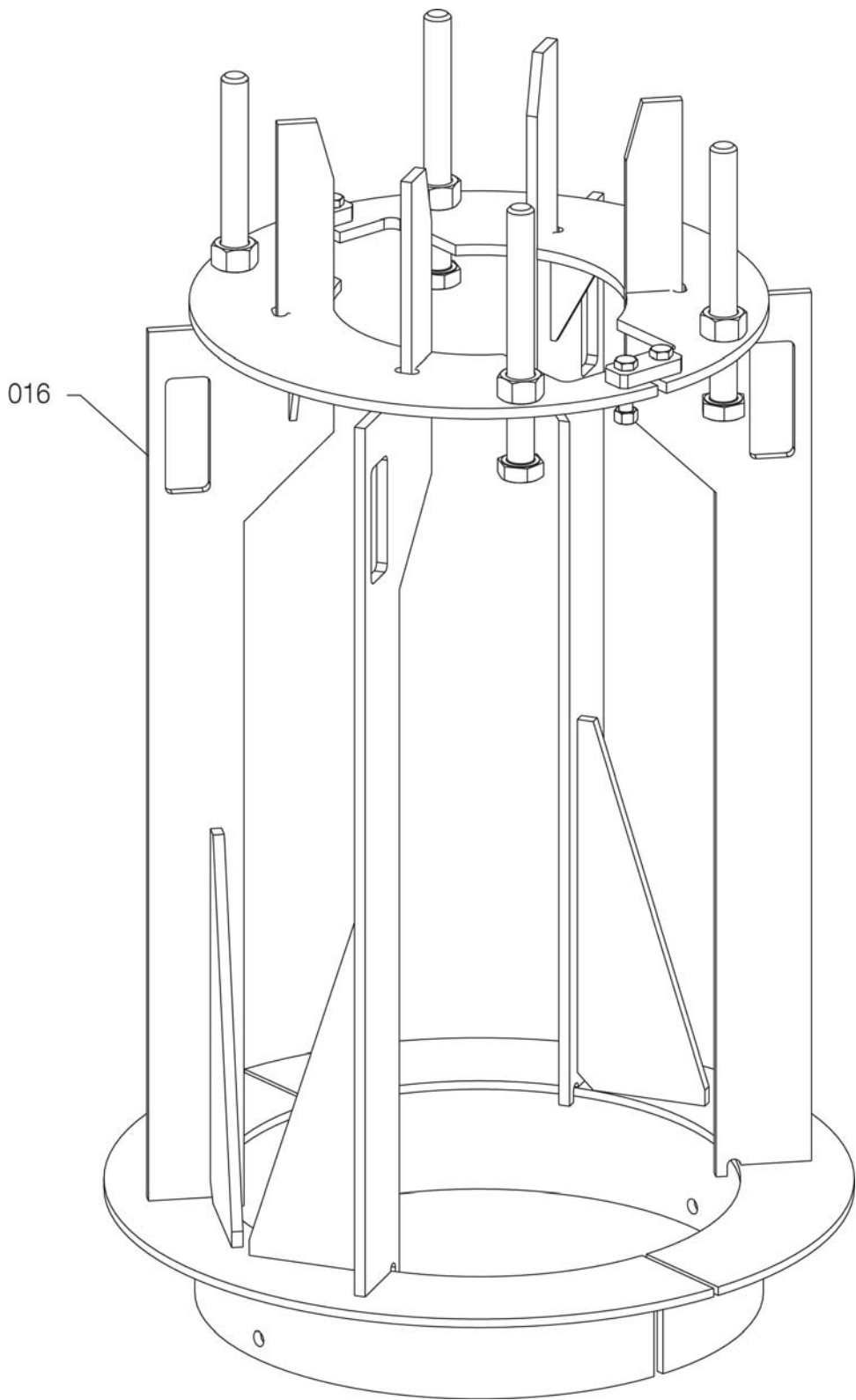
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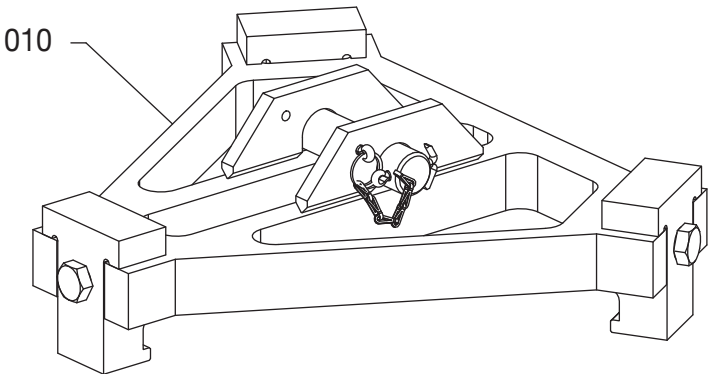
Item No.	Qty	Item Designation
012	-	Hydraulic jack, complete
024	-	Support for hydraulic jack
036	-	Support for hydraulic jack
048	-	Support for hydraulic jack
050	-	Sealing and back-up ring
061	-	Sealing and back-up ring
073	-	Stud setter
085	-	Tommy bar
097	-	Hex key
908	-	Spring



Piston Support Tools

Plate
2270-0470-0010

2013-02-25 - en

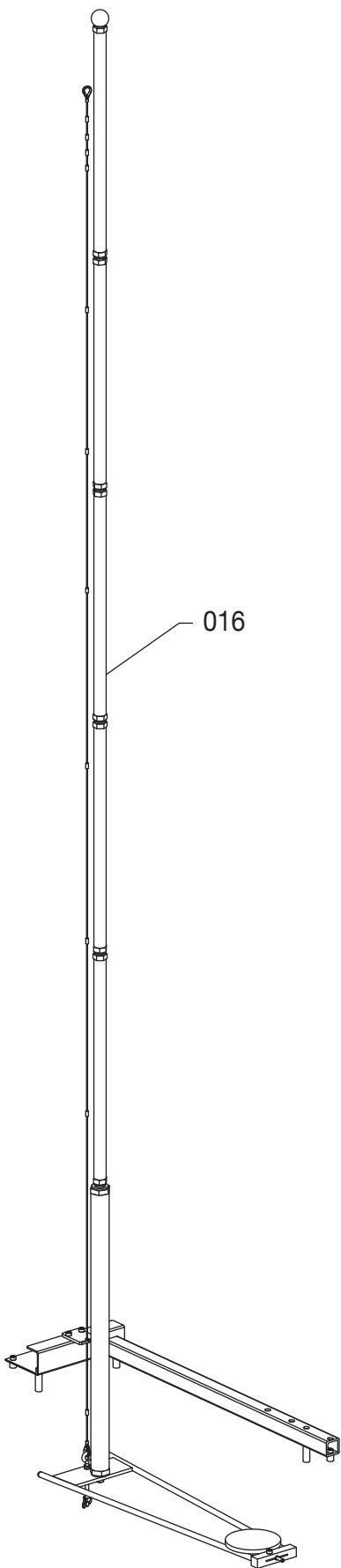


Piston Lifting Tools

Plate

2270-0480-0001.0

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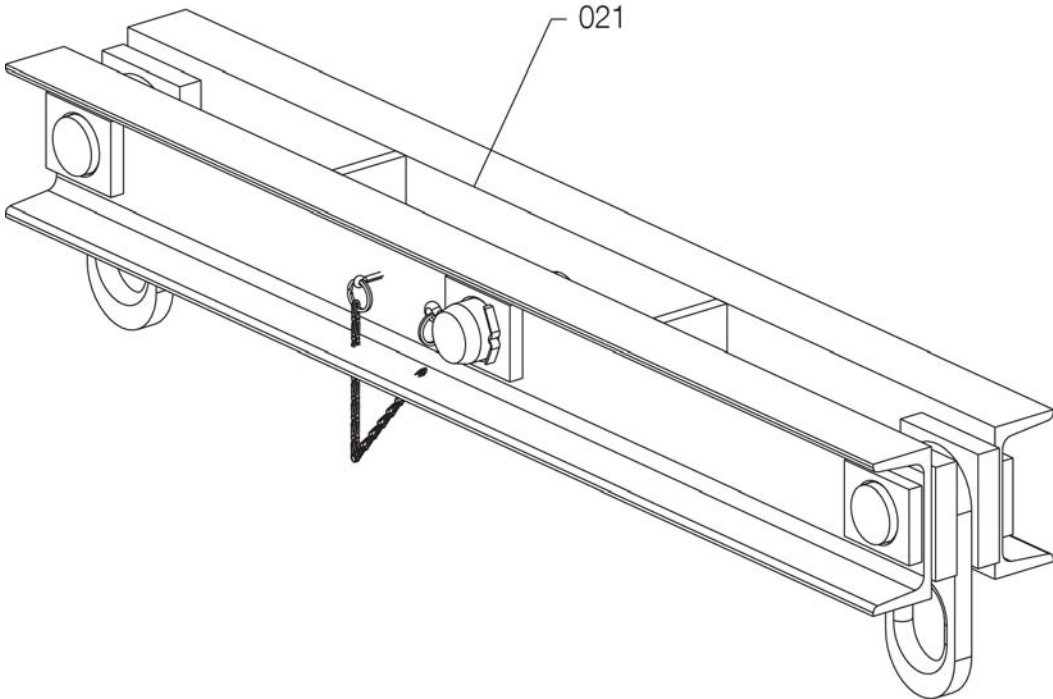


Cylinder Liner Tools

Plate

2270-0610-0001.0

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Crosshead Bearing

The crosshead is equipped with steel shells lined with bearing metal. The lower shell is provided with an overlay coating.

Main Bearing

The main bearings consist of steel shells, lined with bearing metal.

Thrust Bearing

The thrust bearing serves the purpose of transmitting the axial thrust of the propeller through propeller shaft and intermediate shafts to the ship's hull.

The crankshaft is provided with a thrust collar which transmits the thrust to a number of segments mounted in a thrust shoe on either side of the thrust collar.

The thrust shoes rest on surfaces in the thrust bearing housing and are held in place by means of stoppers or cross bars. The segments have white metal cast onto the wearing faces against the thrust collar. *See also Description 2545- 0100.*

The thrust bearing is lubricated by the pressure lubrication system of the engine. The oil is supplied between the segments through spray pipes and spray nozzles.

The thrust bearing is provided with alarm, slowdown, and shutdown devices for low lube oil pressure and high segment temperature. *See also Description 7045-0100.*

Stationary engines and geared marine plants:

The crankshaft is provided with a collar for the guide bearing. The purpose of the guide bearing is to keep the crankshaft in its proper position in the axial direction.

1 General bearing requirements and criteria for evaluation

Bearings are vital engine components; therefore, bearing design and choice of bearing metal is crucial for reliable engine performance.

Bearing design criteria depend on the bearing type and, in general, on:

1. Bearing load
 - Static
 - Dynamic
2. Bearing load direction
3. Journal Orbit
4. Revolutions
5. Cooling
6. Expected lifetime
7. Overhaul aspects
8. Space aspects

The compactness of engines and the engine ratings (gas pressure, engine speed and stroke/bore) influence the magnitude of the specific load on the bearing and make the correct choice of bearing metals, construction, production quality and, in certain bearings, the application of overlayer necessary. (*See item 3., 'Overlayers'.*)

2 Bearing metals

2.1 Tin-based white metal

Tin-based white metal is an alloy with minimum 88% tin (Sn), the rest of the alloy composition is antimony (Sb), copper (Cu), cadmium (Cd) and small amounts of other elements that are added to improve the fineness of the grain structure and homogeneity during the solidification process. This is important for the load carrying and sliding properties of the alloy. *Lead (Pb) content in this alloy composition is an impurity, as the fatigue strength deteriorates with increasing lead content, which should not exceed 0.2 % of the cast alloy composition.*

2.2 Tin-aluminium (AlSn40)

Tin aluminium is a composition of aluminium (Al) and tin (Sn) where the tin is trapped in a 3-dimensional mesh of aluminium. AlSn40 is a composition with 40% tin. The sliding properties of this composition are very similar to those of tin-based white metal but the dynamic loading capacity of this material is higher than tin-based white metals at similar working temperature. This is due to the ideal combination of tin and aluminium, where tin provides good embeddability and sliding properties, while the aluminium mesh functions as an effective load absorber.

3 Overlayers, coatings and running-in layers

An overlayer is a thin galvanic coating of mainly lead (Pb), copper (Cu) and tin (Sn), which is applied directly on to the white metal or, via a thin galvanically applied intermediate layer of either Ag or Ni, on to the tin aluminium sliding surface of the bearing. The overlayer is a soft and ductile coating, its main objective is to ensure good embed ability and conformity between the bearing sliding surface and the pin surface geometry. Overlayer is mainly used in crosshead bearing design.

4 Flashlayer, tin (Sn)

A flash layer is a 100% tin (Sn) layer which is applied galvanically; the thickness of this layer is only a few μm . The coating of tin flash is applied all over and functions primarily to prevent corrosion (oxidation) of the bearing. The tin-flash also functions as a dry lubricant when new bearings are installed and when the crankshaft is turned.

5 Bearing design

See drawings 2555-0100/0105/0110/0115.

Plain bearings for engines are manufactured as steel shells with a sliding surface of white metal or tin-aluminium with or without overlayer/flash layer. Tin-aluminium bearings are always of the thin shell design while the white metal bearings can either be of the thick shell or thin shell design.

The bearing surface is furnished with a centrally placed oil supply groove and other design features such as *smooth run-outs, oil wedges and/or bore reliefs*.

5.1 Smooth runout of oil groove

See drawings 2555-0100/0105/0115, Fig. B-B.

A smooth runout is the transition geometry between the circumferential oil supply groove and the bearing sliding surface. This special oil groove transition geometry prevents an oil scraping effect and enhances the hydrodynamic build-up of the load-carrying oil film towards the loaded area of the bearing (*Main bearing drawings 2555-0100 and 2555-0105 and crankpin bearing drawing 2555-0115*).

5.2 Bore relief

See drawings 2555-0100/0105/0115, Fig. A-A.

The bearing sliding surface is machined near the mating faces of the upper and lower shells to create bore reliefs. Their main objective is to compensate for misalignments which could result in a protruding edge (step) of the lower shell's mating face to that of the upper shell. Such a protruding edge can act as an oil scraper and cause oil starvation. (*Main bearing drawing 2555-0100 and 2555-0105 and crankpin bearing drawing 2555-0115*).

5.3 Axial oil grooves and oil wedges

See drawings 2555-0110 and 2555-0125.

Oil grooves and wedges have the following functions:

1. To enhance the oil distribution over the load carrying surfaces. (The tapered areas give improved oil inlet conditions).
2. Especially in the case of crosshead bearings (drawing 2555-0110) - to assist the formation of a hydrodynamic oil film between the load carrying surfaces.
3. To provide oil cooling (oil grooves).

In order to perform these functions, the oil must flow freely from the lubricating grooves, past the oil wedges, and into the supporting areas - where the oil film carries the load.

5.4 Thick shell bearings

See drawing 2555-0100.

This type of bearing has a steel back with the required stiffness.

1. to ensure against distortion of the sliding surface geometry, and
2. to support the cast-on white metal in regions where the shell lacks support, for example in the area of the upper shell mating faces.

The top clearance in this bearing design is adjusted with shims, while the side clearance is a predetermined result of the summation of the housing bore, shell wall thickness, journal tolerances, and the influence of the staybolt and bearing stud tensioning force which deforms the bedplate around the bearing assembly.

Thick shell bearings are typically 30-60 mm thick and used for main bearings only.

5.5 Thin shell bearings

See drawing 2555-0105.

Thin shell bearings have a wall thickness between 2% and 2.5% of the journal diameter. The steel back does not have the sufficient stiffness to support the cast-on bearing metal alone. The bearing must therefore be supported rigidly over its full length. This type of bearing is manufactured with a circumferential oversize (crush/nip) which, when the shells are mounted and tightened up, will produce the required radial pressure between the shell and the bearing housing.

Thin shell bearings are also made as blended edge design. The blended edge design is a smooth radius that allows the main bearing shaft to incline without risk of touching the bearing edge or causing high oil film pressure at the edge. The blended edge is described by two dimensions, length and depth. The actual values depend on the engine size and configuration. Drawing 2555-0105 Fig. 2

shows an example of a blended edge. With a good blended edge design, the high edge load can be reduced and distributed over a larger area, thus resulting in a decreased max. oil film pressure and increased safety against edge fatigue failure.

NOTICE**Different bearing shells**

Bearing shells can be with or without blended edge and must never be switched between the bearings.

The top and side clearance in this bearing is predetermined and results from a summation of the housing bore, shell wall thickness, journal/pin diameter tolerances and, for main bearings, the deformation of the bedplate from the staybolt and bearing stud tensioning force.

5.6 Top clearance

Correct top clearance in main bearings, crankpin bearings, and crosshead bearings is a balance between sustaining the required oil flow through the bearing, hence stabilising the bearing temperature at a level that will ensure the fatigue strength of the bearing metal and having a geometry, which enhances a proper oil film build-up and maintenance.

Too high top clearance is often the cause of fatigue cracks.

The bearings are checked in general by measuring the top clearances.

In service, top clearance measurements can be regarded:

1. as a check of the correct reassembly of the bearing. For **new** bearings the clearances should lie within the limits specified in the maintenance manual.
2. as an indicator to determine the condition of the bearing at a periodic check without opening up, *see item 7.1, 'Check without Opening up'.*

In both cases, it is vital that the clearance values from the previous check are available for comparison. Therefore, it is necessary to enter clearances in the engine log book with the relevant date and engine service hours (*see for example, drawing 2555-0140 page 5*).

The initial clearances can be read from the testbed results.

5.7 Wear

Bearing wear is negligible under normal service conditions, *see item 7.8, 'Bearing Wear Rate'.* Excessive wear is due to abrasive or corrosive contamination of the system oil which will affect the roughness of the journal/pin and increase the wear rate of the bearing. The so-called spark erosion phenomenon (See item 6.2), will lead to highly increased main bearing wear rates, particularly in case of AISn main bearing type.

5.8 Monitoring

The aim of monitoring engine bearings, is to avoid extensive damage to the engine. Monitoring in a wider perspective, has numerous good side-effects. One in particular is that the well known fact of possible contamination of internal engine parts, when opening up, is decreased. The systems described in the following are designed to monitor the engine bearings continuously using various techniques.

5.8.1 Bearing Wear Monitoring (BWM)

The aim of the BWM system is to detect a bearing damage before the lining (Babbitt or Tin-Aluminium) is worn away by lining scuffing (Tin-Aluminium), wiping, abrasive wear, melting out or extensive fatigue of the lining (Babbitt) and steel to steel contact occurs. However, the intended effect of the system is not to protect the bearing shells as such, but mainly to prevent consequential damage of the crankshaft and bedplate in case of severe bearing failures.

The principle of the BWM system is to measure the vertical position of the crosshead in bottom dead centre (BDC) (see drawing 2555-0136, projection which shows the crosshead and BWM sensor on the guide plane). The BWM system monitors all three principal crank-train bearings using two proximity sensors forward/aft per cylinder unit and is placed inside the frame box.

Targeting the guide shoe bottom ends continuously, the sensors measure the distance to the crosshead in BDC. Signals are computed and digitally presented to computer hardware, from which a useable and easily interpretable interface is presented to the user. The measuring precision is more than adequate to obtain an alarm well before steel-to-steel contact in the bearings occur.

In case of wear in a main bearing, in a crankpin bearing or in a crosshead bearing, this vertical position will reflect the wear. By appropriate signal processing following a Man Diesel & Turbo specification, the system delivers alarm or slow down relay output in the case of abnormal wear of one or more bearings. As such the system must be connected to the alarm and safety systems. *Also refer to checking and maintenance schedule 0760-0301.*

5.8.2 Bearing Temperature Monitoring System (BTM)

The BTM system continuously monitors the temperature of the bearings. The monitoring is performed either by measuring the temperature on the rear side of the bearing shell directly or by detecting the return oil from each bearing in the crankcase. If there is a specified temperature is recorded, either a bearing shell temperature or bearing oil outlet temperature, an alarm is raised. For shell temperature in main, crankpin and crosshead bearings two high-temperature alarm levels apply.

The first-level alarm is indicated in the alarm panel while the second level activates a slow down command. For oil outlet temperature in main, crankpin and crosshead bearings two high temperature alarm levels including deviation alarm apply. The first level of the high temperature/deviation alarm is indicated in the alarm panel while the second level activates a slowdown command.

5.8.3 Water in Oil Monitoring (WIOM)

Water content in the lubricating oil can be extremely damaging to engine bearings. If significantly exceeding the saturation point of a given system oil, typically max. 0.2 vol.%; for a short period up to 0.5 vol.%. This is particularly valid for Tin-Aluminium lined crosshead bearings featuring lead overlay as running layer. The higher the water content, the faster the wear rate.

The excessive water content will cause the lead overlay in crosshead bearings to corrode away rapidly. Main and crankpin bearings lined with Babbitt or Tin-Aluminium may also suffer irreparable damage from water contamination, but the damage mechanism would be different and not as acute.

The above scenario can be prevented by continuously monitoring eventual water contamination of the lubricating oil. For this purpose a Water In Oil Monitoring System is implemented in the engine lube oil system, continuously measuring the relative humidity in the system oil. A probe in the oil piping system transmits a signal to a unit, which calculates the humidity as Water Activity (aw). This method of calculation has the advantage of being independent of oil type, temperature or age. The system is connected to the alarm system.

5.8.4 Propeller Shaft Earthing Device

The Propeller Shaft Earthing Device, is a system designed to avoid so called spark erosion in the engine bearings and journals. The spark erosion phenomenon is a result of difference in electrical potential between metal parts. The level of electrical potential lies generally between 200 - 600 mV on engines without protection from a Propeller Shaft Earthing Device.

In some cases, it has been found that this difference in electrical potential between the hull and the propeller shaft has caused spark erosion on the main bearings and journals of the engine. To avoid this, a continuous electrical earthing circuit between the propeller and the ships structure, must be established. This circuit usually exists when the propeller is at rest, where a metal to metal contact is made between the shaft and the stern tube liners, or main engine bearings and journals.

However, while the shaft is turning the bearing oil film creates an intermittent high resistance which effectively insulates the propeller from the hull structure. Since the propeller presents a relatively large surface area of bare metal, it attracts cathodic protection currents, which tend to discharge by arcing across the bearing oil film. This can result in spark erosion which eventually leads to pitting and 'striping' of white metal bearing surfaces.

In order to reduce the potential between the propeller shaft (crankshaft) and the hull (engine structure), thus protecting the engine, an earthing device is installed on the intermediate shaft, *see drawing 2555-0137*. The plate shows the principal components of a Propeller Shaft Earthing Device. As a Condition Monitor a voltmeter is installed to ensure a continuous display of the shaft/hull potential. The reading is not to exceed 50 mV. Readings in excess of this value (Alarm limit = 80 mV>) are indicative of worn bonding brushes or poorly maintained brush gear and/or slip rings. The system is connected to the alarm system.

5.8.5 Undersize Bearings

1. **Crankpin bearings** are thin shell bearings. Due to relatively long production time, the engine builder has a ready stock of semi-produced shells (*blanks*) that covers a range from nominal diameter to 3 mm undersize, *see also item 6.4, 'Undersize Journals/Pins'*. *Semi-produced shells for journals with undersizes lower than 3 mm are not stocked as standard.* Furthermore, undersizes lower than 3 mm can also involve modification such as the bolt tension, hydraulic tool, etc.

For advice on the application of undersize bearings, it is recommended to contact MAN Diesel & Turbo.

2. The **main bearings** for the engine series can be of the thick or thin shell type (*see drawing 2255-0100 and 2255-0105*); the information under point 1 is also valid here.
3. **Crosshead bearings** are only available as standard shells for engines, as the reconditioning proposal for offset grinding of the pin (refer to 6.4 2.b) facilitates the use of standard shells, but not for AlSn40 crosshead bearings.

It is recommended to contact MAN Diesel & Turbo for advice on such reconditioning.

6 Journals/Pins

6.1 Surface roughness

Journal/pin surface roughness is important for the bearing condition. Increased surface roughness can be caused by:

1. Abrasive damage due to contamination of the system oil.
See also item 7.4.2.
2. Corrosive damage due to sea water or other contamination of the system oil (acidic) or oxidation of the journals due to condensate.
See also item 7.4.2.
3. Spark erosion (only known in main bearings).
See also item 6.2, 'Spark Erosion'.
4. Scratches caused by manhandling.

With increasing journal/pin roughness, a level will be reached where the oil film thickness is no longer sufficient, causing metal contact between journal/pin and the bearing sliding surface. This will cause bearing metal to adhere to the journal/pin, giving the surface a silvery white appearance and roughening the bearing surface at the same time. When such a condition is observed, the journal/pin must be reconditioned by polishing, and the roughness of the surface made acceptable. In extreme cases, the journal/pin must be ground to an undersize (*see item 6.4, 'Undersize Journals/Pins'*). The bearing shell condition determines whether exchange of the shells are necessary or not.

6.2 Spark erosion

Spark erosion is caused by a voltage discharge between the main bearing and journal surface.

The cause of the potential can be insufficient earthing of the engine and generator.

The oil film acts as a dielectric. The spark attack in the bearing depends on the thickness of the oil film.

Since the hydrodynamic oil film thickness varies through a rotation cycle, the discharge will take place at roughly the same instant during each rotation cycle, i.e. when the film thickness is at its minimum. The roughening will accordingly be concentrated in certain areas on the journal surface. However, as the bearings wear, the position of the spark attack may shift and thus other parts get damaged.

In the early stages, the roughened areas can resemble pitting erosion - but later, as the roughness increases, the small craters will scrape off and pick up bearing metal - hence the silvery white appearance.

Therefore, to ensure protection against spark erosion, the potential level must be kept at *maximum 50 mV*, which is feasible with a high efficiency earthing device. If an earthing device is installed, its effectiveness must be checked regularly. (*See also drawing 2555-0137*).

Spark erosion has only been observed in main bearings and main bearing journals. Regarding repair of the journals, *see item 7.11, 'Repairs of Journals/Pins'*.

The condition of the bearings must be evaluated to determine whether they can be reconditioned or if they have to be discarded. *It is recommended to contact MAN Diesel & Turbo if advice is required.*

6.3 Surface geometry

Surface geometry defects such as lack of roundness, conicity and misalignment may give rise to operational difficulties. Such abnormal cases of journal/pin geometry and misalignment may occur after a journal grinding repair.

It is recommended to contact MAN Diesel & Turbo for advice.

6.4 Undersize journals/pins

In case of severe damage to the journal, it may become necessary to recondition the journal/pin by grinding to an undersize.

1. Main and crankpin journals can be ground to 3 mm undersize; undersize journals below this value require special investigations of the bearing assembly.

It is recommended to contact MAN Diesel & Turbo for advice.

2. In service, crosshead pins can be:
 - a. Polished to $(D_{\text{nominal}} - 0.15 \text{ mm})$ as the *minimum* diameter.
 - b. Offset to a maximum of 0.3 mm and ground.
 - c. Undersize (AlSn40) or repaired by welding.

In both cases, since standard bearings are used, the bearing top clearance will increase depending on the surface condition of the pin to be reconditioned. The offset value used for grinding must be stamped clearly on the pin.

It is recommended to contact MAN Diesel & Turbo for advice.

7 Practical information

7.1 Check without opening up

Follow the check list in accordance with the programme stated in *the work cards*. Enter the results in the engine log book. See also item 7.12, 'Inspection of Bearings'.

1. Stop the engine and block the main starting valve and the starting air distributor and block the starting air reservoir valves.
2. Engage the turning gear.
3. Just after stopping the engine, while the oil is still circulating, check that uniform oil jets appear from all the oil outlet grooves in the crosshead bearing lower shell and the guide shoes.
4. Turn the crank throw for the relevant cylinder unit to a suitable position and stop the lube oil circulating pump (it is recommended to turn the engine for 15 - 30 minutes with the pumps off to let the oil drip off).
5. Check the vertical clearance with a feeler gauge.
 - a. The change in clearances must be negligible when compared with the readings from the last inspection (overhaul). If the total increase in clearance as from new is beyond the tolerance, the bearing should be inspected.
 - b. For guide shoe and guide strip clearances and checking procedure, see work card 2565-0201.

6. Examine the sides of the bearing shell, guide shoes and guide strips, and check for squeezed-out or loosened metal; also look for bearing metal fragments in the oil pan, *See: 2565-0401, Wire Feeler Check*.
7. In the following cases, the bearings must be dismantled for inspection, *see item 7.2, 'Open up Inspection and Overhaul'*.
 - a. Bearing running hot.
 - b. Oil flow and oil jets uneven, reduced or missing.
 - c. Increase of clearance since previous reading larger than 0.10 mm.
See also item 7.8, 'Bearing Wear Rate'.
 - d. Bearing metal squeezed out, dislodged or missing at the bearing, guide shoe or guide strip ends.
 - e. The oil having been contaminated with e.g. water.

If item 7.a has been observed excessively in crosshead bearings or crankpin bearings, measure the diameter of the bearing bore in several positions. If the diameter varies by more than 0.06 mm, send the connecting rod complete to an authorised repair shop.

If items 7.a, 7.c or 7.d are observed when inspecting **main bearings**, we will recommend to inspect the two adjacent bearing shells, to check for any abnormalities.

If item 7.e has been observed, check lead content in oil analysis. If high open up the cross head bearing.

7.2 Open up inspection and overhaul

See drawing 2555-0140.

NOTICE

Record the hydraulic pressure level when the nuts of the bearing cap go loose.

Carefully wipe the running surfaces of the pin/journal and the bearing shell with a clean rag. Use a powerful lamp for inspection.

Assessment of the metal condition and journal surface is made in accordance with the directions given below. *The results should be entered in the engine log book.*

See also item 7.12, 'Inspection of Bearings'.

7.3 Types of damage

The overlayer and bearing metal can exhibit the following types of damage.

1. **Tearing of the overlayer** (XH bearings) can be due to substandard bonding. The damage is not confined to specific areas of the bearing surface. The bearing metal/intermediate layer in the damaged area is seen clearly with a sharply defined overlayer border. This defect is regarded mainly as a cosmetic defect, if it is confined to small areas of the bearing surface without interconnection.

Whether the intermediate layer is exposed can be determined, if the layer is of Ni, with a knife test. The knife will leave only a faint or no cut mark in the intermediate layer, since it is very hard.

NOTICE

For tin-aluminium bearings, the total area where the intermediate layer is exposed due to overlayer tearing, wiping or wear must not exceed the maximum limit given in the table on drawing 2555-0150.

2. **Wiping of the overlayer** manifests itself by parts of the overlayer being smeared out. Wiping of the overlayer can take place when running-in a new bearing; however, if the wiping is excessive, the cause must be found and rectified. One of the major causes of wiping is pin/journal surface roughness and scratches.
See also the 'note' above.
3. **Bearing metal wiping** is due to metal contact between the sliding surfaces which causes increased frictional heat, resulting in plastic deformation (wiping) (*see item 7.4, 'Causes of Wiping'*). *See also item 7.10.2.*
Moderate wiping during the running-in stage is normal, and is considered as a "cosmetic" problem. (*See item 7.7 for "dressing-up" wedges.*)

7.4 Causes of wiping

1. Hard contact spots, e.g. originating from:
 - a. Defective pin/journal, bearing, or crosshead guide surfaces
 - b. Scraped bearing or guide shoe surfaces
 - c. Objects trapped between the housing bore and the back of the shell
 - d. Fretting on the back of the shell and in the housing bore.

2. Increased pin/journal surface roughness. In most cases the increase in roughness will have occurred in service, and is attributed to:

- a.

Hard particle ingress: Hard particle ingress may be due to the malfunction of filters and/or centrifuges or loosened rust and scales from the pipings. Therefore, always pay careful attention to oil cleanliness.

- b.

Corrosive attack:

Water contamination of the system oil is by far the most found cause of corrosive attack of bearings.

If the oil develops a weak acid.

If strong acid anhydrides are added to the oil which, in combination with water, will develop acid.

If salt water contamination of the lube oil is higher than 0.5%. The water will attack the bearing metal, and result in the formation of a very hard black tin-oxide encrustation (SnO) which may scratch and roughen the pin surface. The formation of tin oxide is intensified by rust from the storage tank. Therefore, keep the internal surface clean.

NOTICE

Ensure that no dirt enters the crosshead pin oil bores during piston overhaul.

3. Inadequate lube oil supply.
4. Misalignment.

7.5 Cracks

Crack development is a fatigue phenomenon due to high dynamic stress levels in local areas of the bearing metal, typically in combination with weakened bearing metal.

In the event of excessive local heat input, the fatigue strength of the bearing metal will decrease, and thermal cracks are likely to develop even below the normal dynamic stress level. This can typically be found in crankpin and crosshead bearing shells, exceeding 50,000 running hours.

A small cluster of hairline cracks develops into a network of cracks. At an advanced stage, increased notch effect and the influence of the hydrodynamic oil pressure will tear the white metal from the steel back and produce loose and dislodged metal fragments.

7.6 Cause of cracks

1. Insufficient strength of the bonding between the white metal and the steel back (tinning or casting error).
2. Crack development after a short working period may be due to a misalignment (e.g. a twist between the bearing cap and housing) or geometric irregularities (e.g. a step between the contact faces of the bearing shell, or incorrect oil wedge geometry).
3. High local loading: for example, if, during running-in, the load is concentrated on a few local high spots of the white metal.

NOTICE

Bearings with cracks can only be repaired temporarily depending on the extent of the damage.

7.7 Repair of oil transitions

Wedges, tangential run out and bore relief.

NOTICE

It is strongly recommended to contact MAN Diesel & Turbo for advice before starting any repairs.
(See also item 1., 'General bearing requirements and criteria'.)

Formation of sharp ridges or incorrect inclination of the transition to the bearing surface will seriously disrupt the flow of oil to the bearing surface, causing oil starvation at this location.

Oil transitions are reconditioned by carefully cleaning for accumulated metal with a straight edge or another suitable tool. Oil wedges should be rebuilt to the required inclination (maximum 1/100) and length, *see drawing 2555-0110*.

NOTICE

Check the transition geometries before installing the bearings,
see item 13., 'Check of bearings before installation'.

7.8 Bearing wear rate

The reduction of shell thickness in the loaded area of the main, crankpin and crosshead bearing in a given time interval represents the wear rate of the bearing. Average bearing wear rate based on service experience is 0.01 mm/10,000 hrs. As long as the wear rate is in the region of this value, the bearing function can be regarded as normal. *See also item 7.1, 'Check without Opening up', point 7.c.).*

For white metal crosshead bearings, the wear limit is confined to about 50% reduction of the oil wedge length, *see drawing 2555-0110*. Of course, if the bearing surface is still in good shape, the shell can be used again after the oil wedges have been extended to normal length. Check also the pin surface condition, *see items 6.1, 'Surface Roughness' and 7.9, 'Surface Roughness (journal/pin)'.*

For tin-aluminium crosshead bearings, see the 'note' in item 7.3.1.

For further advice, please contact MAN Diesel & Turbo.

7.9 Surface roughness (journal/pin)

Limits to surface roughness

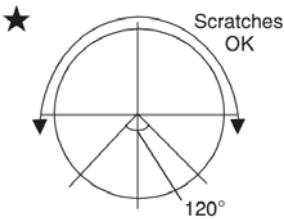
The surface roughness of the journal/pin should always be within the specified limits.

a For main bearing and crankpin bearing journals:

- | | | |
|-------------------------------|--------|--------|
| • New journals: | AlSn40 | 0.4 Ra |
| | HMO7 | 0.8 Ra |
| • Recondition if higher than: | AlSn40 | 0.8 Ra |
| | HMO7 | 1.6 Ra |

b. For crosshead pins: ★

- | | |
|-------------------------------|---------------|
| • New or repolished | 0.05 Ra |
| • Acceptable in service: | 0.05 - 0.1 Ra |
| • Repolishing if higher than: | 0.1 Ra |



Determination of the pin/journal roughness

Measure the roughness with an electronic roughness tester, or evaluate the roughness with a RUGOTESTER®, by comparing the surface of the pin/journal with the specimens on the RUGOTESTER®. When performing this test, the pin surface and the RUGOTESTER® must be thoroughly clean and dry. Hold the tester close

to the surface and compare the surfaces. If necessary, use your finger nail to run over the pin/journal surface and the RUGOTESTER ® specimens to compare and determine the roughness level.

7.10 Repairs of bearings on site

NOTICE

It is recommended to contact MAN Diesel & Turbo for advice before starting any repairs.

(See also item 1., 'General Bearing Requirements and Criteria').

1. Overlayer wiping

a. Overlayer wiping and moderate tearing in crosshead bearing lower shells is not serious, and is remedied by careful use of a scraper.

However, see the 'note' in item 7.3.1.

b. Hard contact on the edges of crosshead bearings is normally due to galvanic build-up of the overlayer. This is occasionally seen when inspecting newly installed bearings and is remedied by relieving these areas with a straight edge or another suitable scraping tool.

2. Bearing metal squeezed out or wiped:

a. The wiped metal can accumulate in the oil grooves / wedges, run-out or bore relief where it forms ragged ridges. Such bearings can normally be used again, provided that the ridges are carefully removed with a suitable scraping tool and the original geometry is re-established (*see item 7.7, 'Repair of Oil Transitions'*). High spots on the bearing surface must be levelled out by light cross-scraping (90 by 90 degrees).

b. In cases of wiping where the bearing surface geometry is to be re-established, it is important:

- to assess the condition of the damaged area and, if found necessary, to check the bearing surface for hairline cracks under a magnifying glass and with a penetrant fluid, if necessary.

- to check the surface roughness of the journal/pin and polish if necessary.

c. In extreme cases of wiping, the oil wedges in the crosshead bearing may disappear. In that event, the shell should be replaced.

3. For evaluation and repair of spark erosion damage, refer to item 6.2, 'Spark Erosion'.

4. **Cracked bearing metal surfaces** should only be repaired temporarily. The bearing must be replaced (*see items 7.5, 'Cracks' and 7.6, 'Cause for Cracks'*).

7.11 Repairs of journals/pins

Crosshead pins

Pin surface roughness should be better than 0.1 Ra (*see item 7.9, 'Surface Roughness (journal/pin)'*). If the Ra value is higher than 0.1 μm , the pin can often be repolished on the spot, as described below. If the pin is also scratched, the position and extent of the scratched areas must be evaluated. If there are also deep scratches, these must be levelled out carefully with hardbacked polishing paper, or similar, before the polishing process is started.

NOTICE

Use a steel ruler, or similar, to support the polishing paper, as the fingertips are too flexible.

The surface roughness not counting in scratches after polishing should be better than 0.1 Ra in the 120° crown. The upper 240° can be accepted up to an average roughness of 0.2 Ra including scratches.

The following methods are recommended for repolishing on site.

- 1. Polishing with microfinishing film**

The polishing process is carried out with a "microfinishing film", e.g. 3M aluminium oxide (30 micron, 15 micron and 5 micron), which can be recommended as a fairly quick and easy method, although to fully reestablish the pin surface it will often be necessary to send the crosshead to a repair shop for regrinding/polishing in an appropriate machine.

The microfinishing film can be slung around the pin and drawn to and fro by hand and, at the same time, moved along the length of the pin, or it is drawn with the help of a hand drilling machine; in this case, the ends of the microfilm are connected together with strong adhesive tape or glued together.

- 2. Braided hemp rope method**

This method is executed with a braided hemp rope and jeweller's rouge.

Before the rope is applied all front end scratches must be removed with fine emery cloth as per 7.11.1.

A mixture of polishing wax and gas oil (forming an abrasive paste of a suitably soft consistency) is to be applied to the rope at regular intervals. During the polishing operation, the rope must move slowly from one end of the pin to the other.

The polishing is continued until the roughness measurement proves that the surface is adequately smooth (*see item 7.9*).

This is a very time-consuming operation and, depending on the surface roughness in prior, about three to six hours may be needed to complete the polishing.

Journals (Main and crankpin journals)

1. The methods for polishing of crosshead pins can also be used here, and method a) Polishing with microfinishing film, will be the most suitable method. A 30 micron microfinishing film is recommended here or 220-270 grade emery cloth of a good quality.
2. Local damage to the journal can also be repaired. The area is to be ground carefully and the transitions to the journal sliding surface are to be rounded carefully and polished. *We recommend to contact MAN Diesel & Turbo for advice before such a repair is carried out. But as temporary repair, any ridges must be filed or ground to level.*

7.12 Inspection of bearings

Regarding check of bearings before installation, see item 13., 'Check of Bearings before Installation'.

For the ship's own record and to ensure the correct evaluation of the bearings when advice is requested from MAN Diesel & Turbo, we recommend to follow the guidelines for inspection, which are stated in *drawing 2555-0140, page 3 to 7. See the example of an Inspection Record on drawing 2555-0140, page 6.*

8 Crosshead bearing assembly

8.1 Bearing type

See also plate 1472-0300

The type of bearing used in the crosshead assembly is a thin shell (insert) bearing (*see item 5.5, 'Thin Shell Bearings'*). The lower shell is a trimetal shell, i.e. the shell is composed of a steel back with cast-on white metal and an overlay layer coating.

See also item 3, 'Overlayers'. The upper shell is a bimetal shell, as it does not have the overlay layer coating; both the upper and lower shells are protected against corrosion with tin flash (*see item 4, 'Flashlayer, Tin (Sn)'*). The upper part can also be cast into the bearing cap.

8.2 Bearing function and configuration

Because of the oscillating movement and low sliding speed of the crosshead bearing, the hydrodynamic oil film is generated through special oil wedges (*see item 5.3, 'Axial Oil Grooves and Oil Wedges'*) on either side of the axial oil supply grooves situated in the loaded area of the bearing. The oil film generated in this manner can be rather thin. This makes the demands for pin surface roughness and oil wedge geometry important parameters for the assembly to function. A further requirement is effective cooling which is ensured by the transverse oil grooves. The pin surface is superfinished (*see item 7.9 1.b*). The lower shell is most often executed with a special surface geometry (embedded arc) which extends over a 120-degree arc, and ensures a uniform load distribution on the bearing surface in contact with the pin. The lower shell is coated with an overlay layer (*see item 3., 'Overlayers'*), which enables the pin sliding geometry to conform with the bearing surface in the embedded arch area.

Another geometry execution is the “Single bore” geometry, which depends on a fully positive yet small clearance. With “Single bore” the overlayer is omitted.

9 Main Bearing Assembly

The engine can be equipped with “Thick shell bearings” (*item 5.4*) or “Thin shell bearings” (*item 5.5*).

The bearing type, i.e. “thick shell” or “thin shell” determines the main bearing housing assembly described below (*see table of installed bearing types, drawing 2555-0100, and housing assemblies, drawing 2555-0120*).

9.1 Thick shell bearing assembly

See drawing 2555-0120, Fig. 1.

The tensioning force of a thick shell bearing assembly (Fig. 1) is transferred from the bearing cap (pos. 1) to the upper shell (pos. 2) and via its mating faces to the lower shell (pos. 3).

The bearing bore is equipped with the following geometry:

1. Central oil supply groove and oil inlet in the upper shell which ends in a *sloping run-out* (*item 5.1*) in both sides of the lower shell, *see drawing 2555-0100*.
2. The bearing bore is furnished with a *bore relief* (*item 5.2*) at the mating faces of the upper and lower shell, *see drawing 2555-0100*.

9.2 Thin shell (insert bearing) bearing assembly

See drawing 2555-0120, Fig. 2.

This forms a rigid assembly (Fig. 2). The bearing cap (pos. 1) which has an inclined vertical and horizontal mating face, is wedged into a similar female geometry in the bedplate (pos. 2), which, when the assembly is pre-tensioned, will ensure a positive locking of the cap in the bedplate.

The lower shell can be positioned by means of screws (pos. 3) (note: some engines do not have locking screws). During mounting of the lower shell, it is very important to check that the screws are fully tightened to the stops in the bedplate. This is to prevent damage to the screws and shell during tightening of the bearing cap. *See also work card 2565-0401.*

See also item 5.5, ‘Thin Shell Bearings’ earlier in this section. For information regarding inspection and repair, see item 7, ‘Practical Information’.

10 Crankpin bearing assembly

See also plate 1472-0300.

This assembly is equipped with thin shells, and has two or four tensioning studs, depending on the engine type. Crankpin bearing assemblies with four studs must be tensioned in parallel, for example first the two forward studs and then the two aftmost studs; the tensioning may be executed in two or three steps. If four hydraulic jacks are available only one step is necessary plus check-step. This procedure is recommended in order to avoid a twist (angular displacement) of the bearing cap to the mating face on the connecting rod.

The oil supply groove transition to the bearing sliding surface is similar to that of the main bearing geometry. For information regarding inspection and repair, *see item 7, 'Practical Information'*.

11 Guide shoes and guide strips

See drawing 2555-0125.

(See also plate 1472-0300.)

The guide shoes, which are mounted on the fore and aft ends of the crosshead pins, slide between guides and transform the translatory movement of the piston/piston rod via the connecting rod into a rotational movement of the crankshaft.

The guide shoe is positioned relative to the crosshead pin with a positioning pin screwed into the guide shoe, the end of the positioning pin protrudes into a hole in the crosshead pin and restricts the rotational movement of the cross-head pin when the engine is turned with the piston rod disconnected.

The guide strips are bolted on to the inner side of the guide shoes and ensure the correct position of the piston rod in the fore-and-aft direction. This alignment and the clearance between the guide strips and guide is made with shims between the list and the guide shoe.

The sliding surfaces of the guide shoes and guide strips are provided with cast-in white metal and furnished with transverse oil supply grooves and wedges (*see item 5.3, 'Axial Oil Grooves and Oil Wedges'*).

For inspection of guide shoes and guide strips, *see item 7.1, 7.3.3 and 7.4.1 a) and b) and chapter 2565.*

12 Thrust bearing assembly

See drawing 2555-0130.

The thrust bearing is a tilting-pad bearing of the Michell type. There are eight pads (segments) or more placed on each of the forward and aft sides of the thrust collar. They are held in place circumferentially by stoppers. The segments can be compared to sliding blocks and are pivoted in such a manner that they can individually take up the angle of approach necessary for a hydrodynamic lubricating wedge. The lubricating/cooling oil is sprayed directly on to the forward and aft sides of the thrust collar by means of nozzles positioned in the spaces between the pads. The nozzles are mounted on a semicircular delivery pipe.

For clearances and max. acceptable wear, *see work cards*.

13 Check of bearings before installation

See drawing 2255-0185.

Clean the bearing shells thoroughly before inspecting.

13.1 Visual inspection

1. Check the condition of the bearing surfaces for impact marks and burrs. Repair by scraping if necessary.
2. Check that the transition between the bore relief and the bearing sliding surface is smooth.

13.2 Check measurements

Place the shell freely, as illustrated in *drawing 2555-0185, Fig. 1*.

Measure the crown thickness with a ball micrometre gauge. Measure in the centre line of the shell, 15 millimetres from the forward and aft sides.

Record the measurements as described in *item 7.12, 'Inspection of Bearings' and drawing 2555-0140 page 3 to 7*.

This will facilitate the evaluation of the bearing wear during later overhauls.

13.3 Cautions

As bearing shells are sensitive to deformations, care must be taken during handling, transport and storage, to avoid damaging the shell geometry and surface.

The shells should be stored resting on one side, and be adequately protected against corrosion and mechanical damage.

Preferably, keep new bearing shells in the original packing, and check that the shells are in a good condition, especially if the packing shows signs of damage.

During transport from the store to the engine, avoid any impacts which could affect the shell geometry.

1 Alignment

During installation of the engine, intermediate shaft and propeller shaft, the yard aims to carry out a common alignment, to ensure that the bearing reactions are kept within the permitted limits, with regard to the different factors which influence the vessel and engine during service.

Factors like the ship's load condition, permanent sag of the vessel, movements in sea, wear of bearings etc., makes it necessary to regularly check the alignments:

- Main bearings, see Items 2.1-2.4
- Engine bedplate, see Item 2.5
- Shafts, see Item 2.6.

2 Alignment of main bearings

See drawing 2555-0175 and 2555-0180.

The bearing alignment can be checked by *deflection measurements (autolog)* as described in the following section.

Example: If two adjacent main bearings at the centre of the engine are placed too high, then at this point the crankshaft centreline will be lifted to form an arc. This will cause the intermediate crank throw to deflect in such a way that it "opens" when turned into bottom position and "closes" in top position.

Since the magnitude of such axial lengthening and shortening increases in proportion to the difference in the height of the bearings, it can be used as a measure of the bearing alignment.

2.1 Deflection measurements (autolog)

See drawing 2555-0175.

As the alignment is influenced by the temperature of the engine the deflection measurements should, for comparison, always be made under nearly the same temperature and load conditions.

It is recommended to record the actual jacket water and lube oil temperatures in *Drawings 2555-0175.*

Procedure

Turn the crankpin for the cylinder concerned to Pos. B1, *see Fig. 2, drawing 2555-0175.* Place a dial gauge axially in the crank throw, opposite the crankpin, and at the correct distance from the centre, as illustrated in Fig. 1. The correct mounting position is marked with punch marks on the crank throw. Set the dial gauge to "Zero".

Make the deflection readings at the positions indicated in Fig. 2.

“Closing” of the crank throw (compression of the gauge) is regarded as negative and “Opening” of the crank throw (expansion of the dial gauge) is regarded as positive, *see Fig. 1*.

Since, during the turning, the dial gauge cannot pass the connecting rod at BDC, the measurement for the bottom position is calculated as the average of the two adjacent positions (one at each side of BDC).

When making deflection readings for the two rearmost cylinders, the turning gear should, at each stoppage, be turned a little backwards to ease off the tangential pressure on the turning wheel teeth. This pressure may otherwise falsify the readings.

Enter the readings in the table Fig. 3. Then calculate the BDC deflections, $1/2 (B_1 + B_2)$, and note down the result in Fig. 4.

Enter total “vertical deflections” (opening - closing) of the throws, during the turning from bottom to top position in the table Fig. 5 (T-B).

2.2 Checking the deflections

See drawing 2555-0180 and Testbed Report.

The results of the deflection measurements (see drawing 2555-0175, Fig. 5) should be evaluated with the commissioning test measurements (recorded by the engine builder in the commissioning test report on site). If realignment has been carried out later on (e.g. following repairs), the results from these measurements should be used.

Values of permissible “vertical deflections” etc. are shown in *drawing 2555-0180*.

NOTICE

The values shown on drawing 2555-0180 are specifically attributed to the crankshaft condition, NOT the bearing wear condition.

The values represent theoretical maximum deflection, which the crankshaft material can sustain, for an unlimited time of operation, without risking to exceed the stress fatigue limits of the crankshaft.

The values are unlikely to exceed the “permissible from new” in static condition (turning of the engine).

For bearing wear measurements derived from deflection readings; always refer to commissioning test results, and judge the relative change in deflection over time.

Abnormal/deviating deflection readings should always be investigated and additional measurements performed, such as top and bottom clearance of adjacent main bearings.

2.3 Floating journals

See also Item 2.2 and drawing 2555-0180.

Use a special bearing feeler gauge to investigate the contact between the main bearing journals and the lower bearing shells. Check whether the clearance between journal and lower shell is zero.

If clearance is found between journal and lower bearing shell, the condition of the shell must be checked and, if found damaged, it must be replaced.

The engine alignment should be checked and adjusted, if necessary.

To obtain correct deflection readings in case one or more journals are not in contact with the lower shell, it is recommended to contact the engine builder.

If the deflection values are within limits and there is bottom clearance found, it may be possible to install an offset bearing to get a positive bearing reaction.

2.4 Causes of crankshaft deflection

1. Excessive wear of main bearings
2. Displacement of bedplate (*see 'Piano Wire Measurements'*)
3. Displacement of engine alignment and/or shafting alignment
4. Loose or broken staybolts
5. Loose foundation bolts
6. Wear of shock absorber material.

2.5 Piano wire measurements. Bedplate alignment

A 0.5 mm piano wire is stretched along each side of the bedplate.

The wire is loaded with 400 N horizontal force.

At the centreline of each cross girder the distance is measured between the wire and the machined faces of the bedplate top outside oil groove.

It will thus be revealed whether the latter has changed its position compared with the reference measurement from engine installation.

This measurement requires special equipment available from MAN Diesel & Turbo.

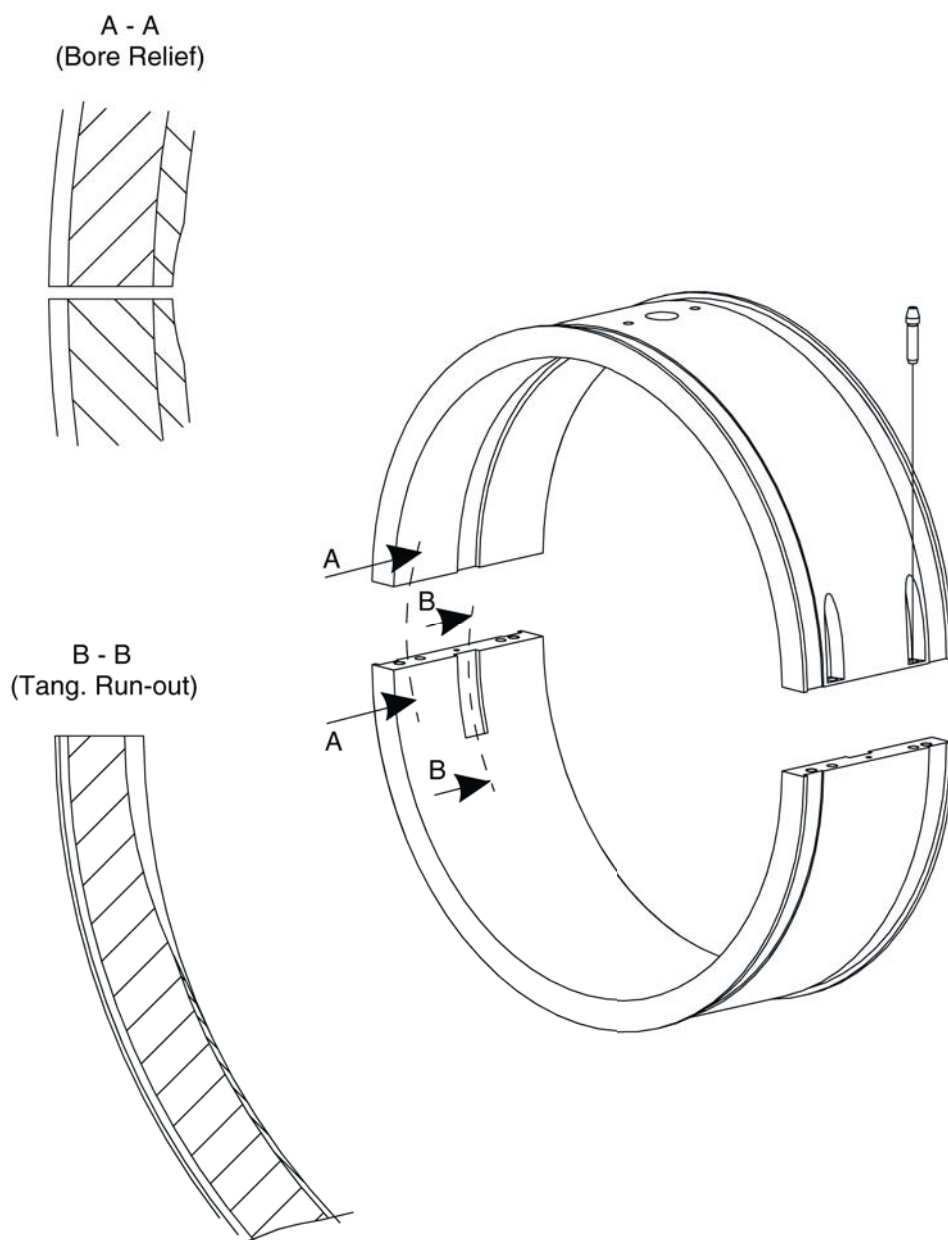
2.6 Shafting alignment, bearing load, “jack-up” test

This can be checked by measuring the load at:

- the aftermost main bearing
- the intermediate shaft bearings (plummer blocks)
- in the stern tube or generator bearing.

Making these measurements normally requires specialist assistance.

As a reliable evaluation of the shafting alignment measurements requires a good basis, the best obtainable check can be made if the contractor/supplier or repair-shop has carried out the alignment based on precalculation of the bearing reactions.



Engine types with thick shell main bearing assemblies:

S/K/L50ME/MC

S/K/L60ME/MC

S/L70ME/MC

L80ME/MC

K/L90ME/MC

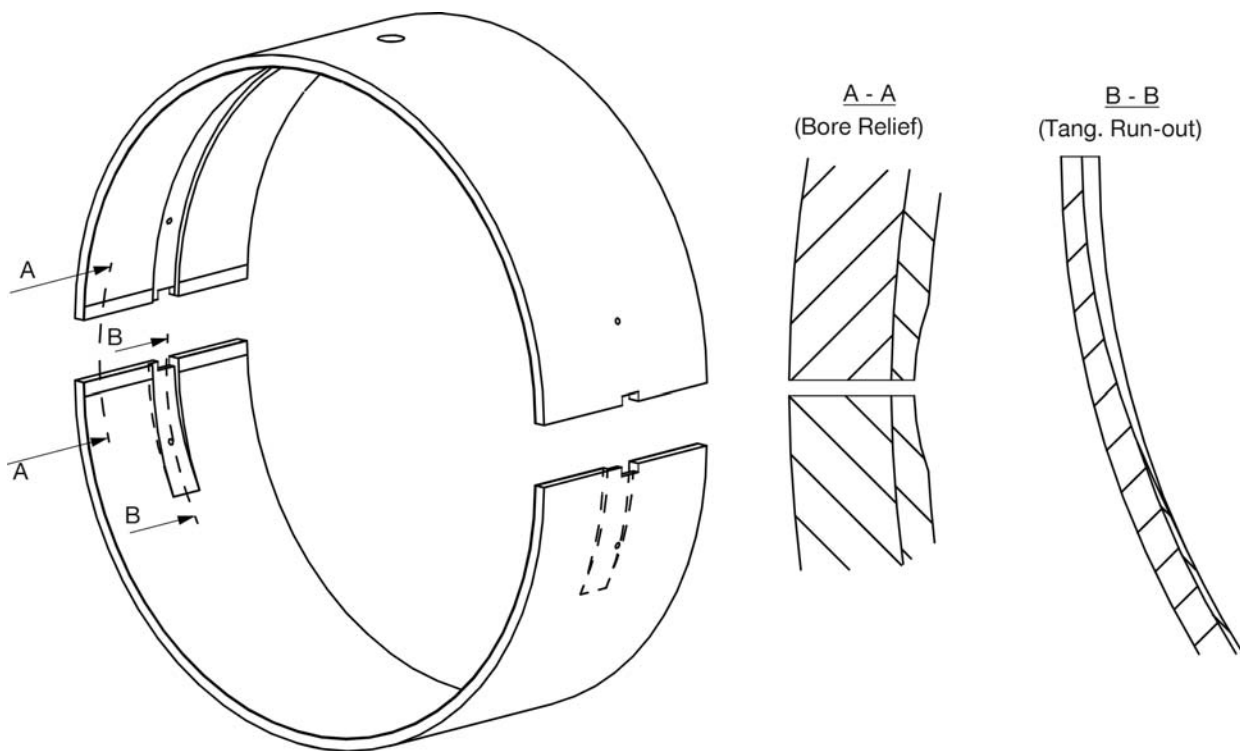


Figure 1: Thin shell bearing

Engine types with thin shell main bearing assemblies:		
S	26	MC
S	30	MC / ME-C / ME-B
S / L	35	MC / MC-C / ME-B
S	40	MC / MC-C / ME-B
S / L	42	MC
G	45	MC-C / ME-C / ME-B
S	46	MC-C / ME-C / ME-B
G / S	50	MC-C / ME-C / ME-B
G / S	60	MC-C / ME-C / ME-B
S	65	MC-C / ME-C / ME-B
G / S / L	70	MC-C / ME-C / ME-B
G / S / K	80	MC-C / ME-C
K / S	90	MC-C / ME-C
G	95	MC-C / ME-C
K	98	MC / ME / ME-C

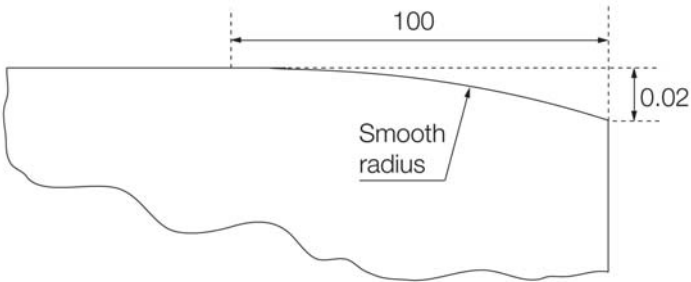
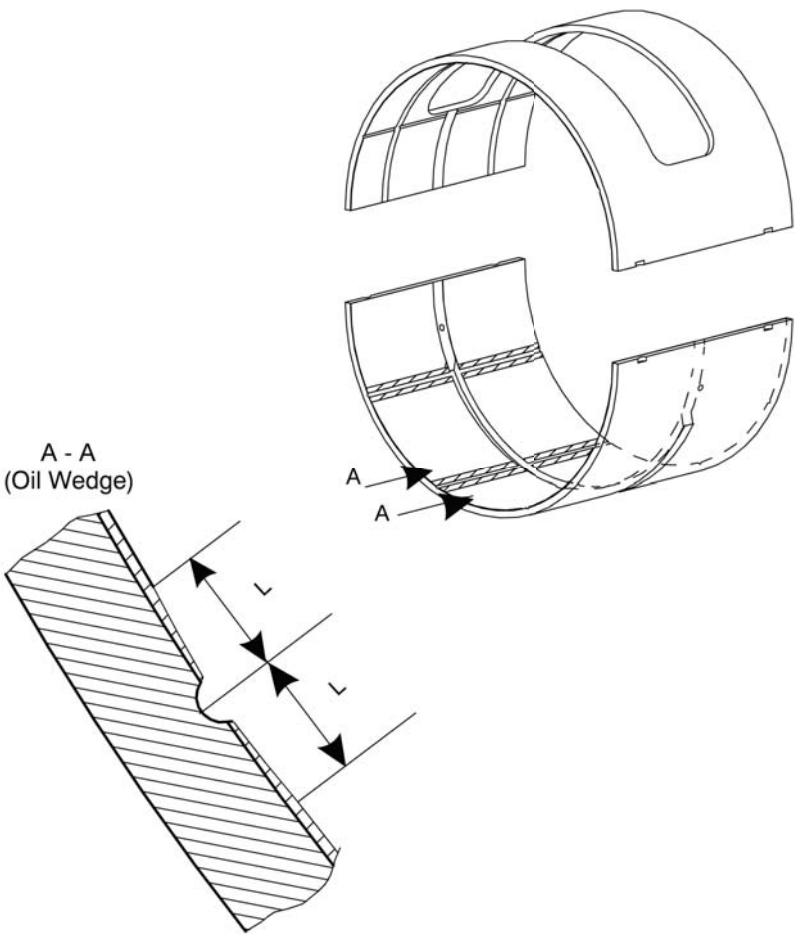


Figure 2: Blended edge



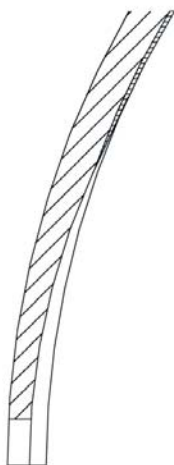
Extent of oil wedges in crosshead bearing lower shell:

Engine type:	Extent L (mm)*
All engine types	For actual values, refer to <i>work card 2565-0200</i> . *) On each side of the axial oil groove

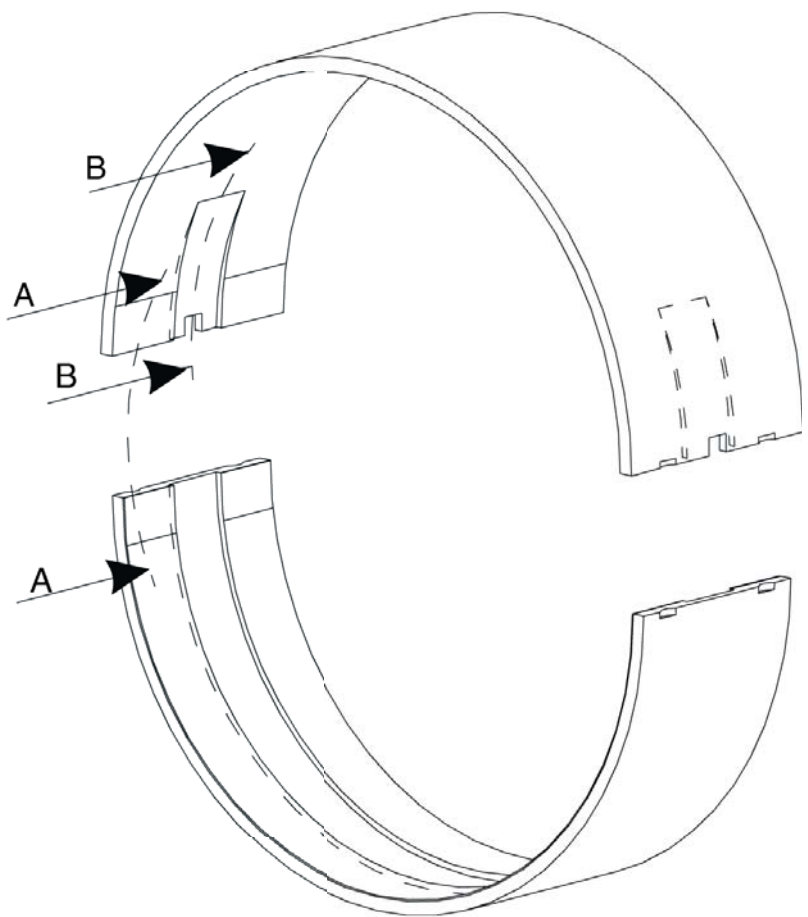
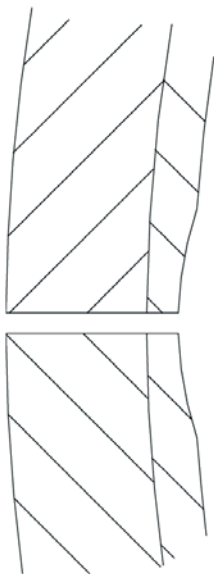
Crosshead Bearing

Drawing
2555-0110-0004

B - B
(Tang. Run-out)



A - A
(Bore Relief)



Crankpin Bearing

Drawing
2555-0115-0002

Fig. 1 Thick Shell

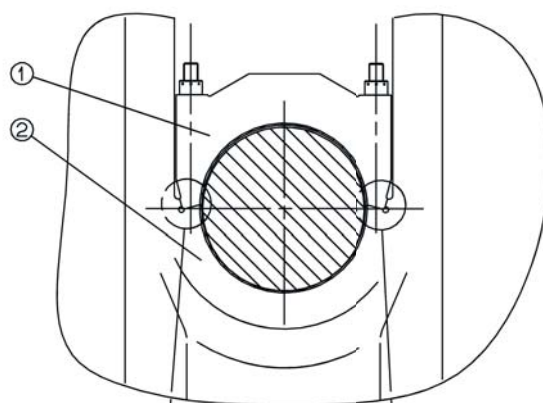
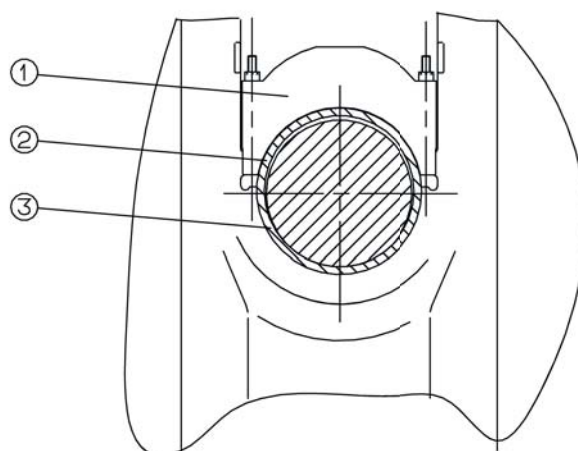
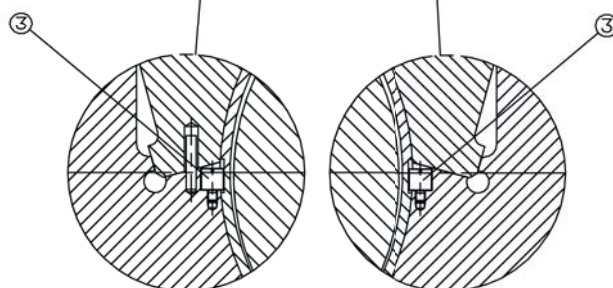
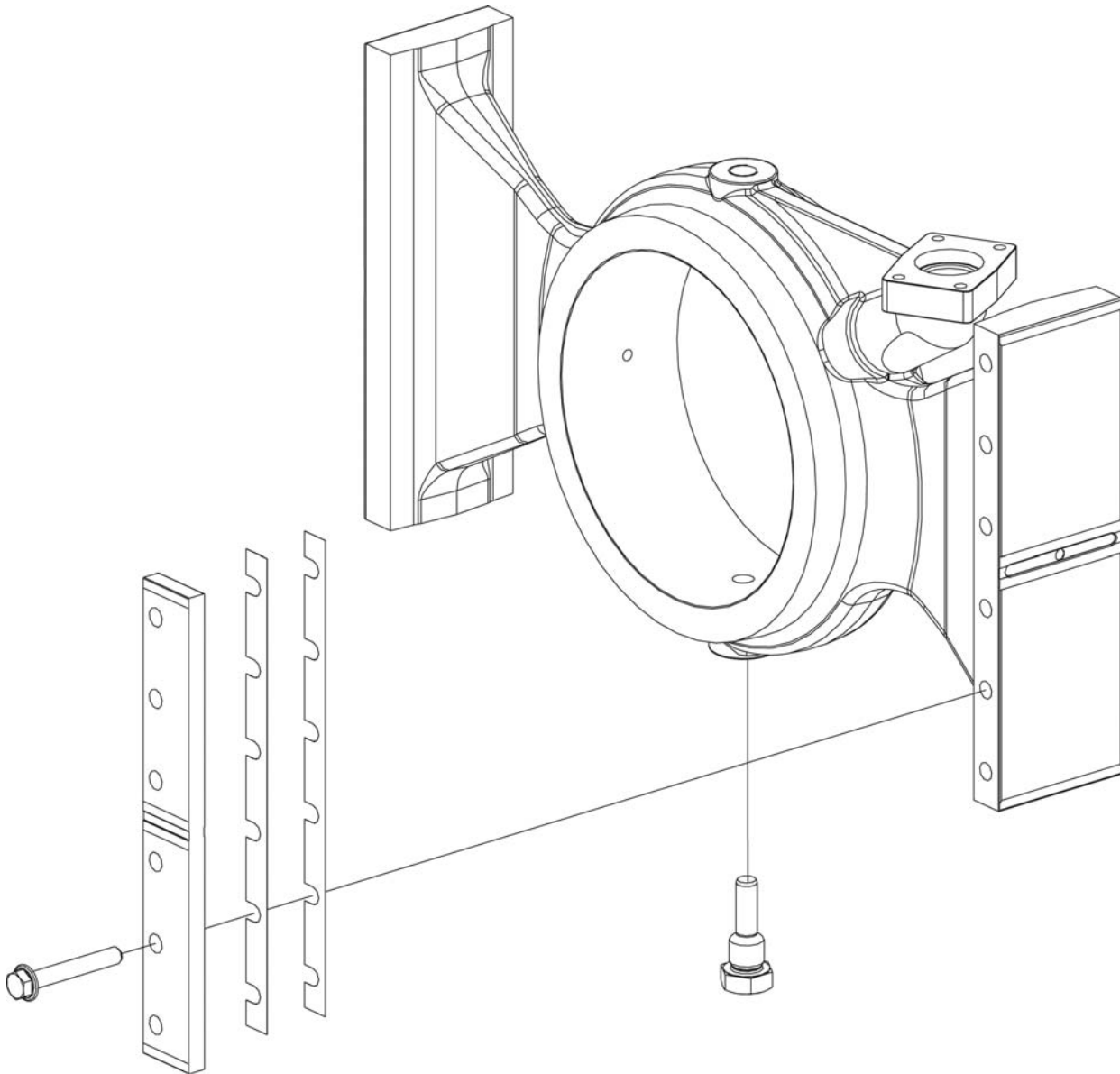
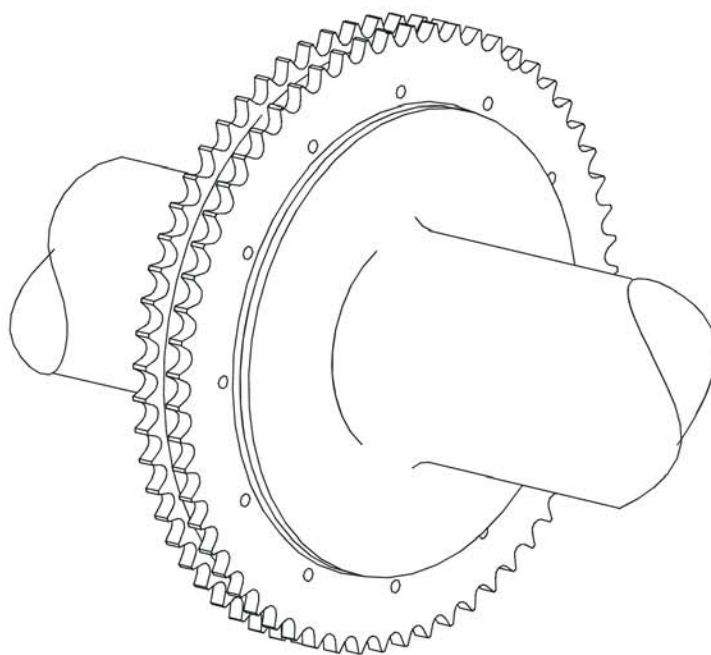
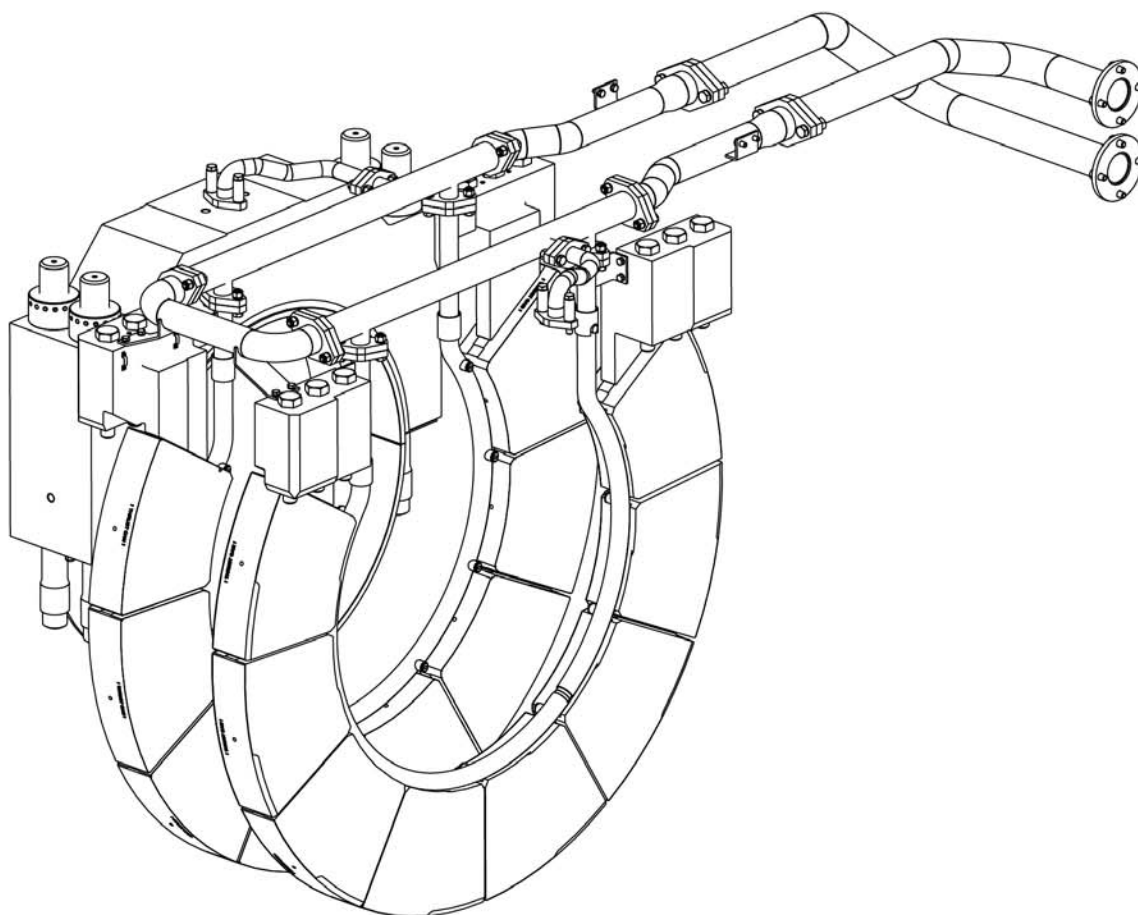


Fig. 2 Thin Shell

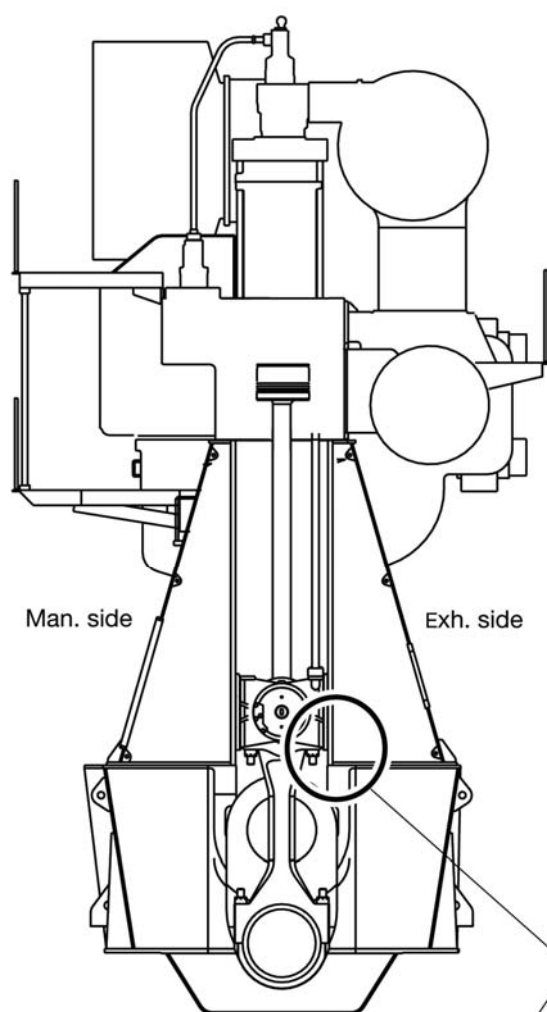






Thrust Bearing Assembly

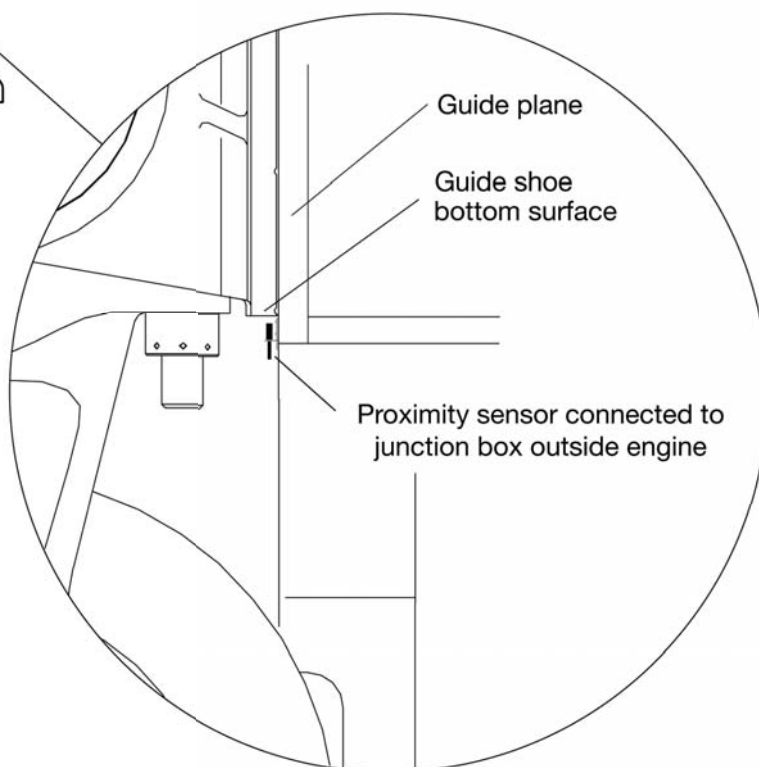
Drawing
2555-0130-0003



Proximity sensors (2 per cylinder, i.e. one for each guideplane) are placed on brackets typically mounted on the Exhaust side structure below both guide shoes.

The system monitors the variation in distance between sensor and guide shoe bottom surface, in bottom dead centre (BDC). The measurements represent the relative wear in all three crank-train bearings, simultaneously.

Via cables, the signals are sent to a junction box outside the engine and computed for further use.



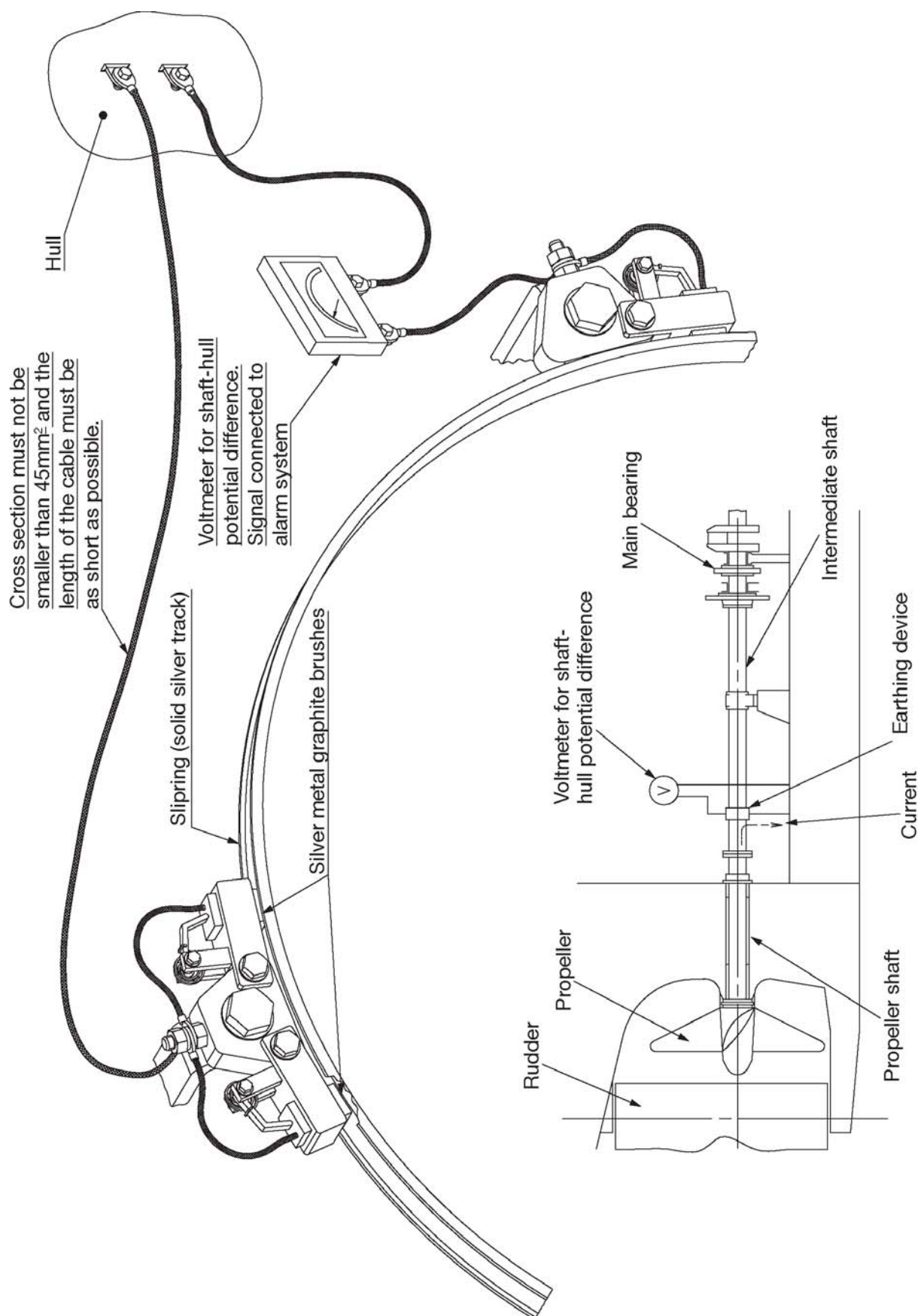
Bearing Wear Monitoring System (BWM)

Drawing

2555-0136-0002

Propeller Shaft Earthing Device

Drawing
2555-0137-0002



Recording of Observations

References to Work Cards		
Bearing Type	Inspection without Opening-up	Open-up Inspection and Overhaul
Main bearing	2565-0401	2565-0401
Crankpin bearing	2565-0301	2565-0301
Crosshead bearing	2565-0201	2565-0201
Guide shoes	2565	-
Crosshead guides	2565	-
Thrust bearing	-	2565-0601
Camshaft bearing (MC/ME-B)	2565-0101	2565-0101

Use the Inspection Sheet, *Drawing 2555-0140 page 7*. For help, refer to example, *Drawing 2555-0140 page 6*.

A. Inspection without Opening-up

State the following information:

Date / Signature / Engine running hours / Type of inspection / Bearing type *Drawing 2555-0140, Table 1* / Bearing number / Observation *Drawing 2555-0140 page 4, Table 3* / Remarks / Clearances.

B. Open-up Inspection and Overhaul

State the following information:

Date / Signature / Engine running hours / Type of inspection / Bearing type *Table 1* / Bearing number / Manufacturer's logo / Damage according to *Table 2* / Observation *Drawing 2555-0160 page 4, Table 4* / Site and extent of damage *described on following pages** / Remarks / Clearances / Hydraulic opening pressure / Roughness.

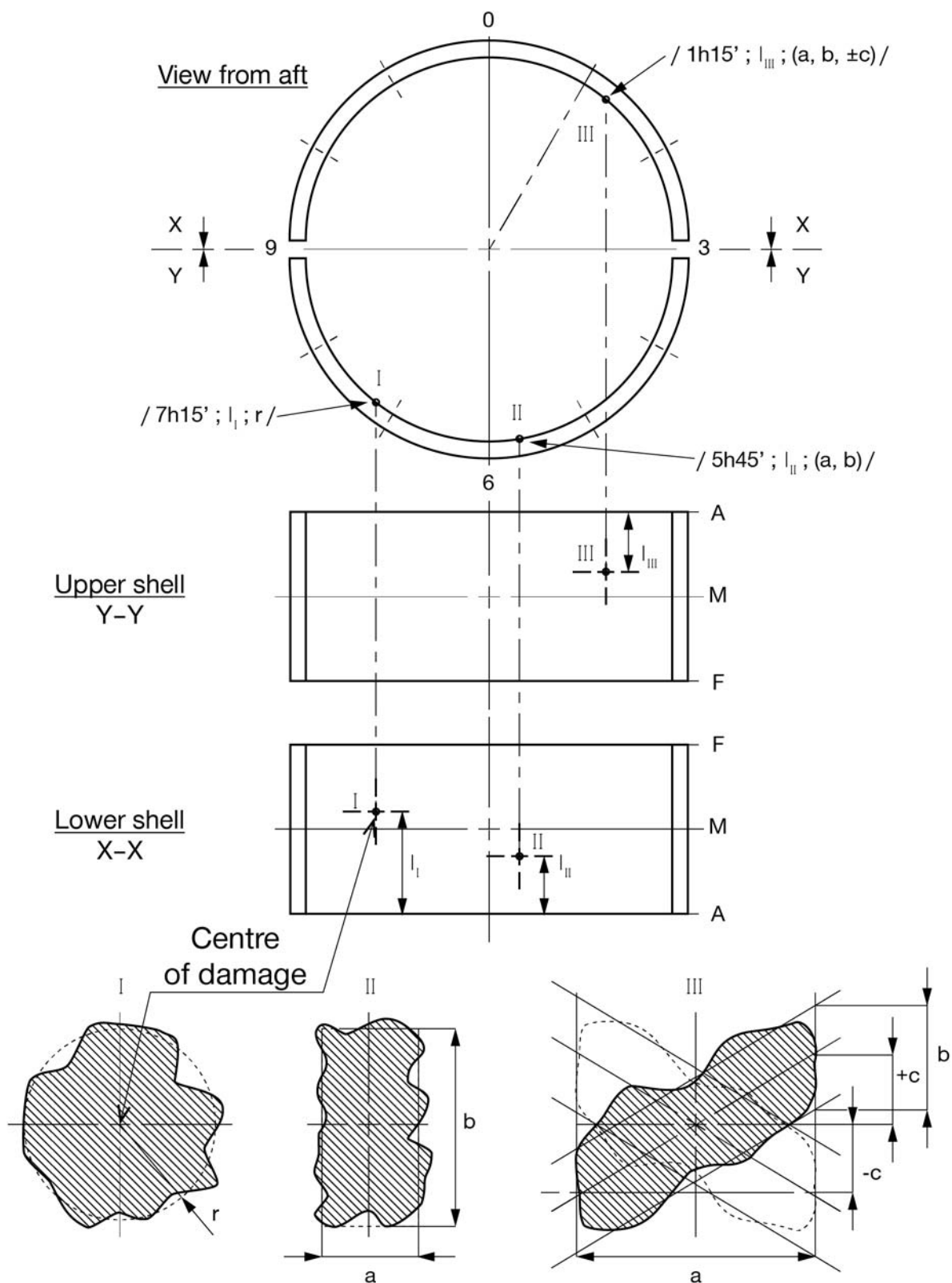
* The site and extent of the damage is determined by:

1. The approximate centre of the damaged area (see examples I, II and III).
The axial location (l) of the centre should be stated in (mm) from the generator end of the bearing or the journal.
2. The extent of the damage defined by a circle with radius (r); or a rectangle (a, b) or (a, b, +/- c), (see examples I, II and III).

Note: For isolated cracks, illustration III is used, with the measurement **b** omitted.

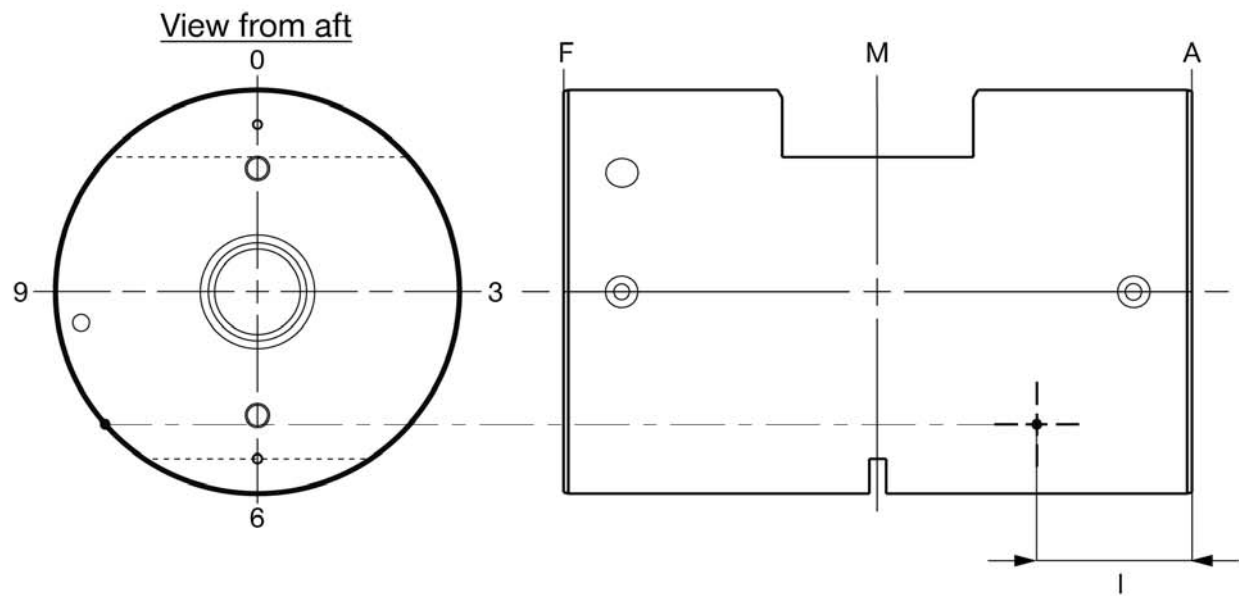
Table 1:		Table 2:	
Bearing Type		Damage	
Main Bearing	MB	Overlayer	OL
Crankpin Bearing	CRB	White Metal	WM
Crosshead Bearing	CHB	Journal	J
Guide Shoes	CG	Pin	P
Thrust Bearing	TB	Transitions:	
Camshaft Bearing (MC/ME-B)	CSB	- Oil Wedge	OW
		- Bore Relief	BR
		- Tang. Run-out	TR
		Back of Shell	BS

Location and Damage and Size in Bearing Shells

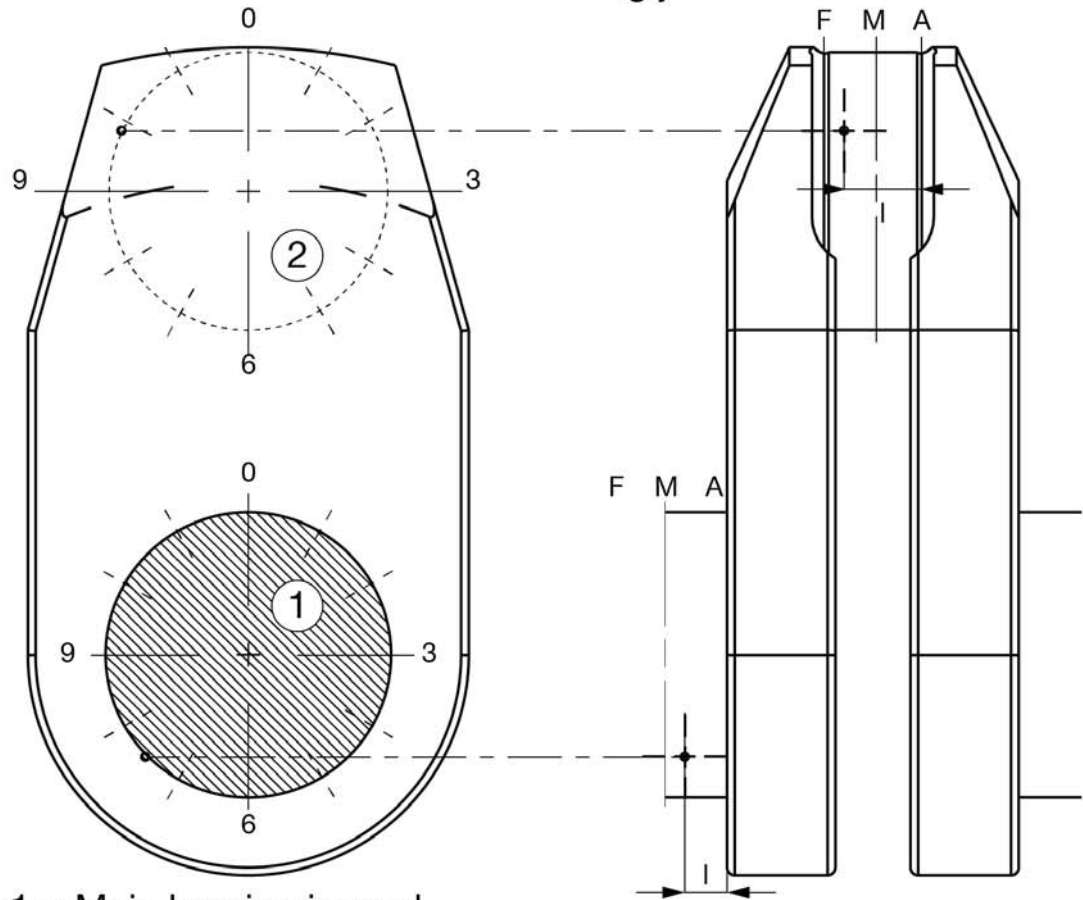


Location of Damage on Pin/Journal

Crosshead pin



Main and crank bearing journals



- 1 = Main bearing journal
- 2 = Crank pin bearing journal

Observations

Table 3 - Inspection without Opening-up (7.1)			
Checks		Symbol	Observations
Oil Flow	OF	• U	OK, similarity Uneven
Oil Jets (Crosshead, Guide Strips)	OJ	• R M TW	OK, similarity Reduced Missing Twisted
White Metal	WM	• SQ CR L M	OK Squeezed out Cracks Loose Missing
Crosshead Guides	CG	• SC CO SW	OK Scratches Corrosion Silvery White
Oil Pan	OP	• WM	OK, clean White metal fragments
Oil Condition	OC	• DK WT	OK Dark Water traces

Table 4 - Open-up Inspection and Overhaul (7.2)				
Checks		Symbol	Observations	Ref. 2545-0100
White Metal	WM	• W HC OS CR CRC L M SSE CO	OK Wiping Hard Contact Oil Starvation Cracks Crack Cluster Loose Missing Spark Erosion Corrosion	7.3 II 7.4 7.7 7.5 7.5 7.1 7.1 6.2 7.4 2B, 6.1
Overlayer (Crosshead only)	OL	• TE W	OK Tearing Wiping	7.3 I 7.3 II
Transitions: Oil Wedge Bore Relief Tang. Run-out	OW BR TR	• RR W D	OK Ragged Ridges Wiping Disappeared	7.7, 7.10 2A 7.7, 7.10 2B 7.10BII, 7.10 2C
Journal/Pin	J/P	• SE CO SW SC	OK Spark Erosion Corrosion Silvery White Scratches	6.2 7.4B, 6.1 6.1 7.4, 7.11
Back of Shell	BS	• FR TH	OK Fretting Trapped hard Particles	7.4 7.4

Inspection Records, Example

M/V	Engine type:		CW / CCW 1)		Running hours Total	4)	Checked by:	4)	
Yard	Builder:		Engine No.:				Date:	4)	
No.:	Built year:								
Journal/pin Roughness 3)		N6 (M)		N3 (E)		N6 (E)			
Hydr. open. pressure		880		900		870			
Clearance (mm)	Top	Aft	0,5		0,4		0,4		
		Fore	0,5		0,4		0,4		
Description of Condition		HB/4 / MBD / WM / CR; L; M; HC / 7h 15' ; l _I ; r //		CHB/5 / MBD / WM; OW / W; RR / 5h 45' ; l _{II} ; (a,b) //		CRB/3 / MBD / WM / M; W / 1h 15' ; l _{III} ; (a,b, +/-c) //		CHB/6 / OF; u / OJ; R; TW / WM; SQ //	
		7.2		7.2		7.2		7.1	
		10000		15000		8000		8000	
		N.N.		N.N.		N.N.		N.N.	
		8/3-93		8/3-93		8/3-93		8/3-93	

1) Engine direction of rotation, seen from aft, must be underlined; CW: Clockwise, CCW: Counter Clockwise

2) Inspection without opening-up: 7.1; Open-up inspection: 7.2

3) It should be stated whether the roughness is measured: M, or evaluated: E.

4) Only to be filled in, if all observations are carried out at the same running hours.

Inspection Records, Blank

M/V	Engine type: CW / CCW 1)		Running hours Total 4)	Checked by: 4)
Yard:	Builder:	Engine No.:		
No.:	Built year:			Date: 4)

Journal/pin Roughness 3)						
Hydr. open. pressure						
Clearance (mm)	Top	Aft				
	Fore					
Description of Condition						
Type of inspection 2)						
Engine running hours						
Checked by						
Date						

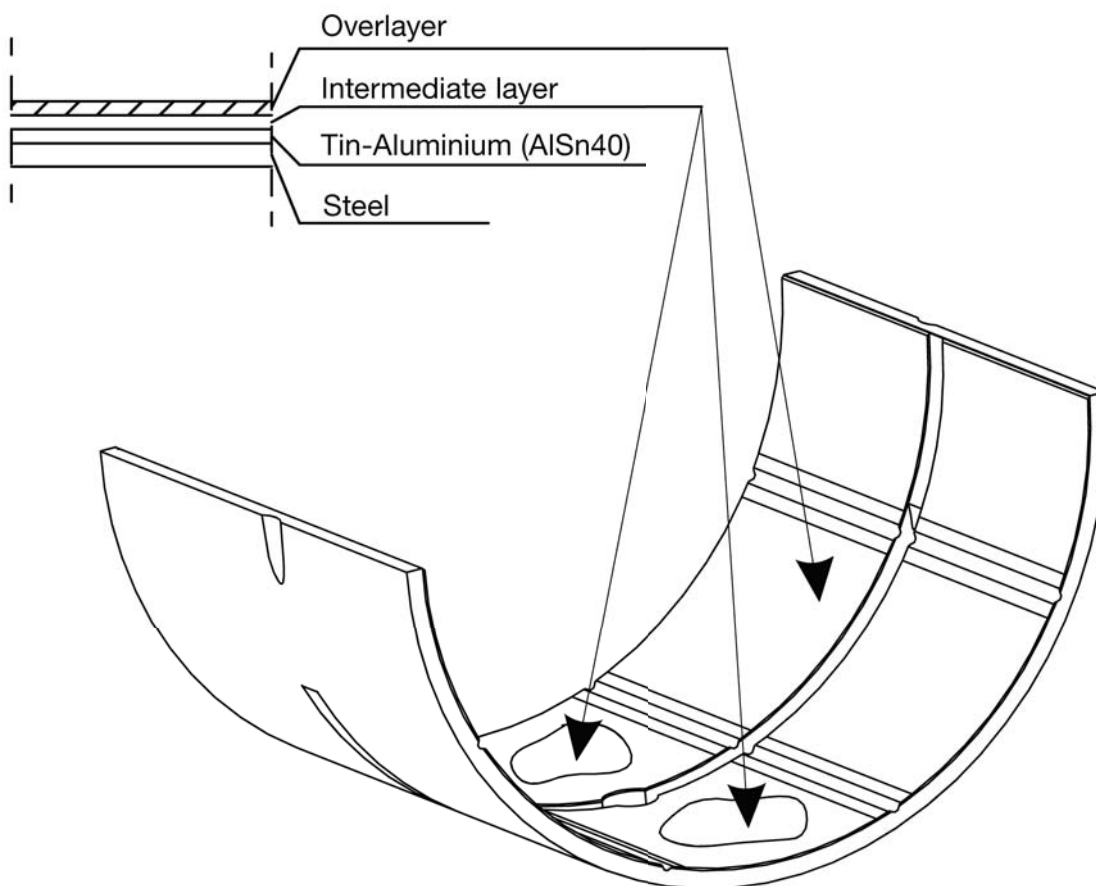
1) Engine direction of rotation, seen from aft, must be underlined; CW: Clockwise, CCW: Counter Clockwise

2) Inspection without opening-up: 7.1; Open-up inspection: 7.2

3) It should be stated whether the roughness is measured: M, or evaluated: E.

4) Only to be filled in, if all observations are carried out at the same running hours.

Crosshead Bearing Lower Shells



Acceptance Criteria for Tin-Aluminium Bearings with Overlayer

Engine Type:	Max. allowed exposure (mm ²)
26MC	2900
S30ME-B	4200
35MC	4300
35ME-B	5700
40ME-B	7500
42MC	6700
45ME-C/ME-B	9100
46MC-C/ME-B	8100
50MC-C/ME-C/ME-B8	9600
G50ME-C9	11200
S/G50ME-B9	11700
60MC-C/ME-C/ME-B	15100
65MC-C/ME-C	16900
70MC-C/ME-C	20400
Maximum allowed exposure of the intermediate layer. Values are calculated according to SL05-460/NHN.	

Drawing

2555-0150-0005

M/V	Engine type:		Total running hours	Checked by:
	Builder:	Engine No.:		Date:
Yard No.:	Built year:			
For comparison of measurements	Ships draught, aft measured (m)		Fully loaded (m)	Ballasted (m)
	Jacket cooling water temp. (°C)		Main lub. oil temp. (°C)	

Fig. 1

For deflection readings, a dial micrometer is to be placed in the punch marks.
Closing of the crankthrow is regarded as negative deflection

Fig. 2

(Unit for measuring and calculating: 1/100 mm)

Fig. 3

Crankpin position		Cyl. No. and deflections						
		1	2	3	4	5	6	7
Near bottom, manoeuvring side	B ₁							
Manoeuvring side	M							
Top	T							
Exhaust side *)	E							
Near bottom, exhaust side	B ₂							

*) Positions M and E are included for reference purposes.

Fig. 4

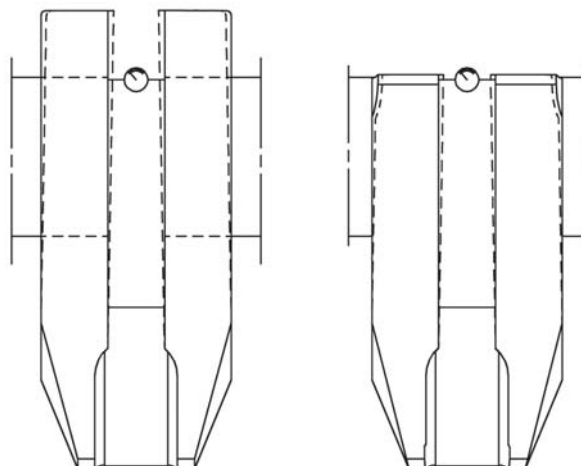
Bottom 1/2 (B ₁ + B ₂) = B								
---	--	--	--	--	--	--	--	--

Fig. 5

Vertical Deflections								
Top-bottom or (T - B) = V								
For permissible deflections, see Drawing 2555-0180. See also item 2.2 'Checking the Deflections' on Description 2545-0110.								

Fig. 6

Horizontal Deflections								
Exhaust - Manoeuvring side (E - M) = H								



Crankshaft Deflections, Limits

Type ME/ME-C/ME-B	Normally obtainable for a new or recently overhauled engine		Realignment recommended		Absolute maximum permissible
	mm		mm		mm
	1	2	1	2	All cyl's
K80ME-C9	0.29	0.75	0.77	0.95	1.16
K98ME7	0.24	0.64	0.65	0.80	0.98
K98ME-C7	0.20	0.53	0.54	0.66	0.81
L60ME-C8	0.22	0.58	0.59	0.73	0.89
L70ME-C8	0.26	0.68	0.70	0.86	1.05
S30ME-_9	0.17	0.43	0.44	0.54	0.66
S35ME-_9	0.19	0.50	0.52	0.63	0.77
S40ME-_9	0.22	0.58	0.59	0.73	0.89
S50ME-_9	0.29	0.75	0.77	0.94	1.15
S80ME-_9	0.45	1.17	1.20	1.48	1.80
S90ME-_9/10	0.42	1.08	1.11	1.36	1.66
S46ME-_8	0.23	0.60	0.62	0.76	0.93
S50ME-_8	0.23	0.61	0.62	0.77	0.94
S60ME-_8	0.28	0.73	0.75	0.93	1.13
S65ME-_8	0.33	0.85	0.87	1.07	1.31
S70ME-_8	0.33	0.86	0.88	1.08	1.32
S80ME-_8	0.38	0.98	1.00	1.23	1.50
S90ME-_8	0.36	0.94	0.96	1.19	1.45

Drawing

2555-0180-0008

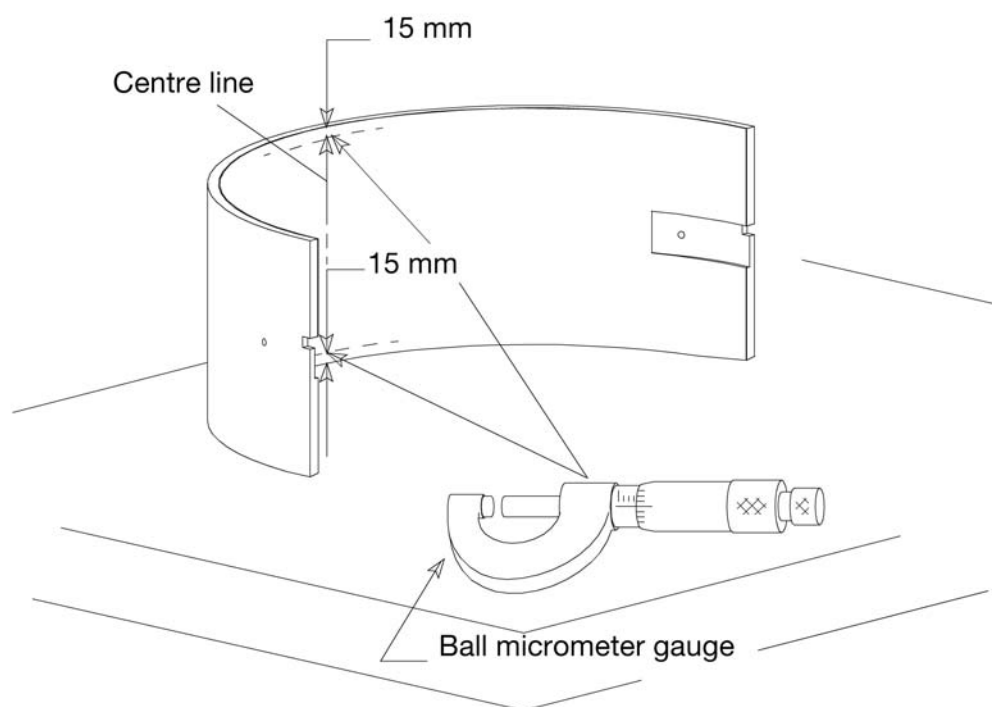
Type ME/ME-C/ME-B	Normally obtainable for a new or recently overhauled engine		Realignment recommended		Absolute maximum permissible
	mm		mm		mm
	1	2	1	2	All cyl's
G40ME-_9	0.26	0.67	0.69	0.84	1.03
G45ME-_9	0.30	0.77	0.79	0.98	1.19
G50ME-_9	0.33	0.86	0.88	1.08	1.32
G60ME-_9	0.36	0.93	0.95	1.17	1.43
G70ME-_9	0.40	1.03	1.05	1.30	1.58
G80ME-_9	0.49	1.28	1.31	1.62	1.97
G95ME-_9	0.45	1.18	1.21	1.48	1.81

1. Normal for all crank throws.
2. Permissible for the **foremost** crank throw, when the crankshaft fore end is provided with a torsional vibration damper, tuning wheel or directly coupled to a generator rotor. Permissible for the **aftmost** crank throw, when the crankshaft generator end is provided with a flexible coupling.

When judging the alignment on the above "limiting-value" basis, make sure that the crankshaft is actually supported in the adjacent bearings.

See description 2545-0110 'Alignment of Main Bearings' point 2.3 'floating journals'.

Measuring of Crown Thickness



See also Chapter 2545-0100 item 13, 'Check of Bearings before Installation'

Check Measurements

Drawing
2555-0185-0002

Safety**Precautions**

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T14-35	Thrust piece tightening torque	450	Nm
T14-42	Crosshead, complete	2800	kg
T14-52	Connecting rod studs, screwing-in torque	680	Nm
T22-78	Piston complete	1500	kg
T25-12	Crosshead bearing, top clearance max.	0.65	mm
T25-13	Crosshead bearing, top clearance min.	0.30	mm
T25-14	Oil wedge length, L	16	mm
T25-15	Crosshead bearing cap	300	kg
T25-16	Crosshead bearing shell, upper	50	kg
T25-17	Crosshead bearing shell, lower	70	kg
T25-18	Crosshead bearing cap with bearing shell	500	kg
T25-19	Crosshead with piston and guide shoes	4200	kg
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1470-0300	041	Wire guide
1470-0300	053	Lifting attachment for connecting rod
1470-0300	077	Chain for suspending piston

Plate	Item No.	Description
1470-0300	090	Bracket, support of crosshead
1470-0300	112	Rubber cover for croshead
1470-0300	124	Rubber cover for croshead
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	059	Hose with unions, 3000 mm
7670-0100	060	Hose with unions, 5000 mm
7670-0100	106	5-way distributor block, complete
7670-0300	-	Lifting tools, etc
7670-0410	054	Feeler gauge set
7670-0410	066	Slide caliper

**WARNING**

Observe safety precautions when working in the crankcase.
See description 0545-0100.

White Metal

The top clearance between the journal and a new bearing shell is the result of a summation of the production tolerances of the bearing assembly components.

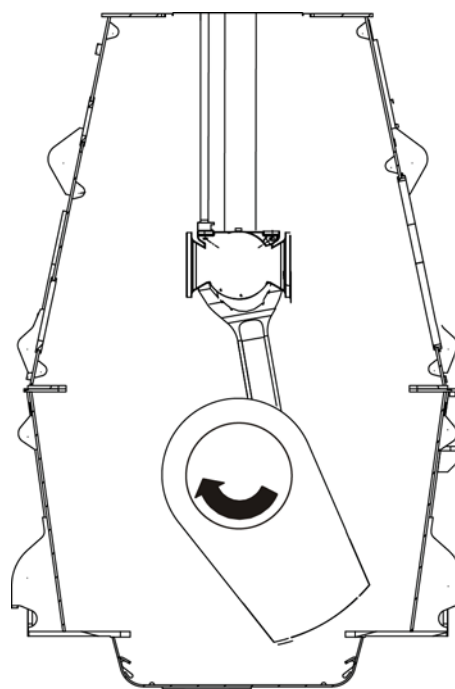
The top clearance for a new bearing will normally be in the range stated *in data*. Note that the figures are to be used for guidance only.

For the top clearance of a specific bearing,
see the measurement in the testbed sheet from engine builder.

1. Crankcase

Open the crankcase door at the relevant cylinder.

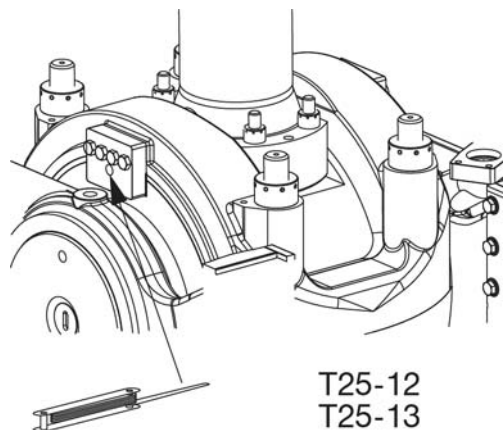
Turn the crankthrow concerned to BDC.



2565-0201-0002C02

2. Measurement of bearing clearance

Insert a suitable feeler-gauge into the hole below the bolts on the locking plate. Push in sufficiently, so that the gap can be registered.



2565-0201-0007C04

3. Measurement difference

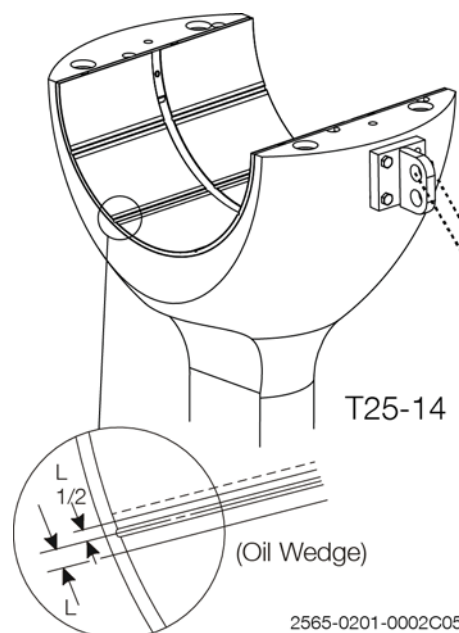
The difference between the **actual** clearance measurement and the measurement recorded in the Adjustment Sheet (or the clearance noted for a new bearing installed later) **must not** exceed 0.1 mm. If so, the crosshead bearing must be disassembled for inspection. *See dismantling procedure.*

For evaluation of the bearing shell, *see description 2545-0100 'Bearings'.*

4. Oil wedge

The wear limit for a crosshead bearing shell is confined to a 50% reduction of the oil wedge length L .

If the wear limit exceeds the 50% reduction, the bearing shell must be replaced by a new one.



2565-0201-0002C05

5. Alternate checking method
In case the reason for opening the crosshead bearing is a routine inspection, the following procedure is sufficient.
6. Measurement
Perform the clearance measurement.
See checking procedure, step 3.
7. Eyebolts
Mount the two eyebolts and tackles in the top of the crankcase in the fore and aft direction. Mount two eyebolts in the top of the guide shoes.

Turn to BDC, mount the connecting rod lifting attachments on the connecting rod. Use tackles to hold the connecting rod in the vertical position.

**WARNING****Safe working load (SWL)**

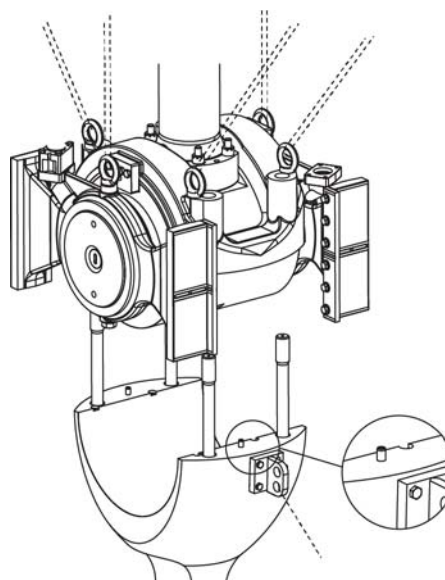
Always use lifting gear with sufficient SWL.

See data.

Unscrew the crosshead bearing cap hydraulic nuts.

For operation of the hydraulic tools, see Section 7665-0101.

8. Bearing cap
Mount two eyebolts in the bearing cap and use two small tackles in the athwartships direction to lift the bearing cap free of the guide pins and to keep the bearing cap balanced.



2565-0201-0002C08

9. Inspection of bearing Use the tackles in the crankcase top to lift the crosshead and piston high enough to allow inspection of the lower crosshead bearing.

NOTICE

Ensure that the crosshead is lifted simultaneously fore and aft, i.e. by placing marks on the guide planes using a felt tipped pen.

If the lower bearing shows no anomalies the piston and crosshead is lowered again and the crosshead bearing cap nuts are mounted.

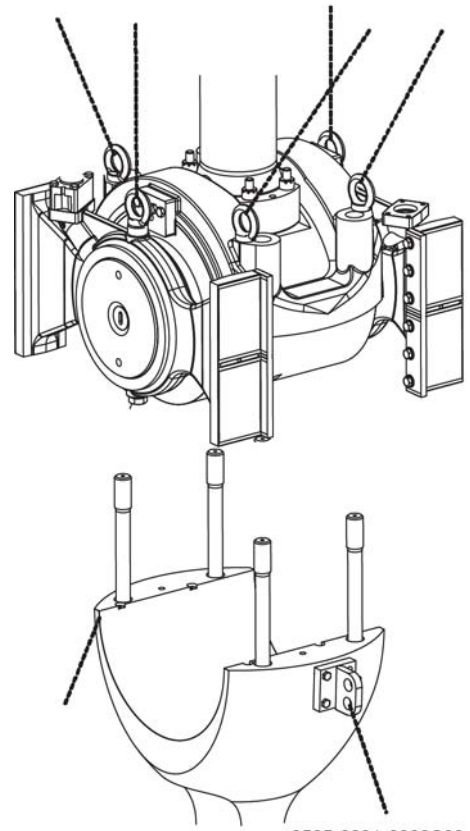
Recheck the bearing top clearance.

Remove all tools.

NOTICE**Remember**

If there are any doubt concerning damage to the upper bearing, the bearing has to be dismantled and checked.

See dismantling procedure.



2565-0201-0002C09

This procedure applies to the following two dismantling situations:

- with piston installed
- with piston removed

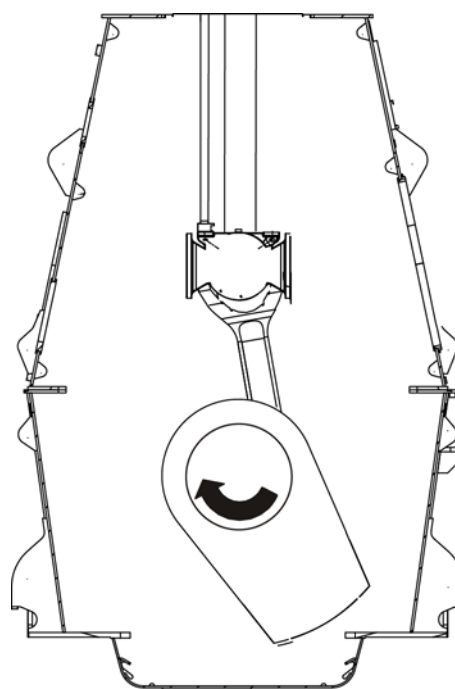
NOTICE

With piston removed

If this procedure is carried out with the piston removed from the engine, the first five steps can be skipped.
See *dismantling procedure, step 6*.

1. Piston rod foot

Turn the crankshaft down far enough to give access to the nuts and screws on the piston rod.



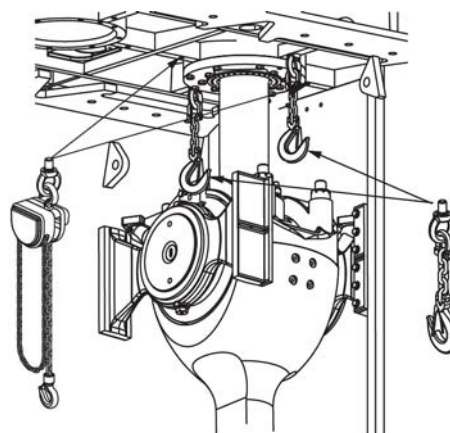
2565-0201-0002C02

2. Securing chains

Mount two chains in the inner screw holes in the top of the crankcase, in the athwartship direction, for suspending the piston rod.

Mount two eyebolts in the fore and aft direction.

Hook two tackles on the eyebolts.



2565-0201-0010D02

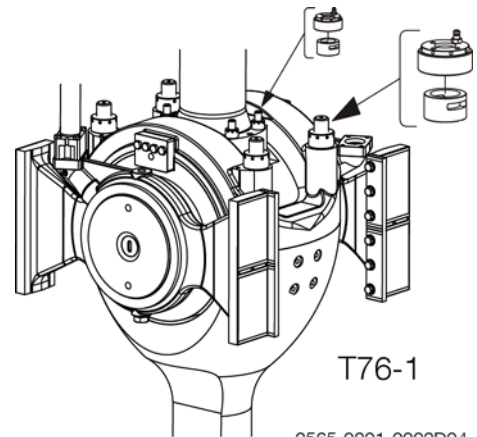
3. Loosen screws

Mount the spacer rings and the hydraulic jacks for loosening the crosshead bearing cap nuts and the piston rod nuts.

Loosen the nuts.

For operation of the hydraulic tools, see work card 7665-0101.

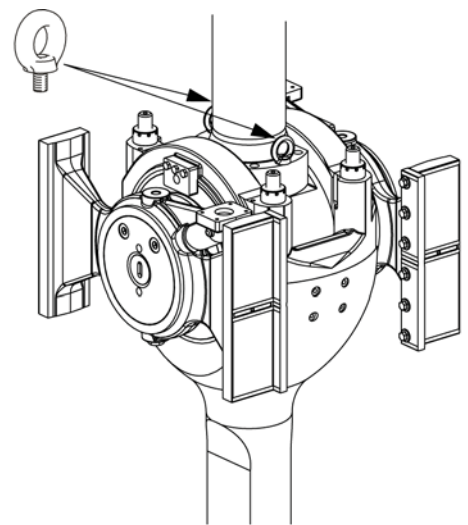
Remove the hydraulic jacks, and unscrew the nuts.



4. Lifting eyebolts

Mount a lifting eyebolt on each side of the piston rod.

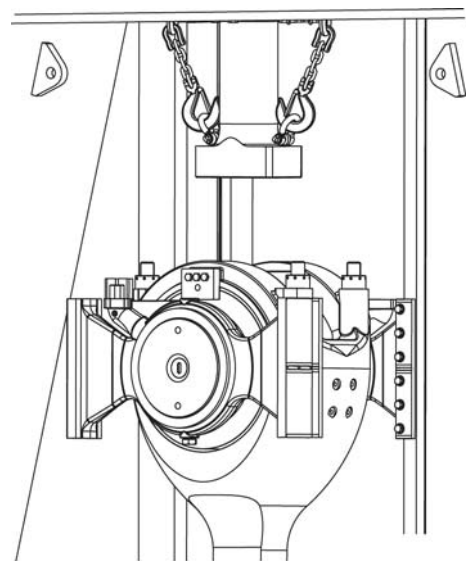
Turn the crosshead to TDC.



5. Suspend the piston rod

Hook the chains to the lifting eyebolts in the piston rod.

Turn the crosshead downward, and the piston rod will then remain suspended from the two chains.



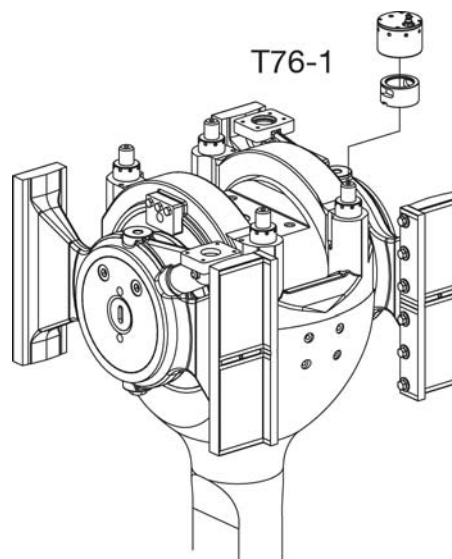
6. With piston removed Turn to BDC.

7. Loosen hydraulic nuts
Place the spacer rings around the nuts and screw the hydraulic jacks on to the studs.

Loosen the crosshead bearing cap nuts.

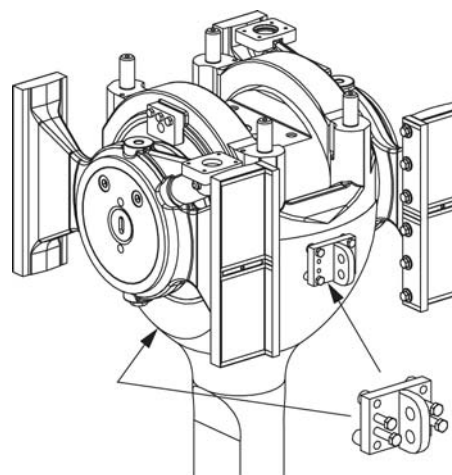
For operation of the hydraulic jacks, see work card 7665-0101.

Remove the hydraulic jacks and the spacer rings, and unscrew the nuts.



2565-0201-0010D07

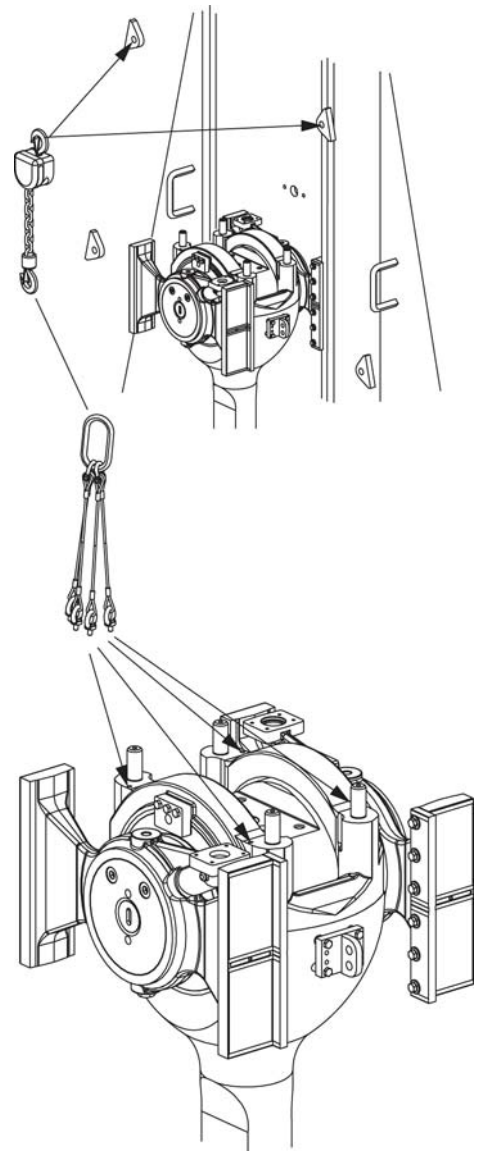
8. Lifting attachment
Mount the lifting attachments on the head of the connecting rod.



2565-0201-0010D08

9. Bearing cap removal Suspend two tackles from the lifting brackets, in the athwartship direction.

Mount the lifting tool on the top of the crosshead bearing cap.



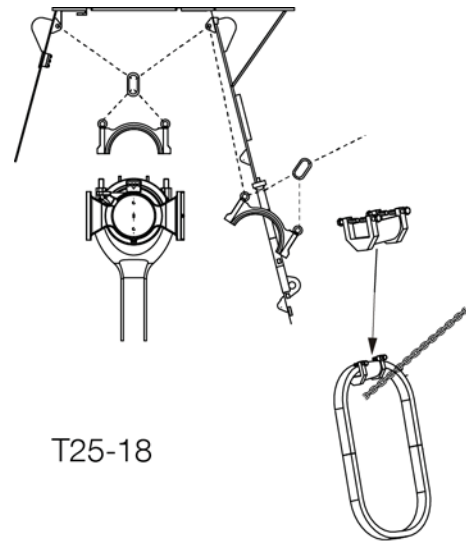
2565-0201-0010D09

10. Wire guide

Mount the wire guide at the top of the crankcase door frame to prevent damage.

Hook the tackles on to the eyebolts, and remove the bearing cap from the engine.

Check the upper part of the journal.



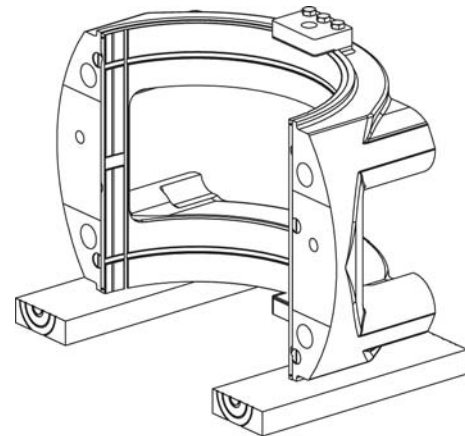
T25-18

2565-0201-0002D10

11. Land the bearing cap

Place the bearing cap on one side on a couple of wooden planks.

Check the bearing shell.
See checking procedure.



2565-0201-0010D11

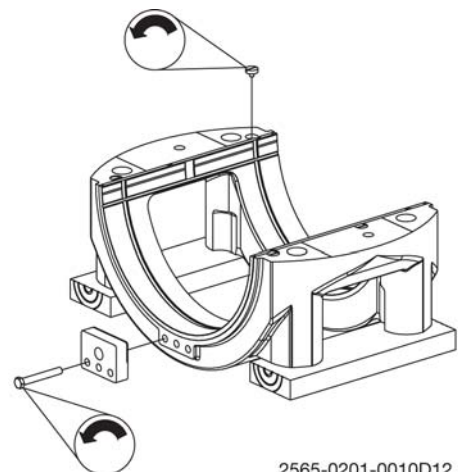
12. Bearing shell

If it is necessary to remove the bearing shell, carefully turn the bearing cap upside down by means of roundslings and the engine room crane.

Remove the screws for the thrust piece.

Remove the locking screws for the bearing shell.

Remove carefully the bearing shell.



2565-0201-0010D12

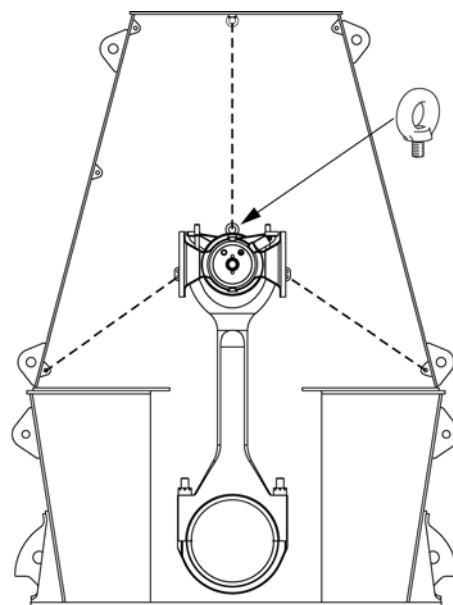
13. The tackle hooks

Attach the tackle hook from the frame box wall to the lifting attachments on the connecting rod.

Haul the tackles tight.

Mount two eyebolts on top of the guide shoes.

Attach the for and aft tackle hook to the guide shoes.



2565-0201-0010D13

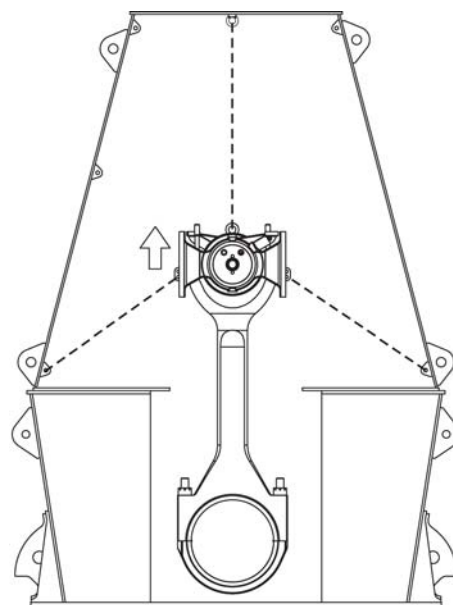
14. Lifting the cross head

Remove the connecting rod studs on the exhaust side.

Using the tackles, lift the guide shoe far enough to ensure clearance between the connecting rod and the guide shoe.

15. Free the crankpin

Turn the crankthrow carefully towards BDC while following with the tackles, thus continuously supporting the connecting rod.



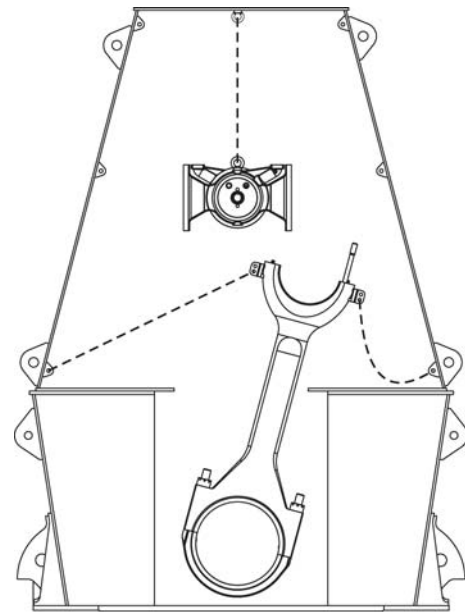
2565-0201-0010D14

16. Tilt the connection rod

Using the tackle tilt the connection rod towards the doorway.

Check the lower part of the crosshead journal and the lower bearing shell.

For checking of journal and bearing shells, see description 2545-0100, *Bearings*.

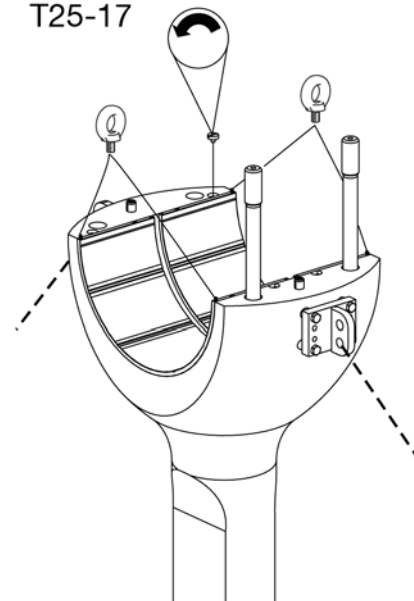


2565-0201-0010D15

17. Bearing shell

Dismount the locking screws, and turn the bearing shell so far out that an eyebolt can be mounted

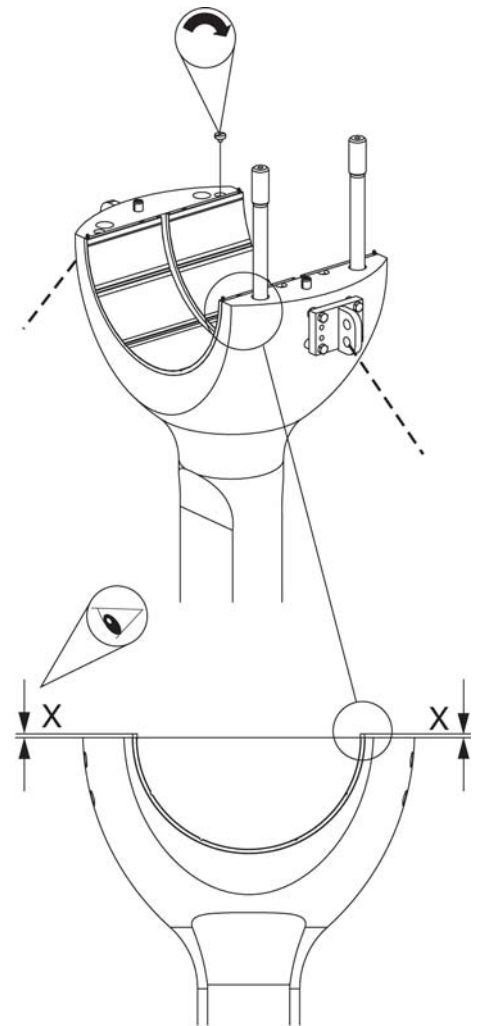
T25-17



2565-0201-0010D16

1. Mounting the bearing shell Mount and secure the bearing shell in the bearing housing.

The excess height **X** is to ensure the correct tightening-down of the bearing shell and **must not** be eliminated.



2565-0201-0010M01

2. Raise the connecting rod
- Raise the connecting rod to an upright position.

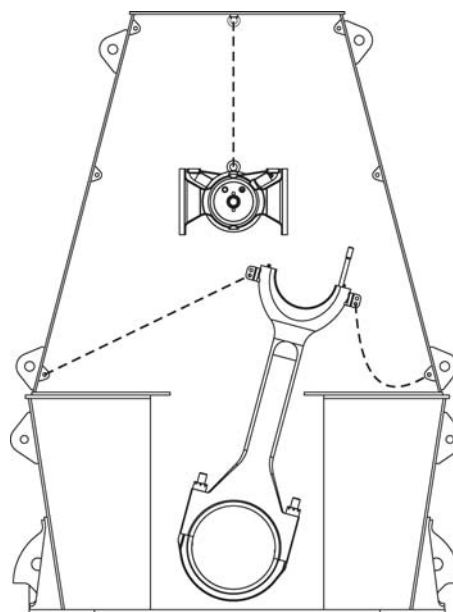
Mount the connection rod studs. *See data.*

NOTICE

Take care that the bearing studs do not damage the crosshead.

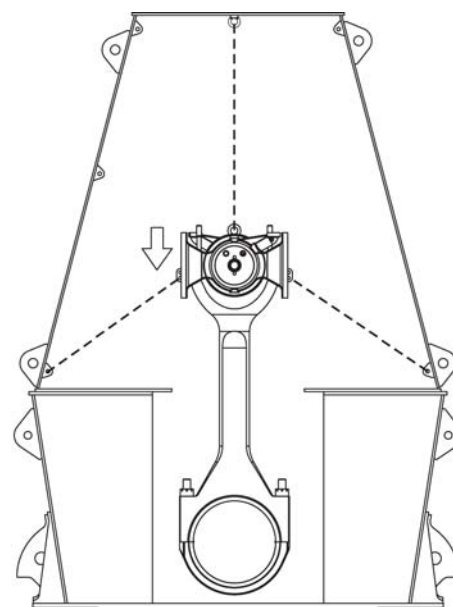
Take care that the guide shoes do not damage the bearing shell.

Lubricate the crosshead bearing with clean lube oil before landing the crosshead journal in the bearing.



2565-0201-0010D15

3. Crosshead guides
- Lower the guide shoes and carefully land it on the crosshead bearing.

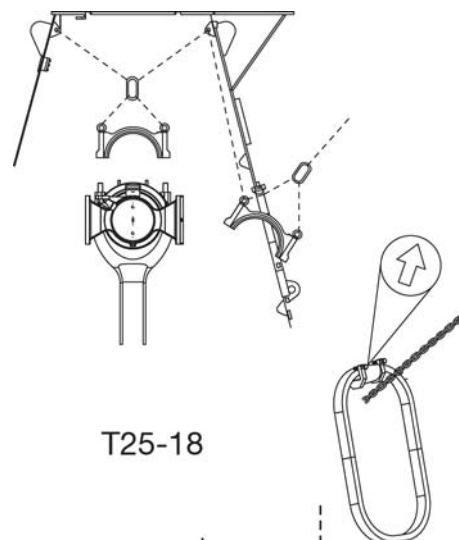


2565-0201-0010M02

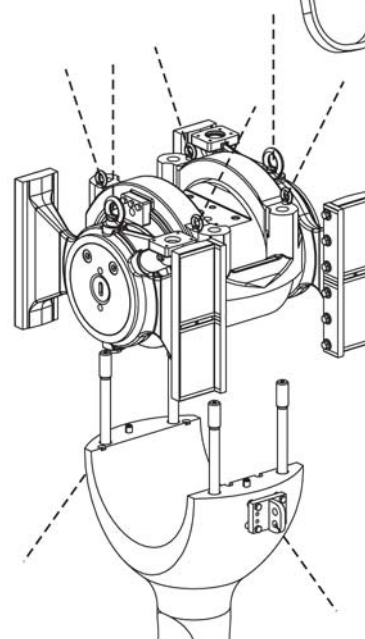
4. Land the bearing cap Lift the bearing cap into the engine.

Lower the bearing cap onto the crosshead and remove the tackles.

Remove the lifting attachments from the connecting rod and the wire guide from the door frame.



T25-18



2565-0201-0010M04

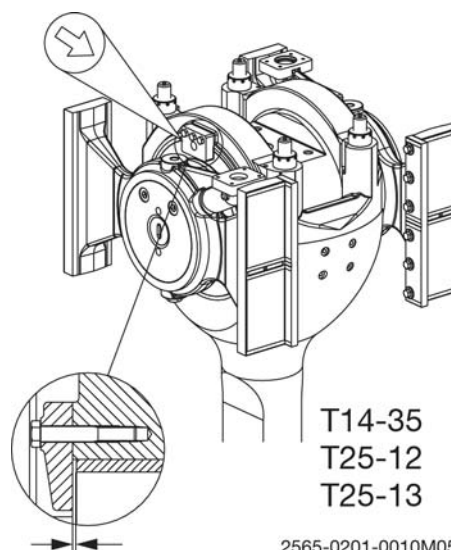
5. Thrust pieces

Mount the thrust pieces for axial guidance of the connecting rod.

For tightening torque, see data.

NOTICE

It must be ensured that a clearance between the thrust piece and the crosshead exists fore and aft before any tightening of the trust piece.

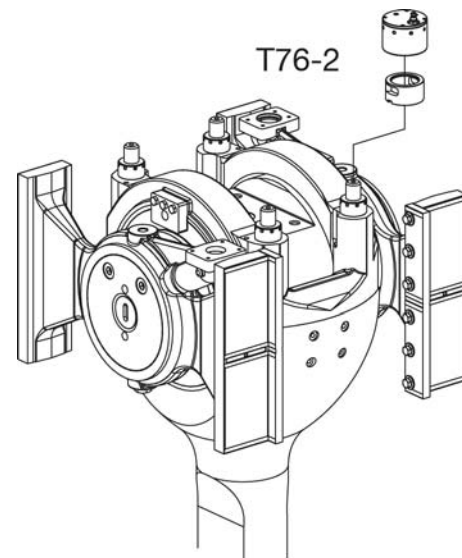
T14-35
T25-12
T25-13

2565-0201-0010M05

6. Hydraulic nuts

Tighten all four crosshead bearing cap nuts simultaneously. *See data.*

For operation of hydraulic jacks, see work card 7665-0101.



2565-0201-0010M06

Crosshead Bearing • Mounting

7. Mount the piston

If the piston has been removed from the engine, mount the piston.

See work card 2265-0401, mounting procedure.

If the piston is suspended, mounting of the piston should be carried out as described in the following steps.

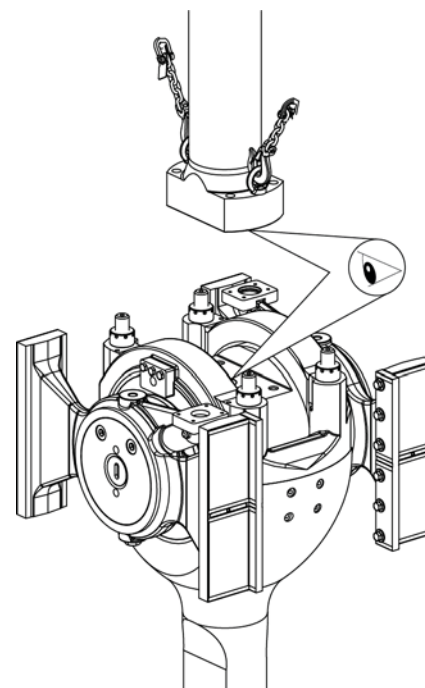
See mounting procedure, step 8-10.

8. Land the piston rod

If any shims have been removed from the crosshead, mount them again.

Turn the crosshead upwards until the piston rod lands on the crosshead.

Ensure that the guide ring in the crosshead fits correctly in the centre hole of the piston rod.

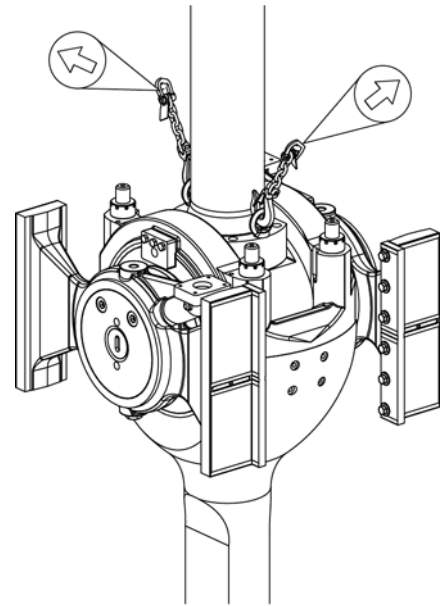


2565-0201-0010M08

Work Card
2565-0201-0011

9. Remove the chains and the eyebolts

Unhook the chains from the lifting eyebolts in the piston rod. Remove the chains and eyebolts from the top of the crankcase, from the piston rod and from the crosshead bearing cap.



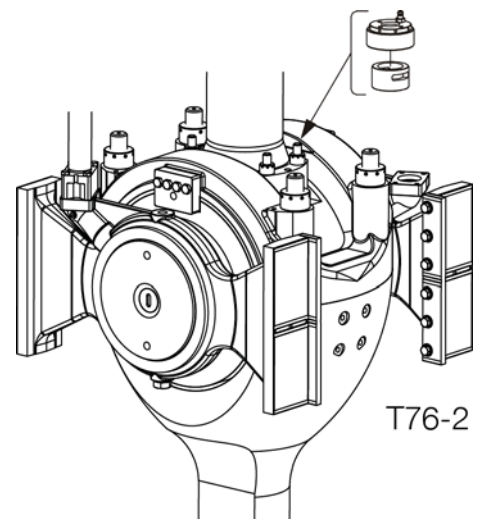
2565-0201-0010M 09

10. Tightening the piston rod screws

Turn down to BDC.

Mount the hydraulic nuts on the studs.

Tighten the nuts on the piston rod foot simultaneously. *See data.*



T76-2

2565-0201-0002M10

Safety**Precautions**

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T14-52	Connecting rod studs, screwing-in torque	680	Nm
T25-22	Crankpin bearing clearance, max.	0.75	mm
T25-23	Crankpin bearing clearance, min.	0.35	mm
T25-25	Crankpin bearing, upper shell	35	kg
T25-26	Crankpin bearing, lower shell	30	kg
T25-27	Crankpin bearing cap+shell+bearing studs	400	kg
T25-28	Piston + Crosshead + Connecting Rod	5700	kg
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1470-0300	041	Wire guide
1470-0300	053	Lifting attachment for connecting rod
1470-0300	090	Bracket, support of crosshead
1470-0310	-	Connecting rod, hydraulic tools
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	059	Hose with unions, 3000 mm
7670-0100	060	Hose with unions, 5000 mm
7670-0100	118	3-way distributor block, complete
7670-0300	-	Lifting tools, etc
7670-0410	054	Feeler gauge set
7670-0410	066	Slide caliper

**WARNING**

Observe safety precautions when working in the crankcase.
See description 0545-0100.

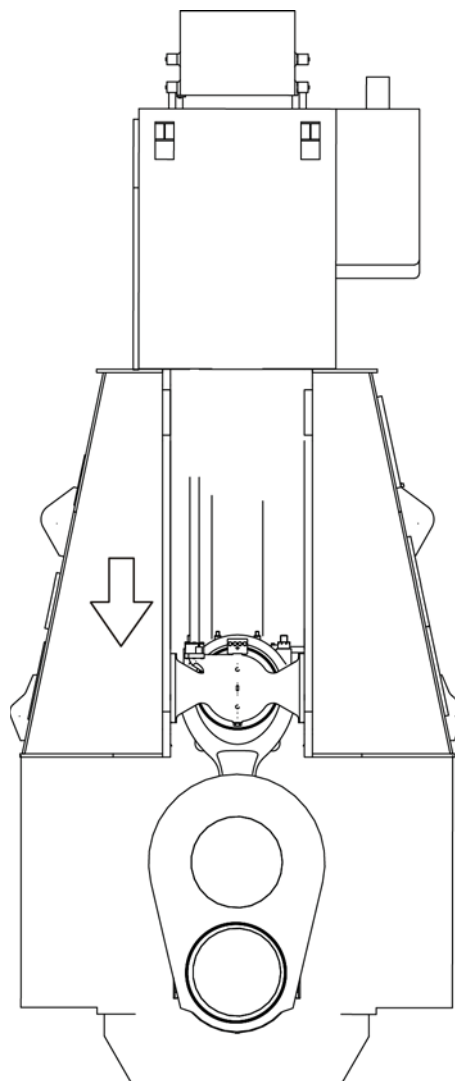
The bottom clearance between the journal and a new bearing shell is the result of a summation of the production tolerances of the bearing assembly components.

For the bottom clearance of a specific bearing, *see the measurement in the testbed sheet from engine builder.*

1. Crankcase

Open the crankcase door at the relevant cylinder.

Turn the crank concerned to BDC.

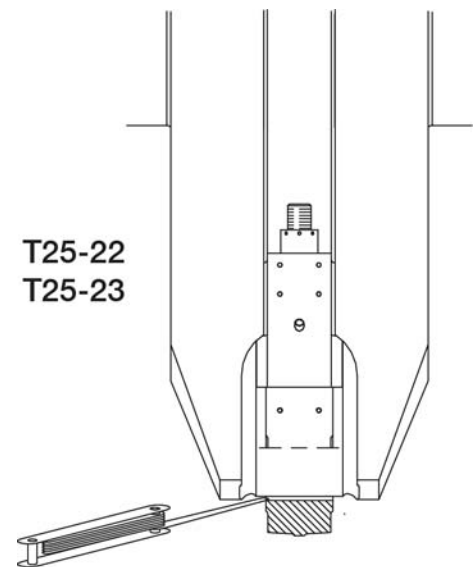


2565-0301-0002C02

2. Clearance

Measure the clearance in the crankpin bearing by inserting a feeler gauge at the bottom of the bearing shell in both sides. For bottom clearance, *see data*.

The difference between the **actual** clearance measurement and the measurement recorded in the Adjustment Sheet (or the clearance noted for a new bearing installed later) **must not** exceed 0.1 mm. If so, the crankpin bearing must be disassembled for inspection.
See dismantling procedure.



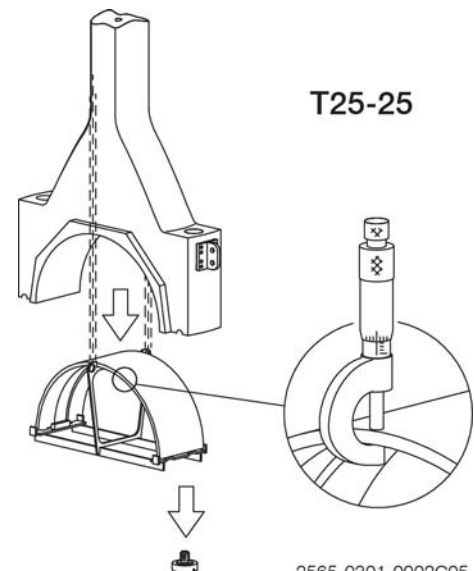
2565-0301-0002C03

3. Wear limit

The wear limit for the crankpin bearing shells is based on an evaluation of the bearing condition at the time of inspection.

An average wear rate of 0.01 mm per 10,000 hours is regarded as normal.

For further external inspection of the crankpin bearing, *see description 2545-0100*



2565-0301-0002C05

1. Wire guide

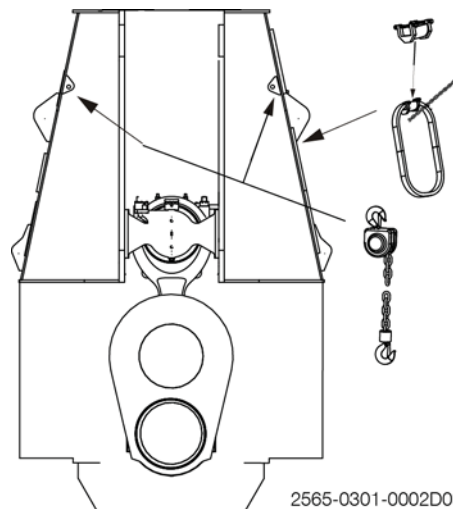
Suspend two tackles from the lifting brackets, in the athwartship direction.

Mount the wire guide in the top of the crankcase door opening.

**WARNING****Safe working load (SWL)**

Always use lifting gear with sufficient SWL.

See data.



2565-0301-0002D01

Crankpin Bearing • Dismantling

2. Turn the crank to TDC

Turn the crank to TDC.

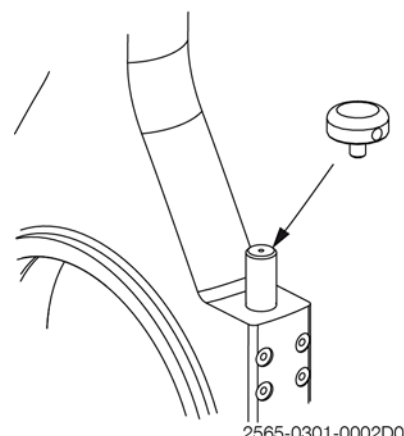
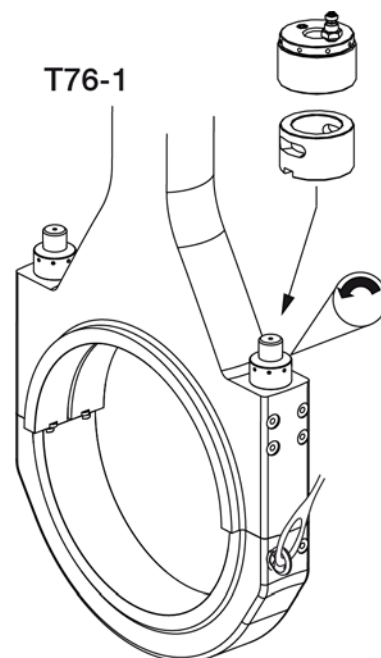
Mount eyebolts in each side of the crankpin bearing cap and, using shackles and wire ropes, hook on the tackles and haul tight.

Loosen the crankpin bearing stud nuts, using the hydraulic jacks.

For operation of the hydraulic jacks, see work card 7665-0101.

Remove the hydraulic jacks and the nuts.

Mount the protective screws on top of the studs. For the protective screws, see tool plate 1470-0300.



2565-0301-0002D02

Work Card

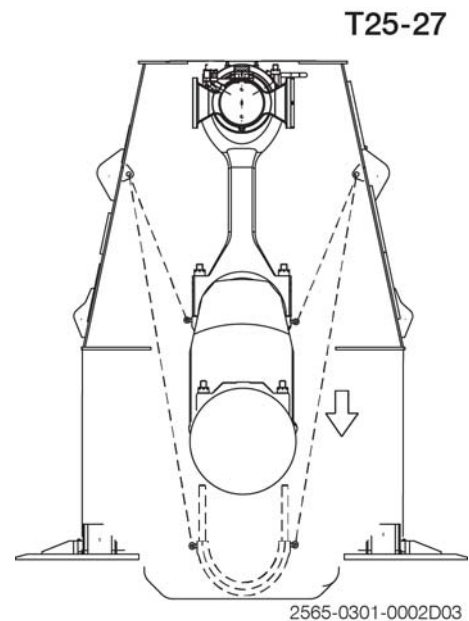
2565-0301-0002

3. Bearing cap

Lower the bearing cap while seeing carefully that the studs do not damage the crankpin journal.

Land the bearing cap on a wooden plate placed in the oil pan.

Inspect the bearing shell.



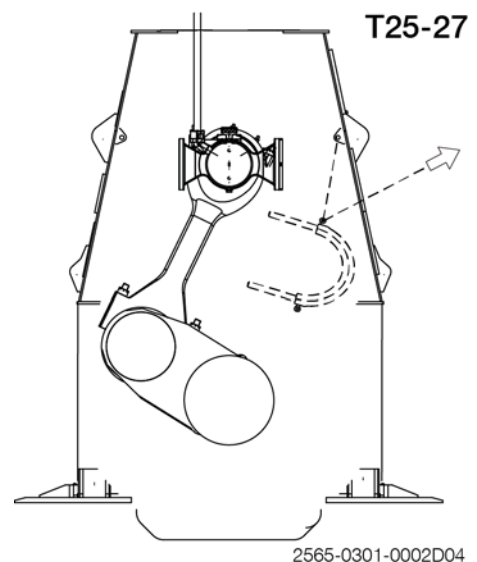
4. Bearing shell

If the bearing shell needs to be replaced, remove the whole bearing cap from the crankcase.

Suspend a tackle outside the engine above the crankcase door opening.

Turn the crankthrow to the exhaust side to give space for lifting out the crankpin bearing cap.

Using the tackle from the frame box inside wall, together with the tackle suspended outside the engine, lift the bearing cap out of the crankcase.

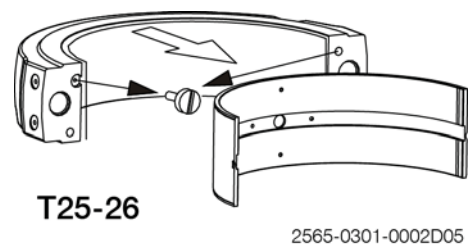


5. Replacing the bearing shell

Place the bearing cap on one side on a wooden plate.

Dismount the bearing shell lock screws and replace the bearing shell by a new one.

The bearing shells must be replaced in pairs. If only one of the shells needs replacement, MAN Diesel & Turbo should be contacted for advise beforehand.

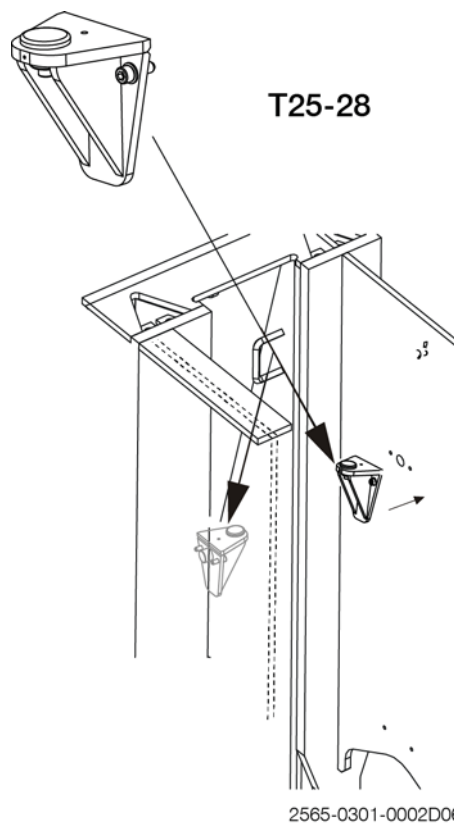


6. Crosshead supports Turn to TDC.

Mount the two supports for crosshead on the web plates.

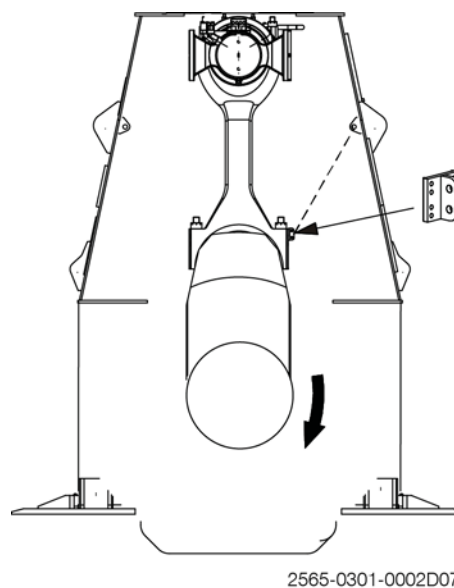
Carefully turn the crank to the manoeuvring side and down until the guide shoes rest on the supports.

Adjust the support brackets to the guide shoes so that the weight of the crosshead is evenly distributed on the two supports.



7. Lifting attachments Mount a lifting attachment for securing the connecting rod at the lower end, on the manoeuvring side.

Hook the tackle on to the lifting attachment.

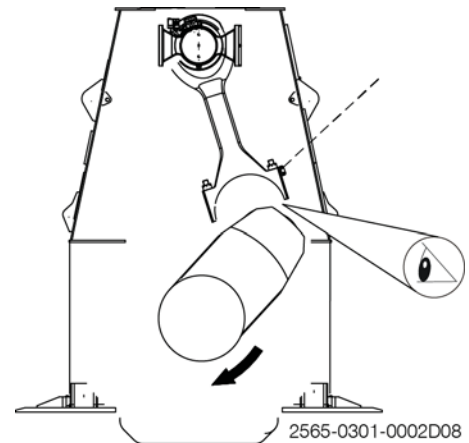


8. Bearing shell surface **Carefully** turn the crankshaft downwards, while following with the tackle. Make sure that the upper part of the bearing comes completely clear of the recess in the crankshaft when the parts begin to separate.

If necessary suspend a second tackle from the bracket below the doorway.

Continue turning the crankshaft until the bearing surface can be freely inspected.

Inspect the bearing shell surface and the crankpin journal.



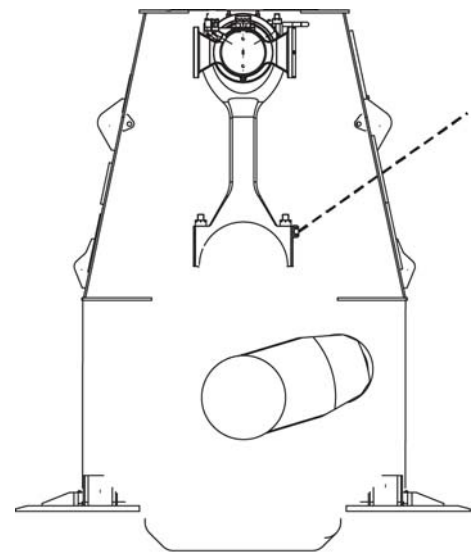
2565-0301-0002D08

9. Replacing bearing shell

If it is necessary to replace the bearing shell, proceed as follows:

Turn the crankshaft to horizontal position.

Release the tackle so that the connecting rod is hanging freely.

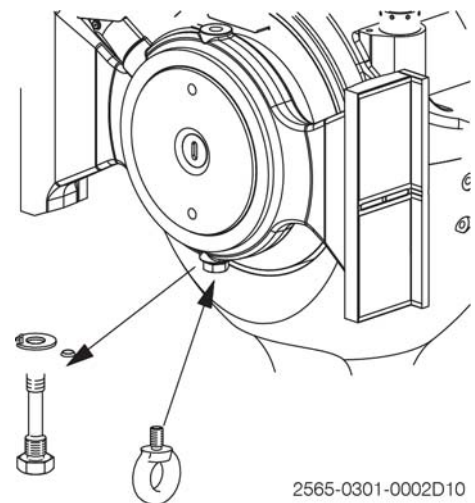


2565-0301-0002D09

10. Eyebolt

Mount an eyebolt in the bottom of each guide shoe.

Suspend two tackles from the eyebolts.

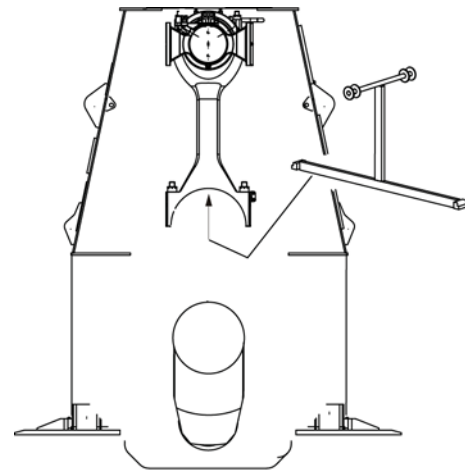


2565-0301-0002D10

11. Lifting tool

Place the lifting tool for the crankpin upper shell on the crank webs and hook the tackles on to the lifting tool.

Mount the tool on the bearing shell in the connecting rod, using the tackles, and haul tight.

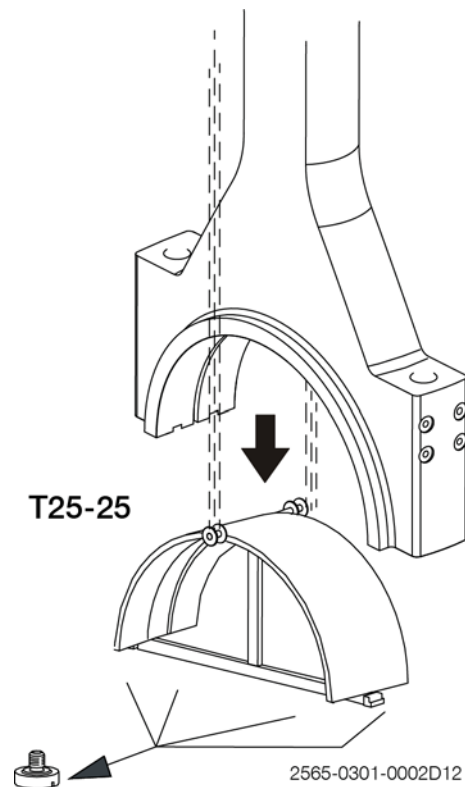


2565-0301-0002D11

12. Dismounting the bearing shell

Dismount the bearing shell lock screws.

Lower the lifting tool with the bearing shell, using the tackles.



2565-0301-0002D12

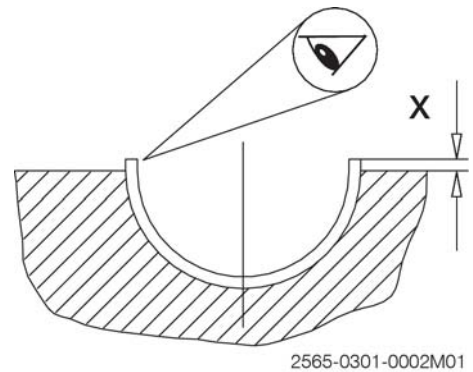
1. Replacing the bearing shells

If necessary, replace the bearing shells with new ones. The bearing shells **must** be replaced in pairs.

Bearing shells of three mm undersize are available as spares in case of journal rectification. Please contact MAN Diesel & Turbo for advice.

Coat the bearing shell surfaces and the journal with clean oil.

The excess height **X** is to ensure the correct tightening-down of the bearing shell, and **must not** be eliminated.

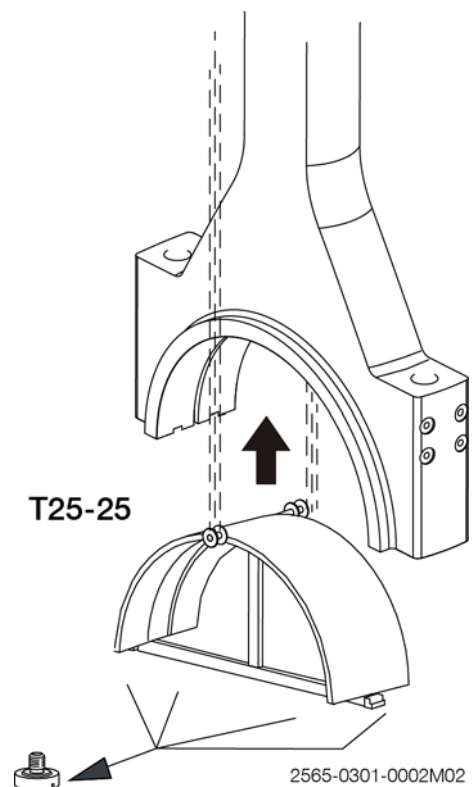


2565-0301-0002M01

2. Upper bearing shell

Lift the upper bearing shell for the crankpin concerned into the crankcase.

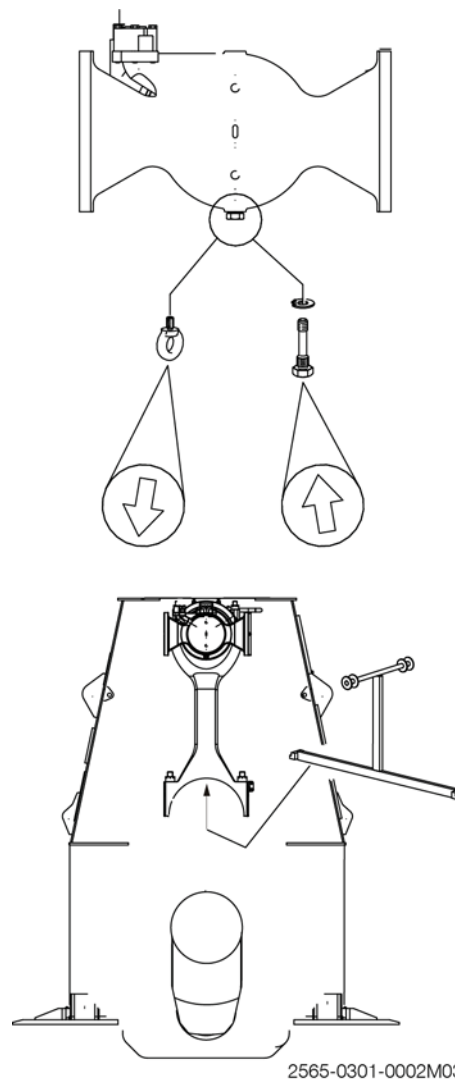
Carefully lift the bearing shell into position in the connecting rod, and mount the lock screws.



2565-0301-0002M02

3. Remove the tools

Remove the lifting tool, the tackles and the eyebolts from the guide shoes.

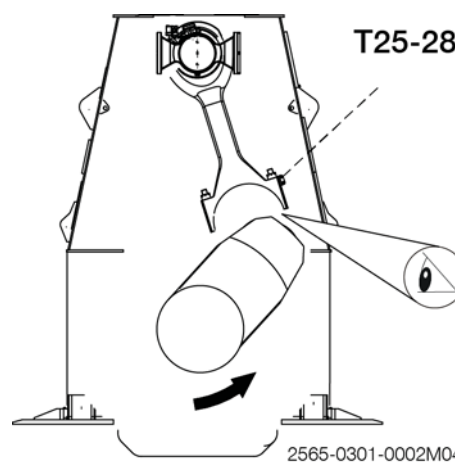


4. Connecting rod assembly

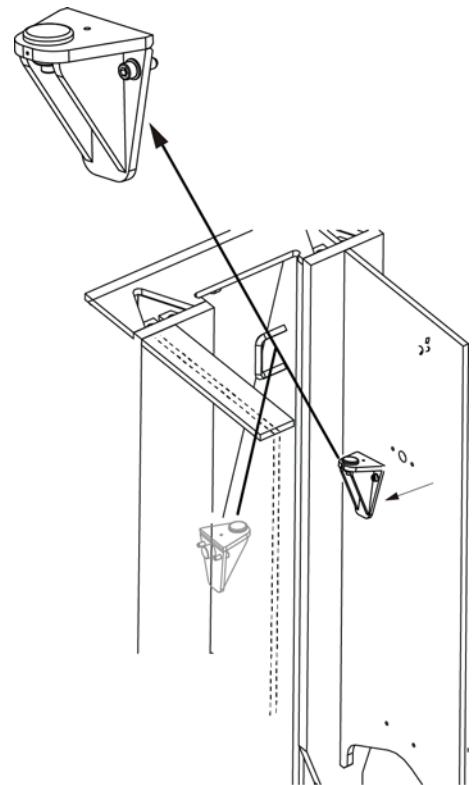
Hook the tackle on to a lifting pipe under the gallery platform and on to the lifting attachment on the connecting rod, and haul tight.

Carefully turn the crankshaft upwards, while following up with the tackle, making sure that the upper part of the bearing enters the recess in the crankshaft when the parts turn together.

Remove the tackle and the lifting attachment from the connecting rod.

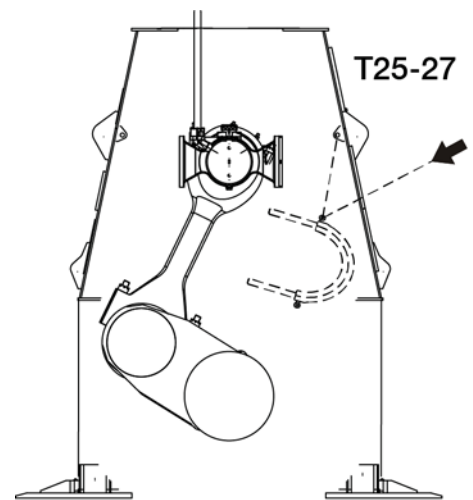


5. Crosshead support Turn the crosshead to TDC.
- Remove the two crosshead support brackets from the crosshead guides.



2565-0301-0002M05

6. Landing the bearing cap Suspend the tackles from the lifting brackets in the side of the frame box.
- Lift the bearing cap assembly into the crankcase and land it on a wooden plate placed in the oil pan.
- Remove the wire guide tool from the engine.



2565-0301-0002M06

7. Bearing cap assembly

Hook the tackles on to the wire ropes and lift the bearing cap into position against the connecting rod.

Check that the protective screws are still mounted on the studs.

NOTICE

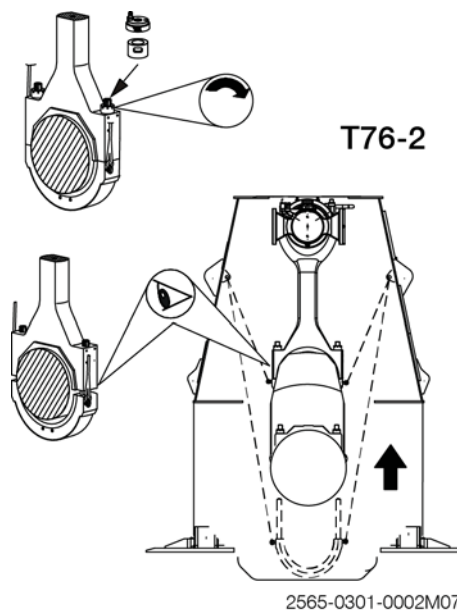
During mounting, take care that the studs do not damage the crankpin journal, and check that the guide pins mounted in the bearing cap enter the holes in the connecting rod.

Remove the protective screws.

Mount the nuts and, by means of spacer rings and hydraulic jacks, tighten the crankpin bearing cap. *See data.*

For operation of hydraulic jacks, see work card 7665-0101.

Remove the tackles from the side of the frame box.



Safety**Precautions**

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T25-30	Main bearing, top clearance max.	0.50	mm
T25-31	Main bearing, top clearance min.	0.20	mm
T25-32	Main bearing cap	600	kg
T25-33	Main bearing shell, upper	35	kg
T25-34	Main bearing shell, lower	40	kg
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1070-1030	-	Crankshaft tools
1470-0300	041	Wire guide
2570-0010	045	Pulley for wire for main bearing
2570-0010	070	Lifting tool for main bearing cap
2570-0010	082	Dismantling tool for main bearing shell
2570-0010	128	Retaining tool for main bearing shell
2570-0010	177	Mounting tool for thin bearing shell
2570-0010	189	Lifting tool for main bearing shell
2570-0400	-	Main bearing hydraulic tools
2570-0430	-	Main bearing measuring tools
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	023	Hydraulic pump, hand operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	106	5-way distributor block, complete
7670-0300	-	Lifting tools, etc
7670-0410	054	Feeler gauge set
7670-0410	078	Dial gauge and stand tool

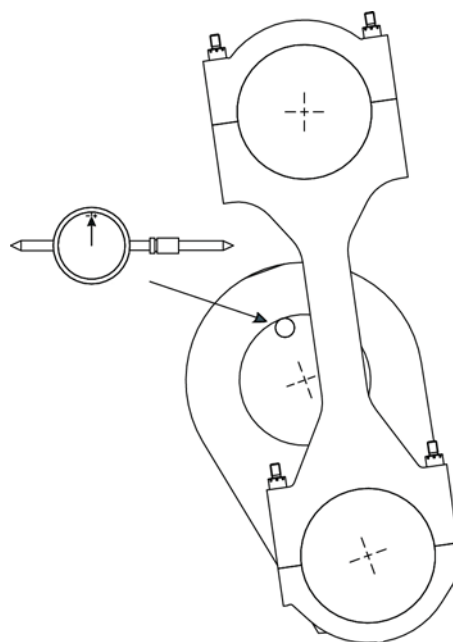
**WARNING**

Observe safety precautions when working in the crankcase.
See description 0545-0100.

1. General
The condition of the main bearings can be checked by:
 - Deflection readings
 - Visual checking
 - Edge checking and
 - Measuring of top clearance.
2. Crankshaft deflection readings
Crankshaft deflection readings should be taken while the ship is afloat (i.e. not while in dry dock).

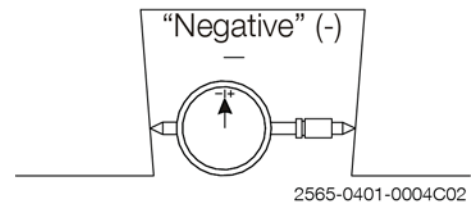
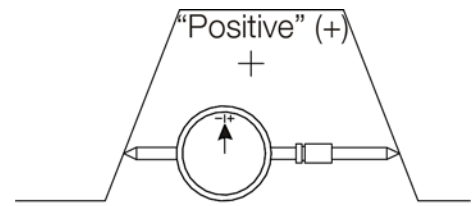
As the alignment is influenced by the engine temperature as well as the loading conditions, deflection measurements should, for comparison purposes, always be made under nearly the same temperature and load conditions.

3. Dial gauge
Place a dial gauge axially in the crank throw opposite the crankpin, as illustrated on the sketch. The correct mounting position is marked with punch marks on the crank throw. See also *Description 2545-0101*.



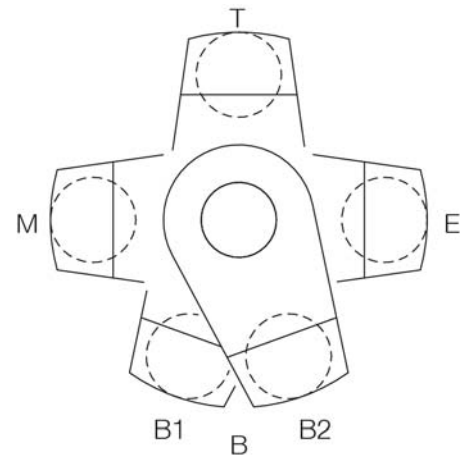
2565-0401-0004C01

4. The compression of the gauge “Closing” of the crank throw (compression of the gauge) is regarded as negative (–) and “opening” as positive (+).



5. Readings to be taken Set the dial gauge to zero at the **B1** side near BDC. Whilst turning clockwise, take the readings when the throw passes the positions:

- **B1** (near bottom)
- **M** (manoeuvring side)
- **T** (top)
- **E** (exhaust side)
- **B2** (near bottom)



Looking forward

B1
M
T
E
B2
$\frac{1}{2} (B1+B2)=B$

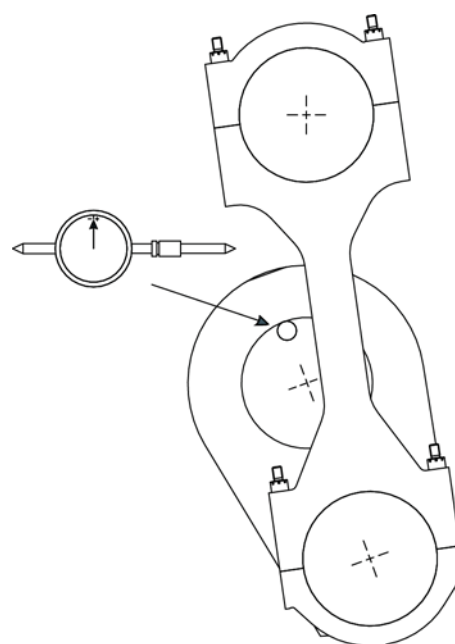
2565-0401-0004C03

6. Deflection readings When taking deflection readings for the three aftmost cylinders, the turning gear should, at each stoppage, be turned a little backwards to ease off the tangential pressure on the turning wheel teeth. Otherwise, this pressure may falsify the readings.

For evaluation of the crankshaft deflection readings, *see Description 2545-0100*.

If the crankshaft deflection (alignment indicator) is approaching the tolerance limits (*see Description 2545-0100*), the two adjacent main bearings must be checked for wear. See next page for checking of main bearing.

If the bearings are found to be in good order, please contact MAN Diesel & Turbo or the engine manufacturer for checking of the bedplate alignment. As reference, use the "after seatrial" deflection table.



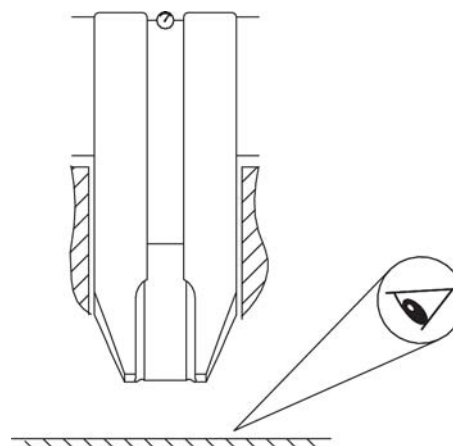
2565-0401-0004C01

7. Visual check

The condition of the bearing can be checked as follows:

Visually look for bearing metal fragments in the oil pan, and check the filters for metal fragments.

Such fragments can be from crosshead, guide shoe or crankpin bearings. If fragments are found, the damaged bearing can be found by edge checking with a feeler.



2565-0401-0004C05

8. General

Bearing damage usually propagates rather quickly towards the edge of the bearing where, eventually, it causes chips to be broken off, which means that loose pieces of white metal can fall down into the crankcase beneath the bearing support.

Large, thick pieces will normally be found during a crankcase inspection, and small, thin pieces can enter the filter. A check of the bearing edges together

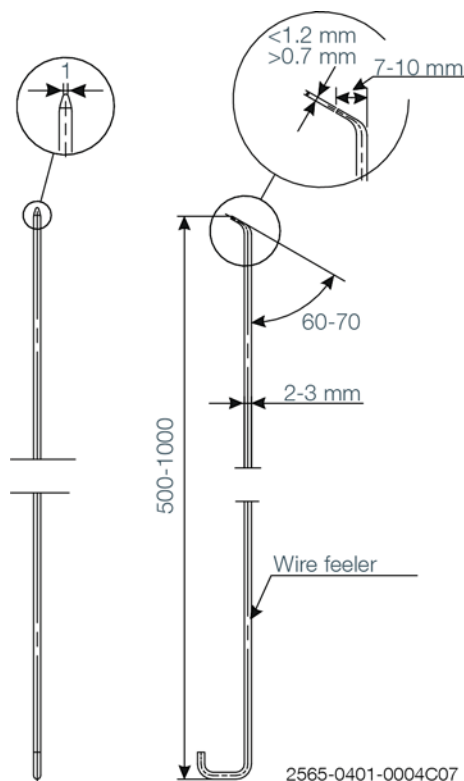
9. Wire-feeler

with inspection of the crankcase and the filter normally provides a good indication of the bearing condition.

It is rather easy to make a feeler (see sketch). The "feeler" should be made from a piece of steel wire (e.g. a welding rod) approx. 0.6 - 1 m long depending on the engine type, and 2 to 3 mm thick. Approx. 7 to 10 mm of the wire should be bent to an angle of approx. 65° to form a "feeler tip". Grind the tip smooth to obtain the shape and dimension shown on the sketch. Note that the thickness of the white metal is approx. 1.5 mm, which is why the tip should be less than 1.2 mm thick, and bigger than the max. top clearance. At the other end of the tip, a "handle" should be made by bending a hook or similar in the same direction as the tip.

NOTICE

The above dimensions of the "wire-feeler" are guideline values and may depend on the engine type as well as individual, personal designs.

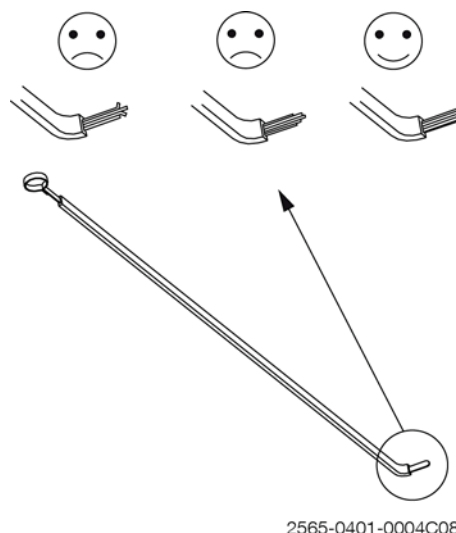


10. The clearance in the bearings

If there is too large a difference in the crankshaft deflection readings (autolog) check the clearance in the individual bearings.

Bearing clearance checks should also be carried out during time-based overhauls, surveys and during crankcase inspections.

If there is a suspicion of a damaged bearing, it is recommended to edge check the bearing, without opening up.



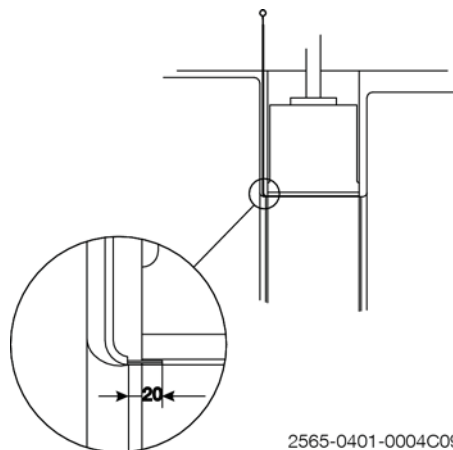
11. Feeler blades

Before measuring, check that the feeler blades are in good condition.

The feeler is inserted along the crank throw. When the feeler hits the journal, gently attempt to enter the feeler gauge into the bearing. Do not use force.

Measure until a Go/No go difference of 0.05 mm has been found, e.g. Go = 0.75 mm / No go = 0.8 mm.

Check the feeler blades after measuring.



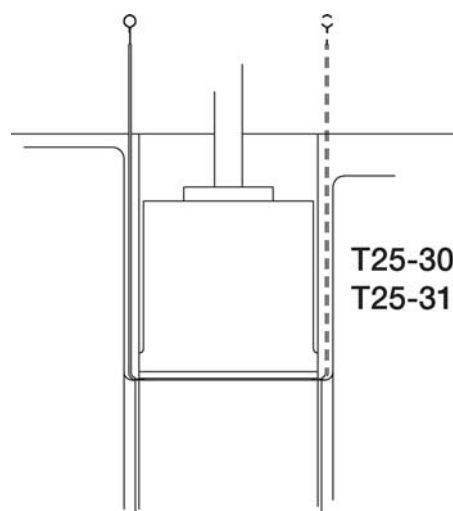
2565-0401-0004C09

12. Remember !

The clearance is measured at both the fore and the aft part of the bearing.

NOTICE

The bearing clearances for a new bearing stated in Data (*see Data*) are for guidance purposes only. Also note that bearings shells can be with or without blended edge and must never be switched between the bearings. When ordering spare parts, always specify the bearing no. See also note on 2572-0400 page 2.



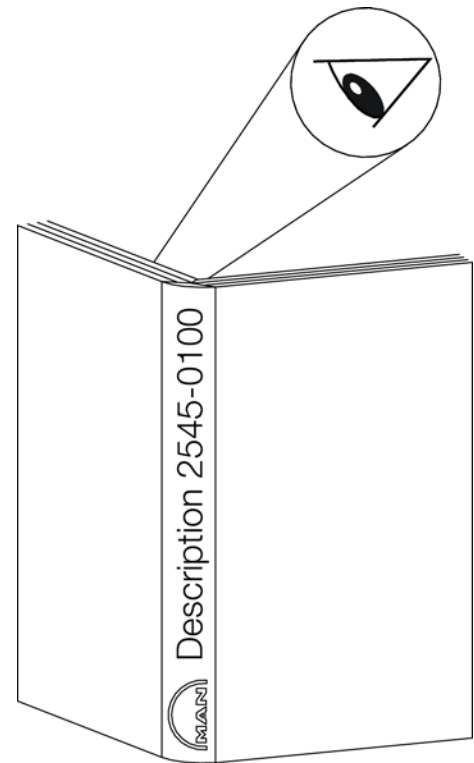
2565-0401-0004C10

13. Evaluation of the bearing

The difference between the actual clearance measurement and the measurement recorded in the adjustment sheet (or the clearance noted for a new bearing installed later) must not exceed 0.10 mm. If it does, see *Description 2545-0100*.

For evaluation of the bearing, see *Description 2545-0100*.

If the bearing needs to be disassembled for inspection, see *"Dismantling"*.



2565-0401-0004C11

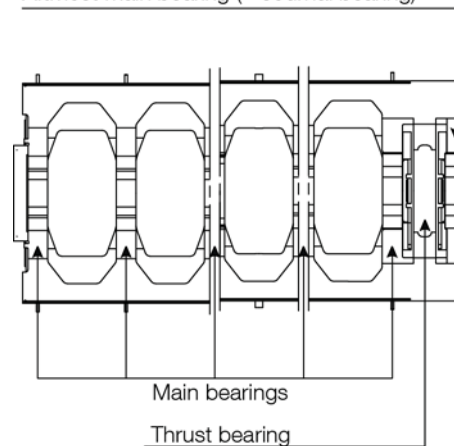
Positioning the Crankshaft

1. Dismantling of main bearing

The bearings are divided into two categories:

- The bearings are divided into two categories:
- The aftmost main bearing often referred to as "Journal bearing" (See work card 2565-05).

Aftmost main bearing (= Journal bearing)



2565-0401-0004D01

2. Before any dismantling

Check and write down the main bearing top clearances and crankshaft deflection readings for the cylinder unit concerned.

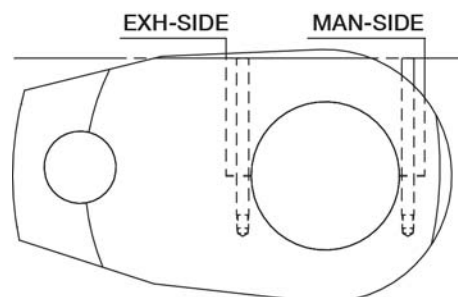
AUTOLOG + CLEARANCES						
CYL 1						
CYL 2						
CYL 3	0,0	0,0	0,0	0,0	0,0	
CYL 4						
CYL 5						
CYL 6						
CYL 7						
CYL 8						

2565-0401-0004D02

3. Turn the crank throw Turn the crank throw to the position shown on the sketch and in such a way that the top of the studs is flush with or slightly above the crank throw.

NOTICE

Be sure that the crosshead for the neighbouring cylinder is in a higher position than for the cylinder you are working on, otherwise it will be impossible to lift the cap.

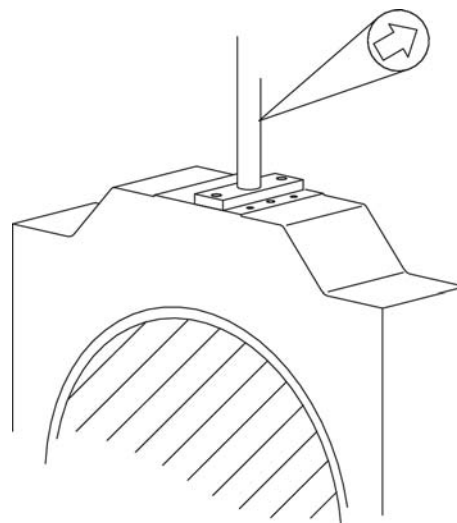


2565-0401-0004D03

4. Oil pipes Disconnect the lubricating oil pipe from the main pipe.

NOTICE

On some engines, the oil pipes for the Axial Vibration Damper (AVD) have to be removed together with the oil pipe on main bearing No. 1.



2565-0401-0004D04

NOTICE

Some engines have temperature sensors fitted to the main, crosshead, and crankpin bearings. These sensors must be carefully handled to avoid damaging the equipment.

5. Mounting of tools and tackles

Mount pulley **E** above the bearing cap and an eyebolt in the stop screw fitted in the bottom of the opposite guideshoe.

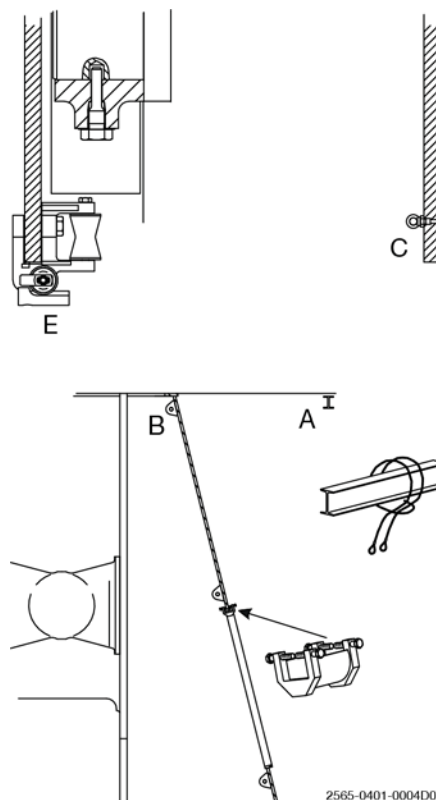
Be sure that the eyebolt is tightened to full contact.

Mount the wire guide as shown. Mount tackles in the following positions:

A: a 3 tonne chain tackle, in a wire strap around the beam

B: a 3 tonne chain tackle

C: a 3 tonne pull lift



WARNING

Safe working load (SWL)

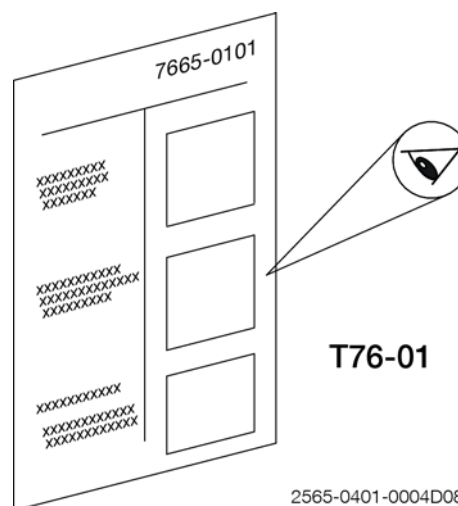
Always use lifting gear with sufficient SWL.
See data.

6. Loosening the nuts

To transfer the jacks inside the engine, use the beam and the bearing cap lifting tool.

7. Mounting the jacks

Before mounting, assemble and check the jacks are as shown in workcard 7665-0101.



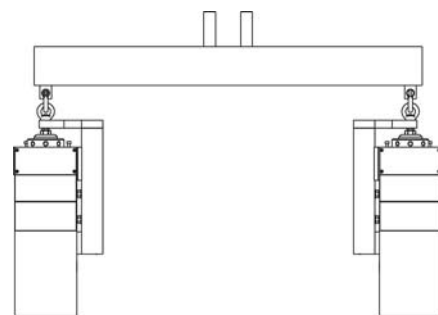
8. Mounting the lifting tool

Mount the beam and the bearing cap lifting tool.

Mount the short wire rope on the bearing cap lifting tool. The short wire rope should remain on the tool during the whole operation.

Mount tackle **A** in the short wire rope across the lifting attachment.

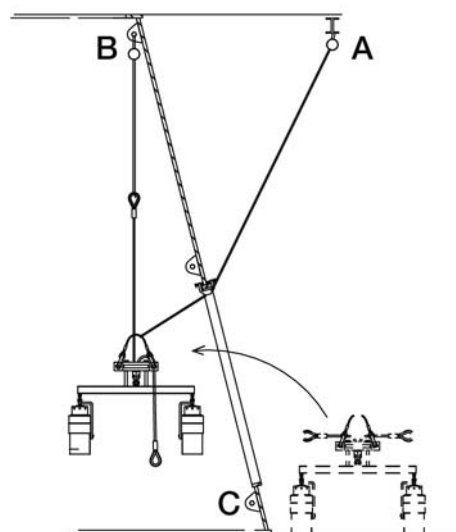
Mount tackle **B** in the shortest of the free wires on the lifting attachment.



2565-0401-0016D08

9. Removing the jacks

Lift the jacks through the door by means of tackles **A** and **B** until the position shown.

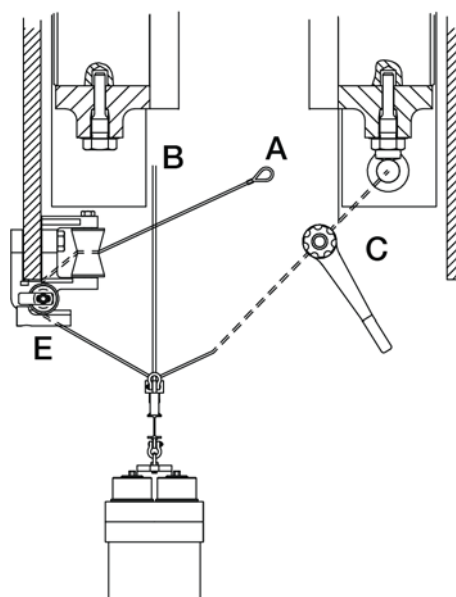


2565-0401-0014D09

10. Release the tackle

Wind the longest of the free wire ropes around pulley **E**, as shown, and attach it to tackle **A**, from outside the door.

Attach the pull lift **C** to a short wire rope across the lifting attachment.

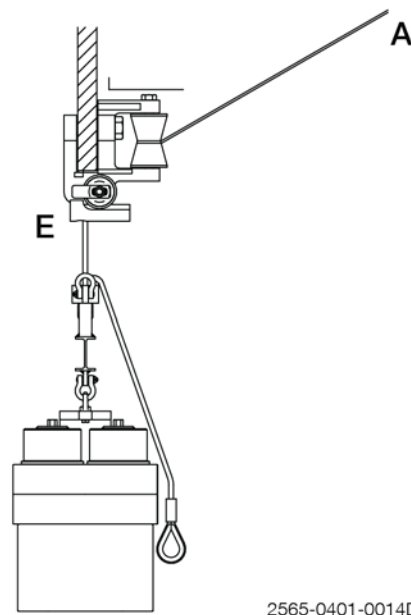


2565-0401-0014D10

11. Moving the jacks

By tightening tackle **A** and pull lift **C**, and at the same time loosening tackle **B**, move the hydraulic jacks in below the connecting rod.

When tackle **B** is released, continue tightening tackle **A** and start loosening pull lift **C** until the hydraulic jacks are hanging above the main bearing cap.



2565-0401-0014D11

12. Mounting the jacks

Lower the jacks on to the main bearing nuts, and screw the extension studs on to the main bearing studs, using a ratchet spanner, until the extension studs are landed on the main bearing studs.

NOTICE

The extension studs are in place when the measuring pin is flush with the top of the extension studs.

When all the studs have been screwed down, lower the jacks on to the main bearing cap.

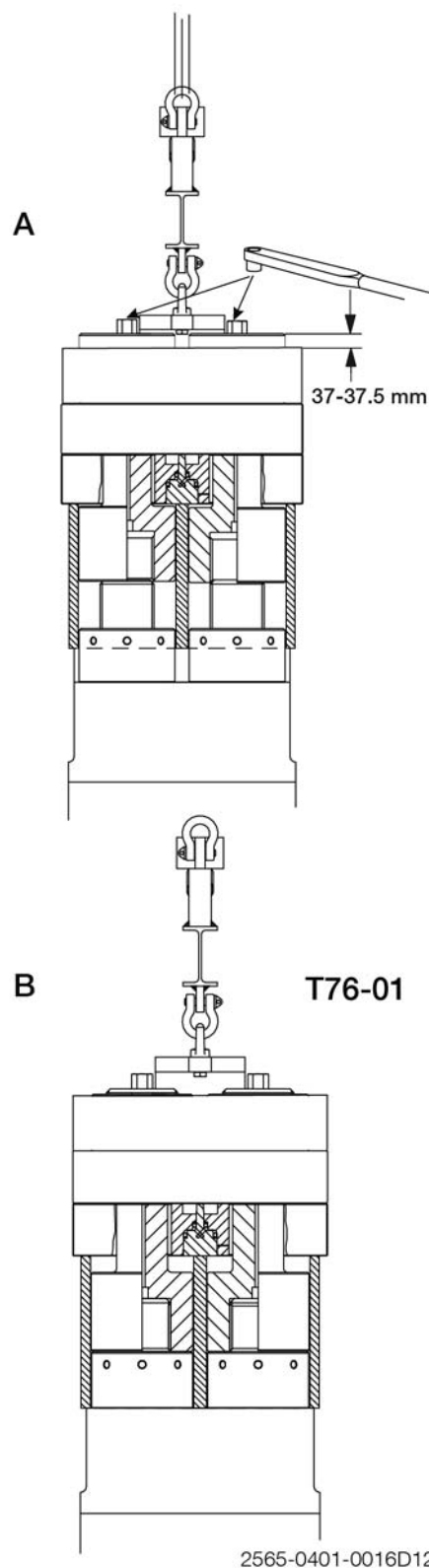
Screw down the nuts.

Unscrew the nuts 3/4 turn. (37 - 37.5 mm).

Apply hydraulic pressure. See data.

Unscrew the lower nuts 3/4 turn. (12 - 14 holes).

Release the hydraulic pressure.



13. Removal of main bearing cap

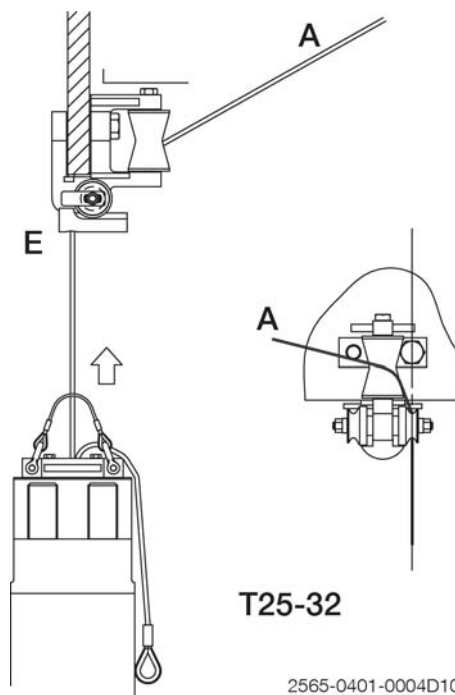
Mount the main bearing lifting tool on the main bearing cap.

Wind the longest of the free wire ropes around pulley E as shown, and attach it to tackle A from outside the door.

NOTICE

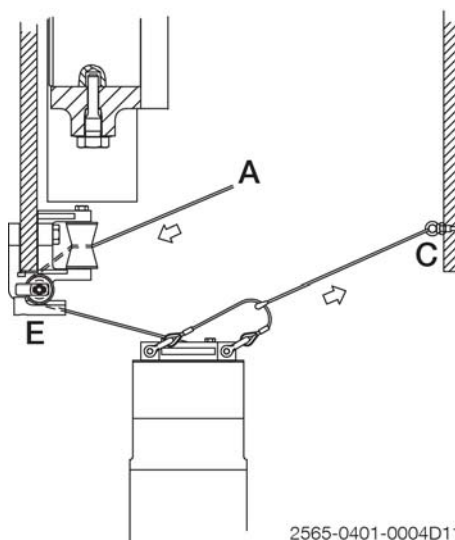
When tightening up the tackle, be sure that the wire guide is positioned correctly to protect the doorframe.

Carefully lift the main bearing cap clear of the studs.



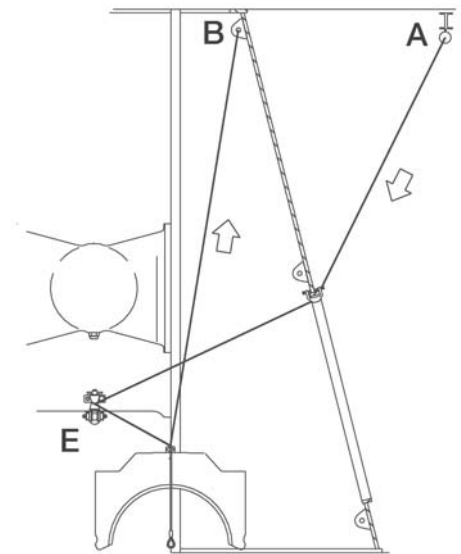
14. Moving the bearing cap in for or aft direction

Attach pull lift C to the short wire rope across the lifting attachment. By tightening pull lift C, and loosening tackle A, pull the bearing cap clear of the crosshead guides.



15. Moving the bearing cap towards the manoeuvring side

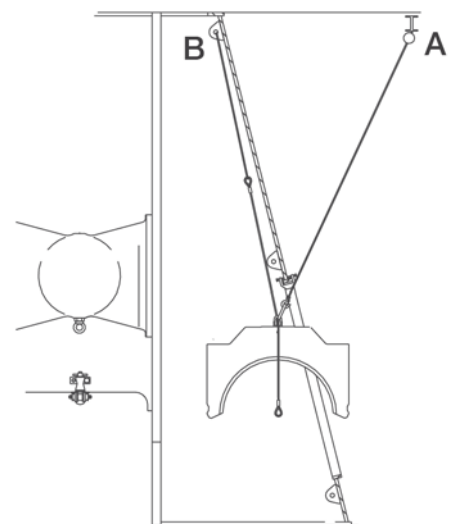
Attach tackle **B** to the shortest of the free wire ropes. By loosening tackle **A** and pull lift **B**, move the bearing cap until it is hanging freely below tackle **B**. Release tackle **A** and wind the long wire rope off pulley **E**.



2565-0401-0013D12

16. Moving the bearing cap out of the engine

Attach tackle **A** to the short wire rope across the lifting tool, and lift the bearing cap out of the engine.



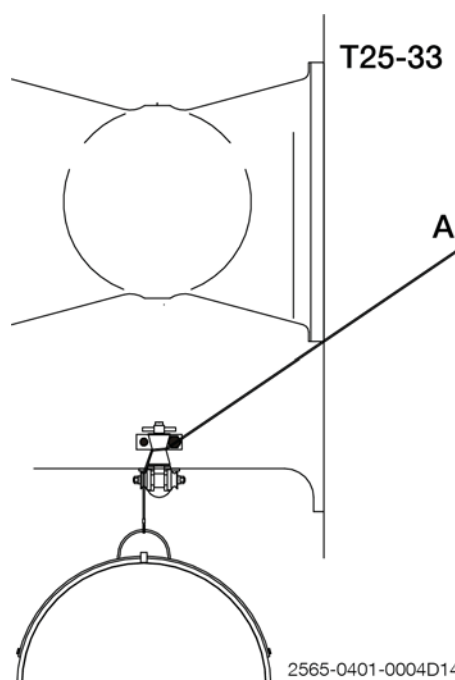
2565-0401-0013D13

17. Removal of upper bearing shell

Mount the bearing shell lifting tool on the upper main bearing shell, pull the wire around pulley **E**, as shown, and attach it to tackle **A** outside the engine.

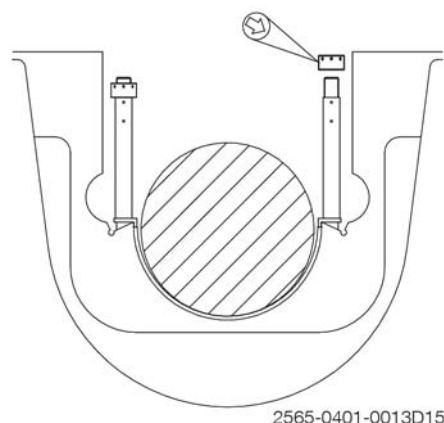
Carefully lift the bearing shell until it is hanging freely below the guide shoe.

Lift the bearing shell out of the engine in the same way as the bearing cap.



18. Remember!

If the crankshaft is turned with the bearing cap dismantled, use the two stops to prevent the lower shell from being rolled out.



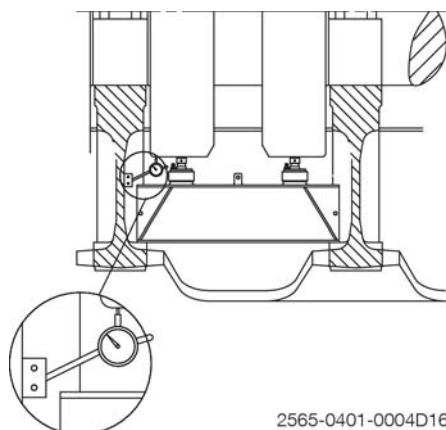
19. Lifting the crankshaft

Place the crosspiece in the bedplate with the ends resting on the cross girders, and position the hydraulic jacks beneath the crank webs as shown.

Tighten the screws against the crank webs and compress the jacks.

Connect the hydraulic jacks to the high pressure pump, and raise the pressure until the crankshaft has been lifted 0.2-0.5 mm, but max. the clearance in the two adjacent bearings.

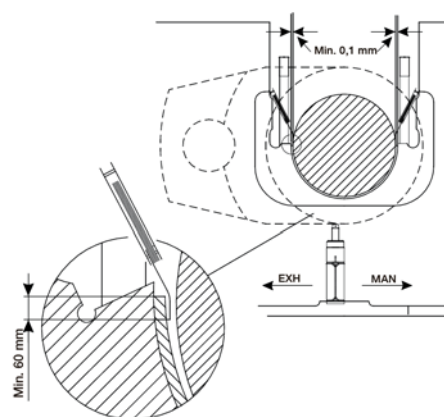
Note down the pressure for later reference.



20. Check the clearance between the journal and the bearing shell
- Check that there is min. 0.1 mm clearance between journal and bearing shell, or between bearing shell and main bearing support, on both sides of the journal.

NOTICE

The feeler blade must be inserted minimum 60 mm into the gap to pass the bore relief in the bearing shell.



2565-0401-0013D17

If the clearance is less than 0.1 mm, move the crosspiece sideways until clearance is obtained. Normally, adjustment needs to be 50-150 mm to the exhaust side (the side where the clearance is missing).

NOTICE

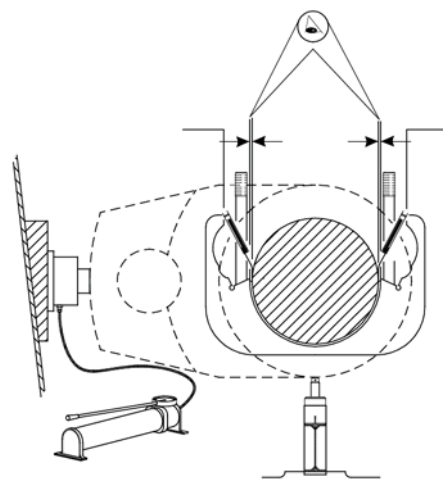
The lower shell must be lifted out to the side with the most clearance, which is normally the manoeuvre side.

21. Correcting the journal position
- If re-positioning of the crosspiece does not ensure a vertical lift, place a 5-tonne jack between the side wall and the crank throw, to correct the journal position in this way.

If it is available, note down the pressure applied to the jack. This data is used to ensure that the crankshaft is in the same position when the new bearing is installed.

NOTICE

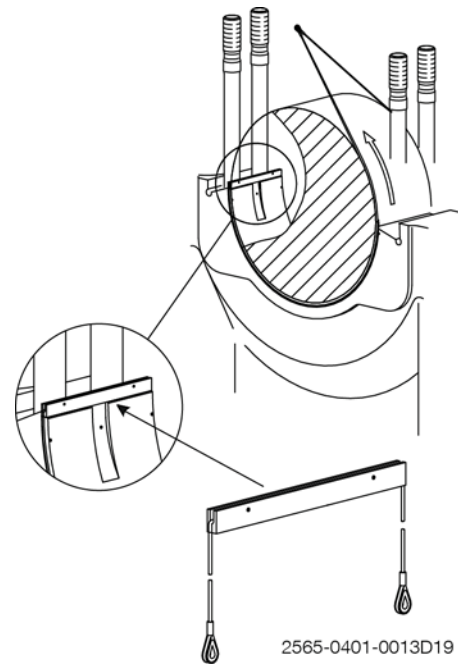
It is recommended that the crankshaft lifting tool is only removed if it is urgently necessary and then only after the main bearing shell has been reinstalled.



2565-0401-0013D18

22. Dismantling tool

Place the dismantling tool on top of the lower bearing shell.

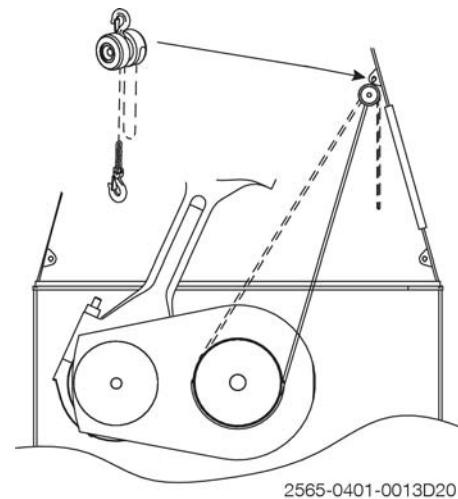


23. Removing the lower shell

Pull the lower shell around and up until it lies over the main bearing journal. Never use a tackle larger than 0.5 tonne.

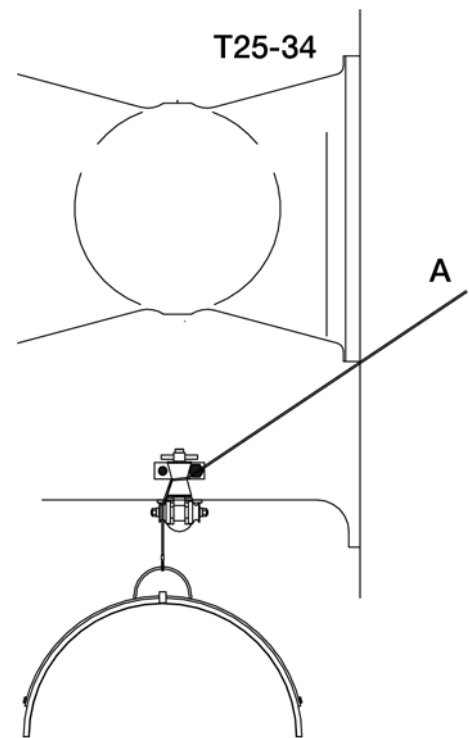
NOTICE

While pulling out the shell, it is recommended to hold a foot or hand on the wire rope, to tighten it up and to observe whether the shell is sticking.



24. Lifting tool

Take the lower shell out of the engine in the same way as the upper shell, using the lifting tool.



2565-0401-0004D21

1. Clean and inspect the bearing shells

Clean and inspect the bearing shells.

For assessing the condition of the bearing,
see description 2545-0100.

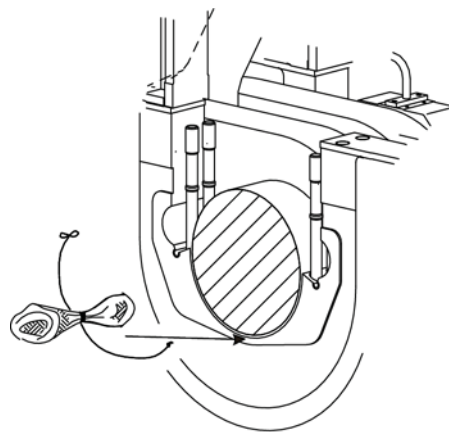
If a bearing is damaged and replacement of one or two bearing shells is necessary, contact MAN Diesel & Turbo for advice.

2. Preparation before mounting the shells

Check the bearing support for damage and burrs. If damage is found, contact MAN Diesel & Turbo for advice.

Make sure that all parts are clean, use non-fluffy cloth to clean between journal and main bearing support.

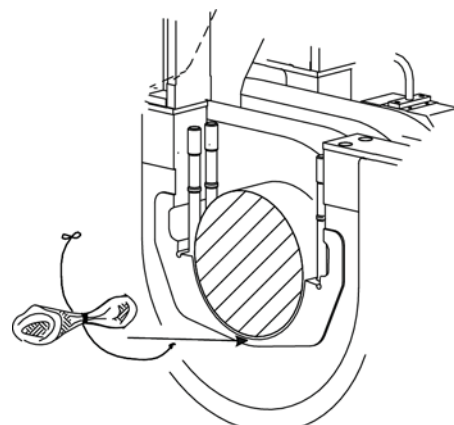
Lubricate the bearing journal, the main bearing support and the back of the lower shell.



2565-0401-0001001

1. Bearing shell lifting tool

Using the bearing shell lifting tool, the pulleys and tackles, lift the lower bearing shell into the crankcase until it is hanging above the crankshaft journal.



2565-0501-0003O01

2. Mounting of bearing shells

Place the dismantling tools for the bearing shell in the same side as when the shell was dismantled and attach them to the 0.5 tonne tackle.

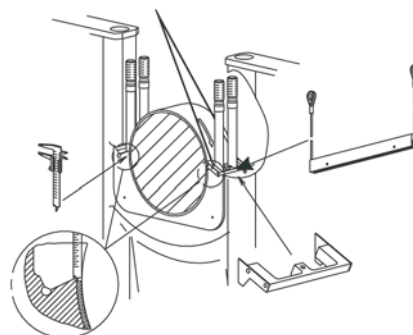
Position the guide tool for the lower bearing shell on the main bearing support.

Lubricate the journal, the lower bearing shell and the bearing support with clean oil.

Land the bearing shell on the journal, and remove the lifting tool from the bearing shell.

Push down, by hand, the bearing shell, while following with the dismantling tool, in order to prevent the bearing shell from falling.

To ensure that the shell is correctly mounted, check that the distance from the main bearing support to the shell is equal in both sides.



2565-0401-0013M02

NOTICE

The bearing shell should always be mounted in the same side as it was dismantled.

3. After placing the bearing shell

Remove the guide tool when the lower bearing shell has been mounted.

4. Mounting the upper bearing shell

Lower the crankshaft and remove the hydraulic jacks and the crosspiece from below the crankshaft.

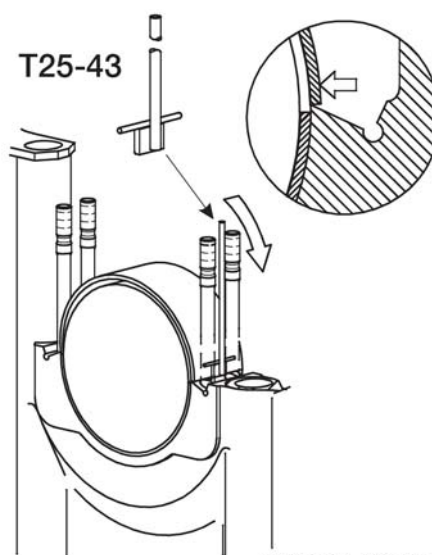
Wipe the contact surfaces between the upper and the lower bearing shells clean with a non-fluffy piece of cloth.

Land the upper bearing shell on the main journal in the same way as the lower bearing shell.

Make sure that none of the edges of the upper bearing shell are resting on the edge of the bearing support.

If available, place the special tool, or similar, between the studs and press the shell into place.

Clean the contact surfaces between the bearing support and the bearing cap. Make sure that no oil is left on the contact surfaces.

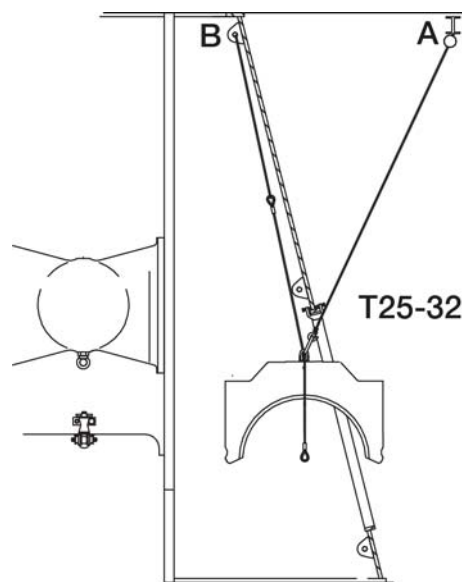


2565-0401-0013M04

5. Returning the bearing cap

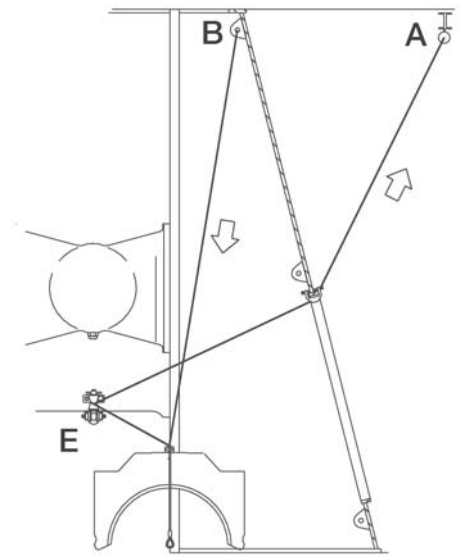
Mount the lifting tool on the bearing cap. Using the tackles and wire ropes on the main bearing cap lifting tool, lift the bearing cap into the crankcase in reverse order to dismantling.

See *"Dismantling - Moving the bearing cap"*.



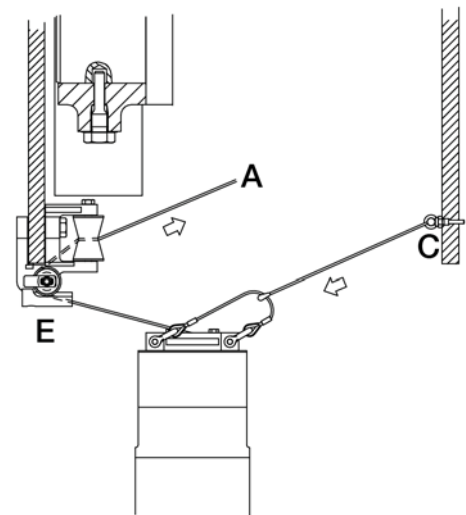
2565-0401-0004M05

6. Moving the bearing cap into the engine
- Using pulley E mounted above the bearing and the pull lift mounted below the opposite guideshoe, move the bearing cap into position vertically above the bearing journal in the reverse order to dismantling. See *"Dismantling - Removal of the main bearing cap"*.



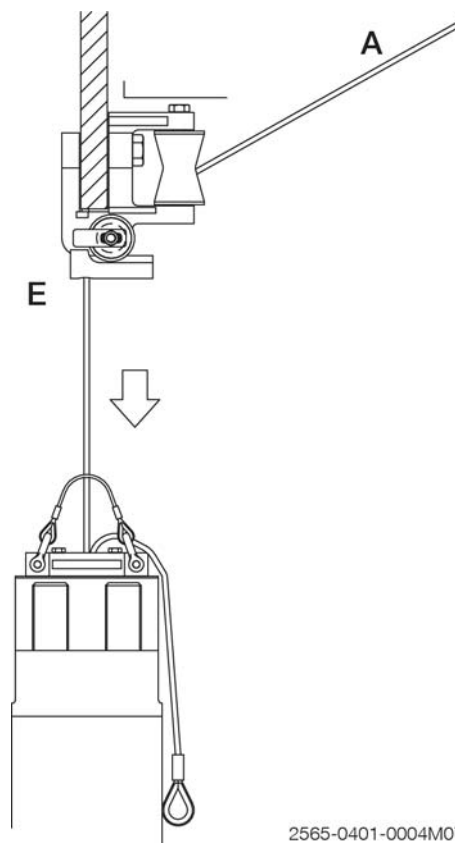
2565-0401-0013M06

7. Wire rope and pulley E
- Be sure that it is the longest wire rope that is pulled around pulley E below the webplate.

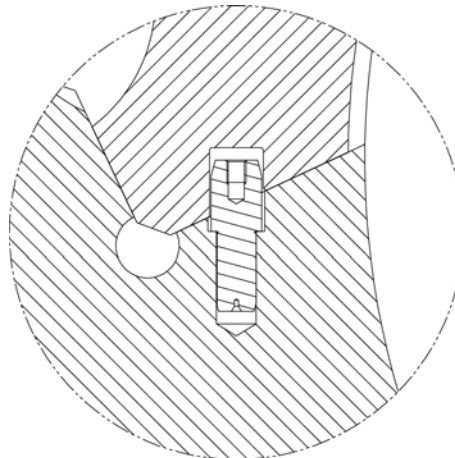


2565-0401-0013M07

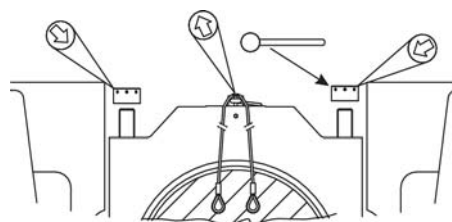
8. Landing the bearing cap
- Carefully lower the main bearing cap on to the upper bearing shell. Keep a hand on the wire rope while lowering, so that sticking of the bearing cap is immediately felt.



9. The Guide pin
- Be sure that the cap lands correctly and that the guide pin in the assembly surface enters the hole in the bearing cap.

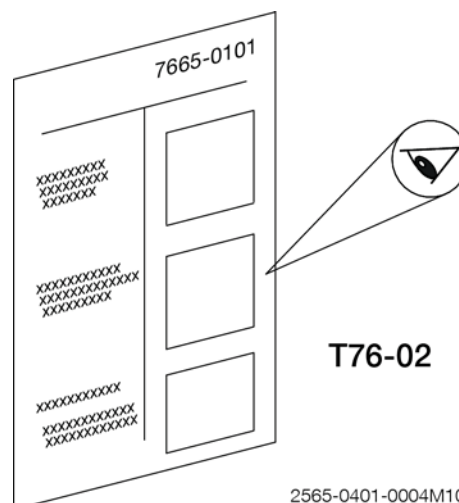


10. Remove the bearing cap lifting tool
- Screw the nuts on to the main bearing studs. Using a tommy bar, tighten the nuts on both sides of the bearing cap.



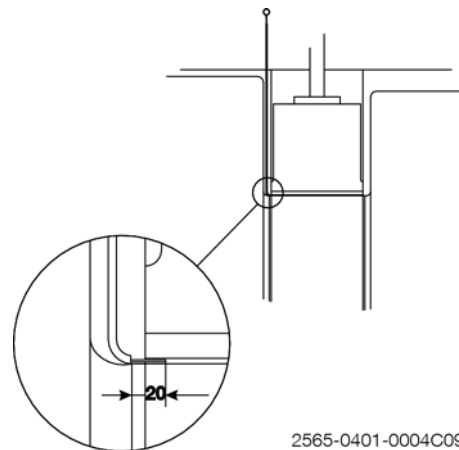
11. Tightening of hydraulic nuts

Mount the hydraulic jack nuts on the studs. *See "Dismantling". For operation of the hydraulic tools, see work card 7665-0101.*



12. Checking the clearance

Before removing the hydraulic jacks, check the top clearance between the upper bearing shell and the journal. *See "checking"*



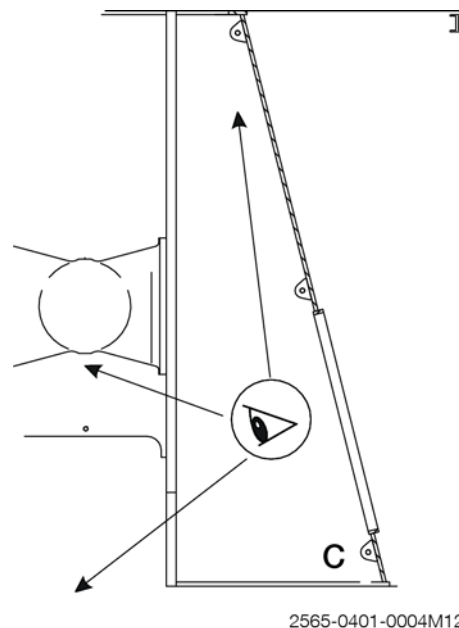
13. Remove all tools from the engine

Search the crankcase to ensure that there are no tools, shackles or rags left behind.

NOTICE**Bearing wear monitoring**

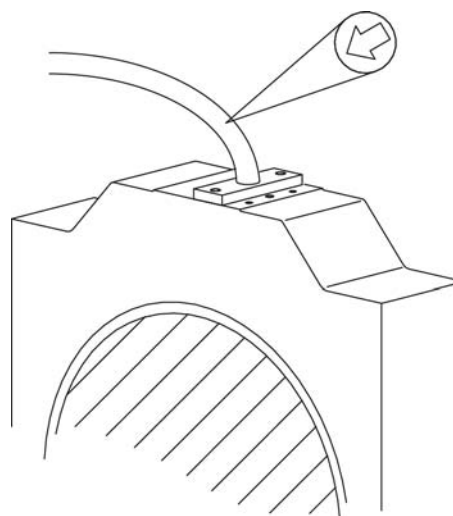
The engine may be equipped with a bearing wear monitoring (BWM) system.

If the bracket for the BWM probe has been dismantled, re-mount the bracket and re-adjust the BWM system according to the BWM system manufacturer's instructions.



14. Oil pipe

Mount the lubricating oil pipe on the main bearing cap.



2565-0401-0004M13

Main Bearing • Mounting

Work Card
2565-0401-0016

Safety**Precautions**

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T25-40	Journal bearing, top clearance max.	0.50	mm
T25-41	Journal bearing, top clearance min.	0.20	mm
T25-42	Journal bearing cap	600	kg
T25-43	Upper bearing shell	35	kg
T25-44	Lower bearing shell	40	kg
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
1070-1040	-	Thrust shaft tools
1470-0300	041	Wire guide
2570-0010	070	Lifting tool for main bearing cap
2570-0010	082	Dismantling tool for main bearing shell
2570-0010	128	Retaining tool for main bearing shell
2570-0010	177	Mounting tool for thin bearing shell
2570-0010	189	Lifting tool for main bearing shell
2570-0400	-	Main bearing hydraulic tools
2570-0430	-	Main bearing measuring tools
7670-0100	011	Hydraulic pump, pneumatically operated

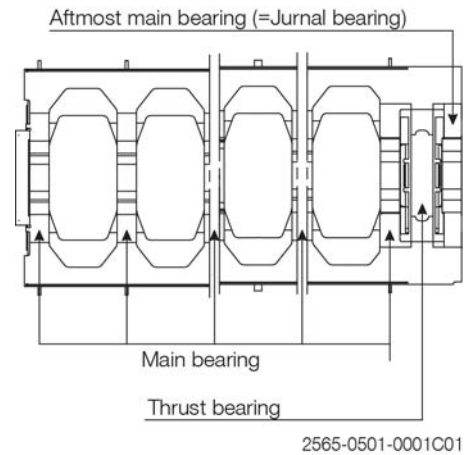
Plate	Item No.	Description
7670-0100	023	Hydraulic pump, hand operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	106	5-way distributor block, complete
7670-0300	-	Lifting tools, etc
7670-0410	054	Feeler gauge set
7670-0410	078	Dial gauge and stand tool

**WARNING**

Observe safety precautions when working in the crankcase.
See description 0545-0100.

1. Journal bearing

Check the journal bearing in the same way as the remaining main bearings, see work card 2565-0401.

**2. Bearing clearances**

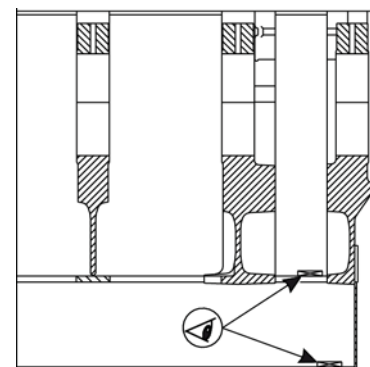
Write down the journal bearing clearances.

AUTOLOG + CLEARANCES									
CYL 1									
CYL 2									
CYL 3	0,0	0,0	0,0	0,0					
CYL 4									
CYL 5									
CYL 6									
CYL 7									
CYL 8									

2565-0401-0001D02

3. Visual check

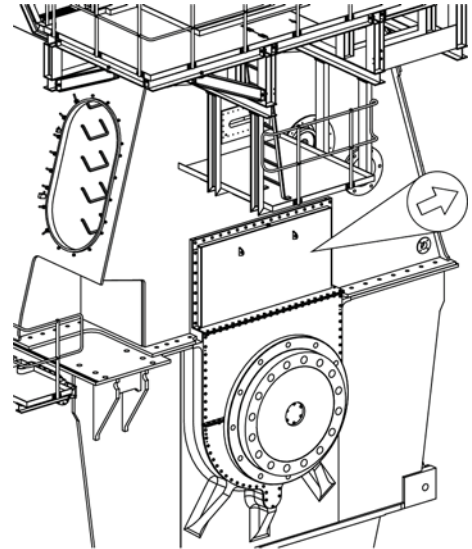
Also check the journal bearing by visually searching the area underneath the bearing support for bearing material.



1. End cover

Remove the screws for the end cover.

Remove the end cover.



2565-0501-0009D01

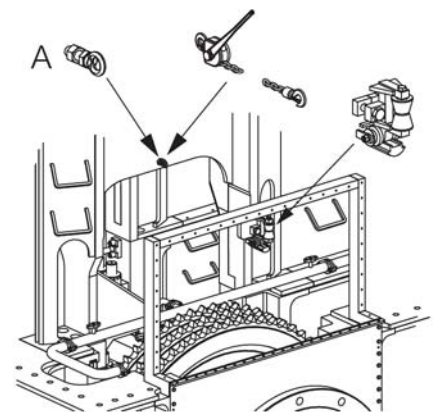
2. Preparation

Mount the pulley for wire for the main bearing on the welded lifting bracket on the aftermost part of the frame box.

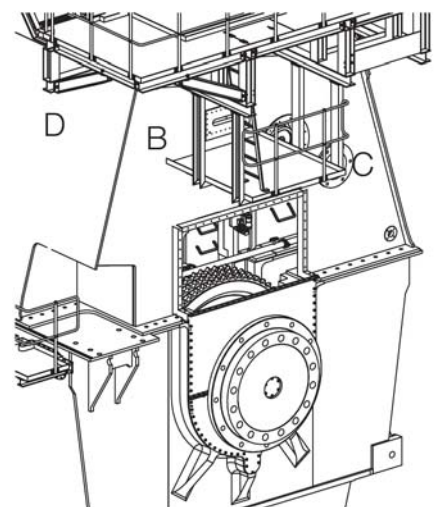
Mount the eye bolt in the chain box and attach a chain tackle **A**.

It is also necessary to mount two chain tackles in the gallery above the turning wheel **B** & **C** and one tackle in the gallery on the manoeuvring side **D**.

Remove gallery as necessary.

**WARNING****Safe working load (SWL)**

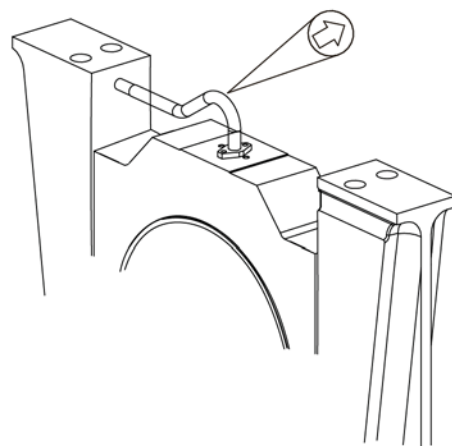
Always use lifting gear with sufficient SWL.
See data.



2565-0501-0009D02

3. Oil pipes

Remove the oil pipes necessary to dismantle the journal bearing cap.

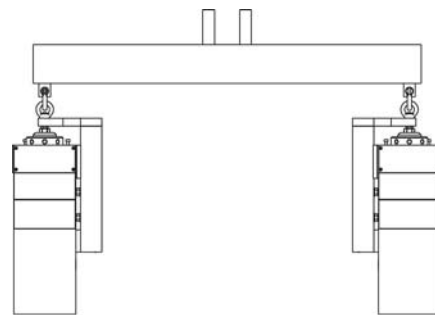


2565-0501-0007D02

4. Hydraulic jacks and lifting tools

Assemble the main bearing hydraulic tools and the lifting tools.

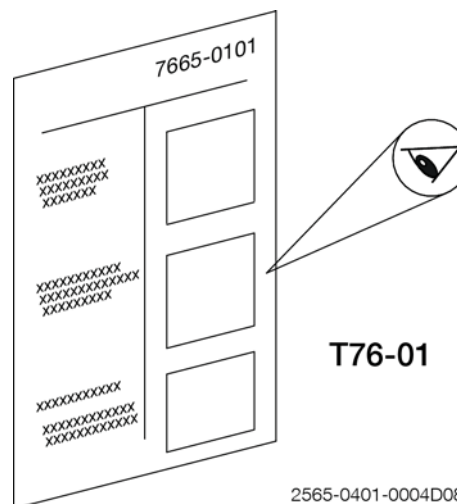
To transfer the jacks inside the engine, use the beam and the bearing cap lifting tool.



2565-0401-0016D08

5. Hydraulic tools

For operation of the hydraulic tools, see work card 7665-0101.

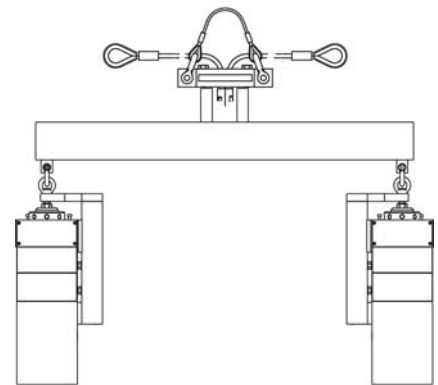


2565-0401-0004D08

6. Before lifting

Mount the short wire rope on the bearing cap lifting tool.

The short wire rope should remain on the tool during the whole operation.



2565-0501-0011D08

7. Lifting procedure

Mount tackle **D** in the short wire rope across the lifting attachment.

Mount tackle **B** in the shortest of the free wires on the lifting attachment.

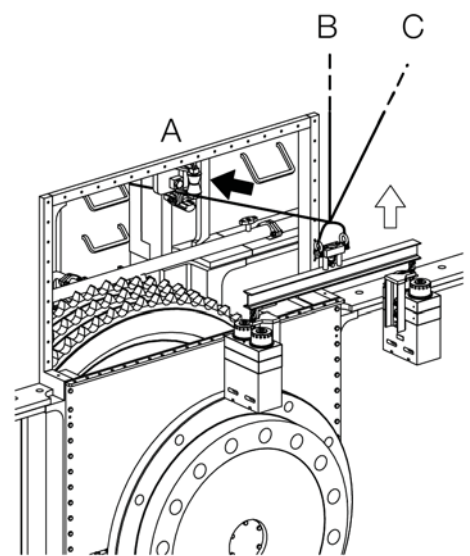
Start the lift and manipulate tackle **B** and **D** until the all the weight is transferred to tackle **B**.

Remove tackle **D** and attach tackle **C**. Continue lifting by manipulated tackle **B** and **D** until the lifting tool reaches the centre of the engine.

Attach tackle **A** through the pulley.

Manipulate tackle **A**, **B** and **C** until all weight is transferred to tackle **A**.

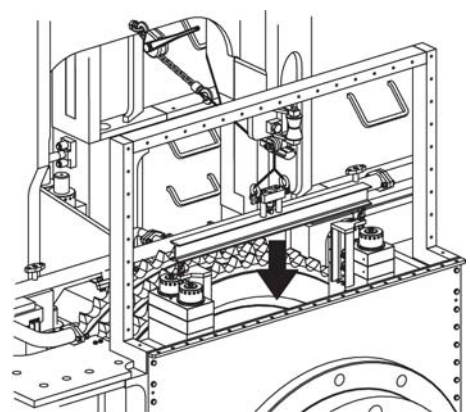
Remove tackle **B** and **C**.



2565-0501-0009D07

8. Positioning the jacks

Lower the jacks on to the journal bearing nuts.



2565-0501-0009D08

9. Removing nuts

Screw the extension studs on to the main bearing studs, using a ratchet spanner, until the extension studs are landed on the main bearing studs.

NOTICE

The extension studs are in place when the measuring pin is flush with the top of the extension studs.

When all the studs have been screwed down, lower the jacks on to the journal bearing cap.

Screw down the nuts and make sure that the jacks are fully compressed.

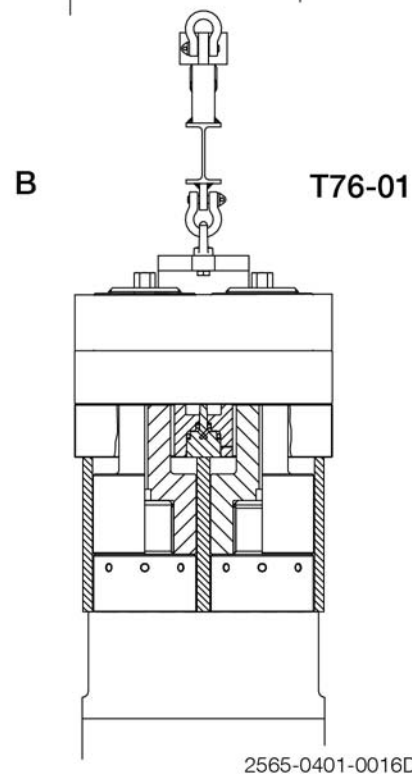
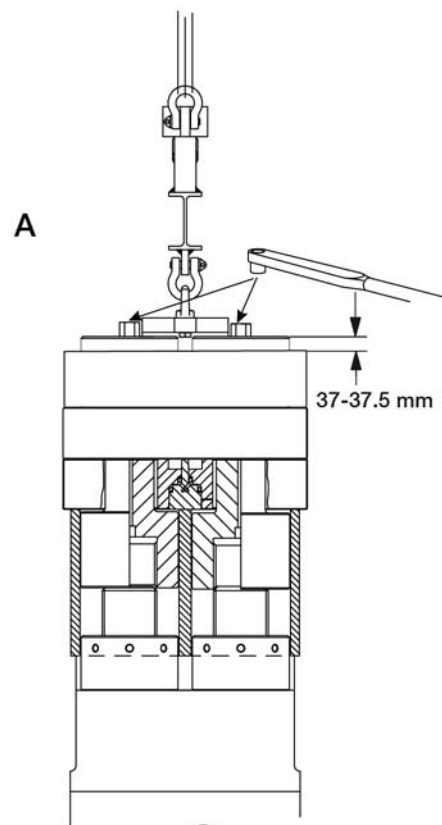
Unscrew the nuts 3/4 turn. (37-37.5 mm).

Apply hydraulic pressure.
See data.

Unscrew the lower nuts 3/4 turn. (12 - 14 holes).

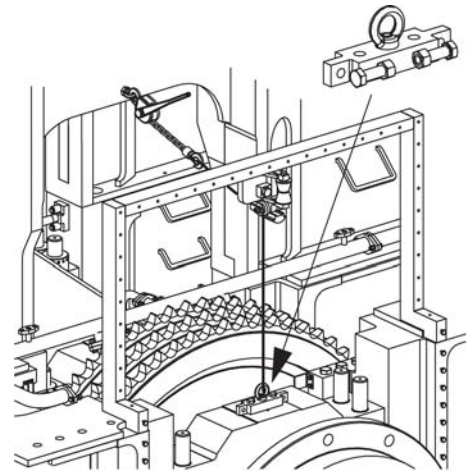
Release the hydraulic pressure.

Remove the lifting tools in accordance with the mounting procedure, but in reverse.



10. Main bearing lifting tool

Mount the main bearing lifting tool (with wire and shackles) on the journal bearing cap.

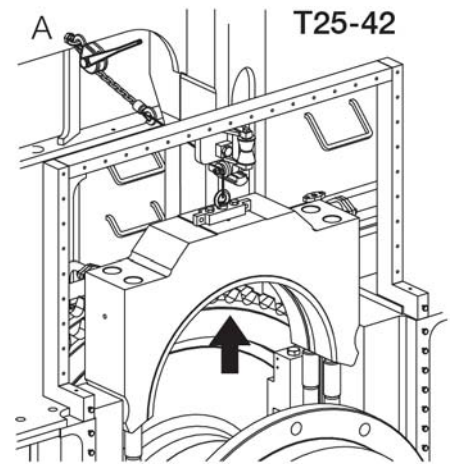


2565-0501-0009D09

11. Vertical lift

Lift the bearing cap vertically free from the studs using the pulley and chain tackle **A**.

Continue lifting as high as possible.



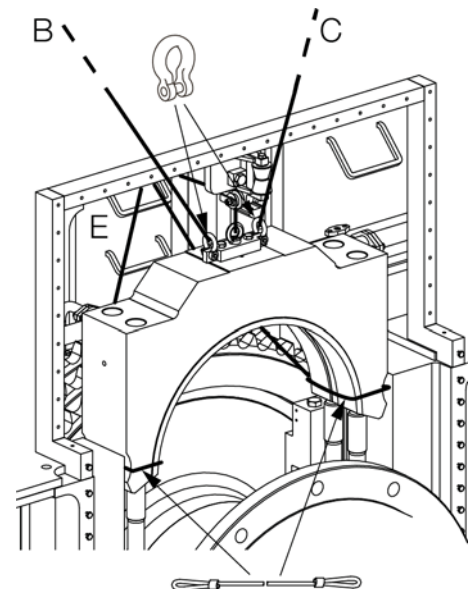
2565-0501-0009D10

12. Add tackle E

Mount tackle **B** and **C** and tighten up.

Attach another chain tackle **E** to a suitable place close to tackle **A**.

Mount two straps through the bends in the bearing cap and attach the straps to tackle **E**.

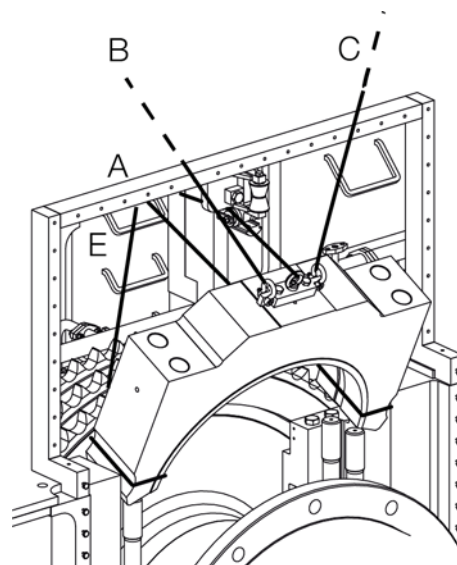


2565-0501-0009D11

13. Tilt the bearing cap Tighten up tackle **E**.

Carefully tilt the bearing cap by loosening tackle **A**.

Tighten tackle **B** and **C**.



2565-0501-0009D12A

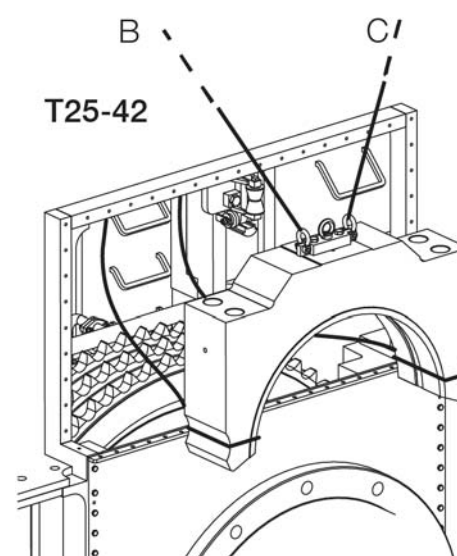
14. Move the bearing cap

When possible loosen tackle **E** until the bearing cap is hanging freely with all its weight suspended from tackle **B** and **C**.

Remove the connection to tackle **A** and **E**.

Mount tackle **D**.

Manipulating tackle **B**, **C** and **D** until it is possible to land the bearing cap on i.e. plywood.



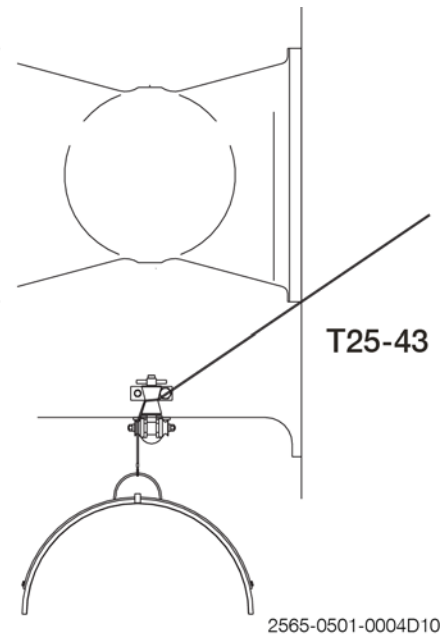
2565-0501-0009D15

15. Removing the upper bearing shell

Mount the bearing shell lifting tool on the upper main bearing shell, pull the wire around the pulley as shown and attach it to a tackle outside the engine on the exhaust side.

Carefully lift the bearing free below the pulley.

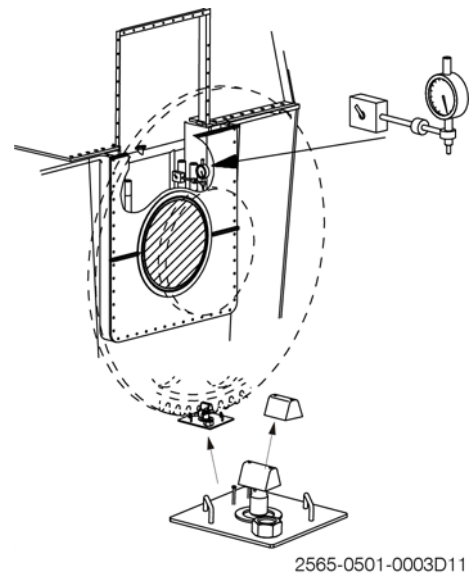
Lift the bearing shell out of the engine to the exhaust side.

**16. Lifting the crankshaft**

Place the lifting tool for thrust shaft under the turning wheel as shown. Mount a dial gauge to measure the lift of the crankshaft.

Tighten the screw against the turning wheel and compress the jack.

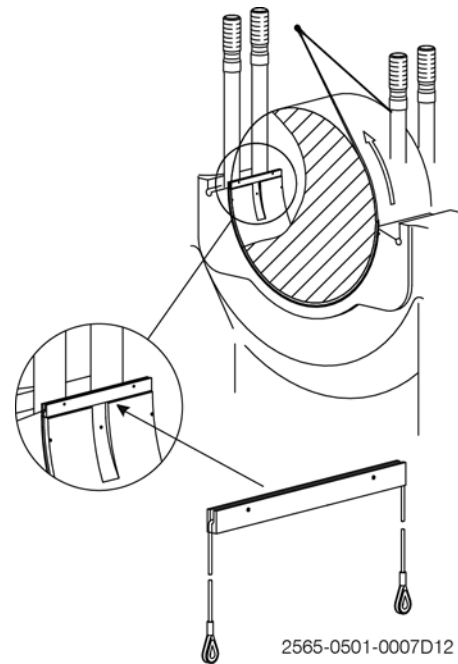
Connect the hydraulic jack to the high pressure pump, and raise the pressure until the crankshaft has been lifted 0.2-0.5 mm, but max. the clearance in the adjacent bearing.



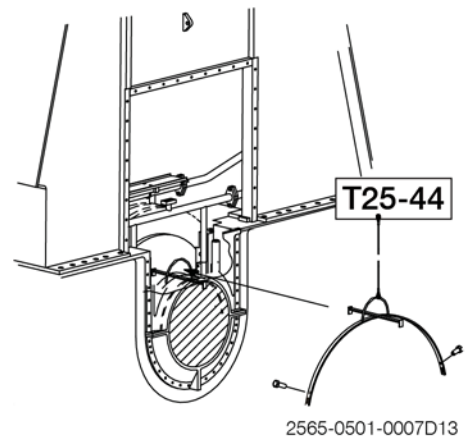
17. Pulling out the lower shell Remove the locking screws.

Place the dismantling tool on top of the lower bearing shell. Make sure that the flap on the dismantling tool enters the oil groove in the bearing shell.

Pull the lower bearing shell around and upwards until it lies over the bearing journal. Never use a tackle larger than ½-ton.



18. Removing the lower shell Take the lower shell out of the engine in the same way as the upper shell, i.e. using the lifting tool.



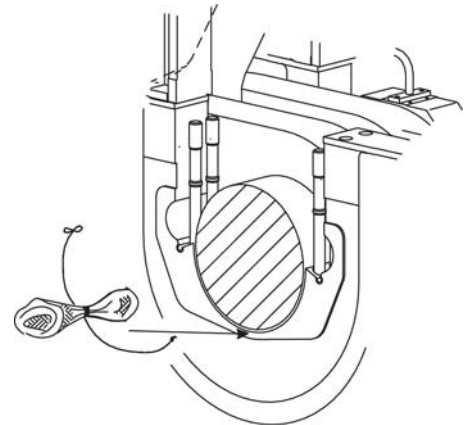
1. Bearing shell

Clean and inspect the bearing shells. It is recommended that the main bearing shells are replaced in pairs.

If it is nevertheless desired to replace only one shell, this requires a careful evaluation of the condition of the shell that is to be reinstalled.

See description 2545-0100.

For advice on replacing individual bearing shells, it is recommended to contact MAN Diesel & Turbo or the engine builder.



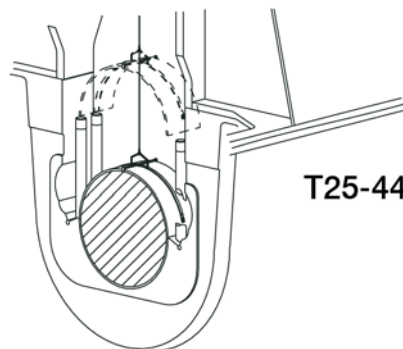
2565-0501-0001001

Before reinstalling

- Check the bearing support for damage and burrs. If damage is found, contact MAN Diesel & Turbo for advice.
- Make sure that all parts are clean, use non-fluffy cloth to clean between journal and bearing support.
- Lubricate the bearing journal, the bearing support and the back of the shell, with main engine lubricating oil.

1. Lower bearing shell Lubricate the journal, the lower bearing shell and the bearing support with clean oil.

Using the bearing shell lifting tool, the pulleys and tackles, lift the lower bearing shell into the crankcase and land it on the crankshaft journal.



2565-0501-0007M01

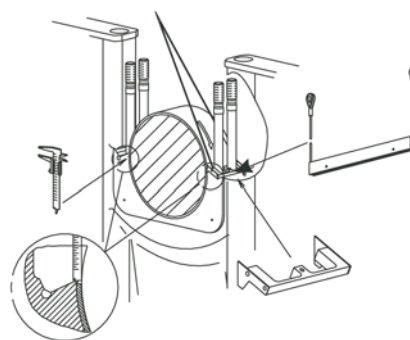
2. Mounting of bearing shells Place the dismantling tools for the bearing shell in the same side as when the shell was dismantled and attach them to the 0.5 tonne tackle.

Position the guide tool for the lower bearing shell on the bearing support.

Lubricate the journal, the lower bearing shell and the bearing support with clean oil.

Land the lower bearing shell on the journal and remove the lifting tool from the bearing shell.

Push down, by hand, the bearing shell, while following with the dismantling tool, in order to prevent the bearing shell from falling.



2565-0401-0013M02

NOTICE

The bearing shell should always be mounted in the same side as it was dismantled.

To ensure that the shell is correctly mounted, check that the distance from the bearing support to the shell is equal in both sides.

3. After placing the bearing shell

Remove the guide tool when the lower bearing shell has been installed.

Lower the crankshaft and remove the lifting tool for thrust shaft under the turning wheel.

Wipe the contact surfaces between the upper and the lower bearing shells clean with a lint-free piece of cloth.

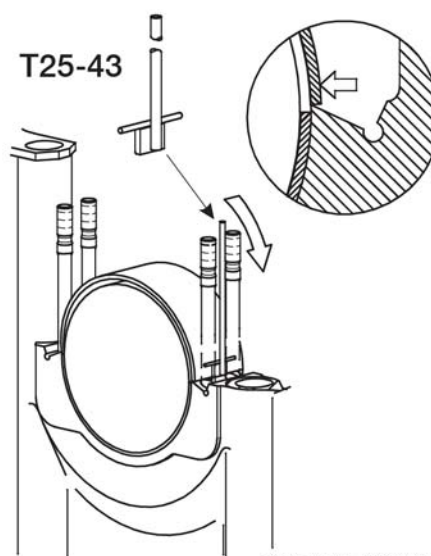
4. Mounting the upper bearing shell

Land the upper bearing shell on the main journal in the same way as the lower bearing shell.

Make sure that none of the edges of the upper bearing shell are resting on the edge of the bearing support.

If available, place the special tool, or similar, between the studs and press the shell into place.

Clean the contact surfaces between the bearing support and the bearing cap. Make sure that no oil is left on the contact surfaces.



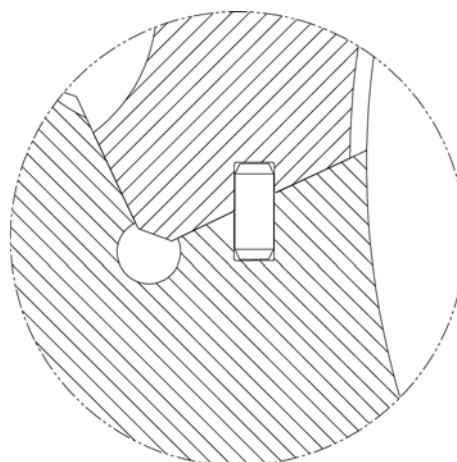
2265-0501-0007M04

5. Bearing cap

Using the lifting tool and the tackles, lift the bearing cap in place in reverse sequence to dismantling.

NOTICE

Be sure that the cap lands correctly and that the spring pin in the assembly surface enters the hole in the bearing cap.



2565-0501-0009M05

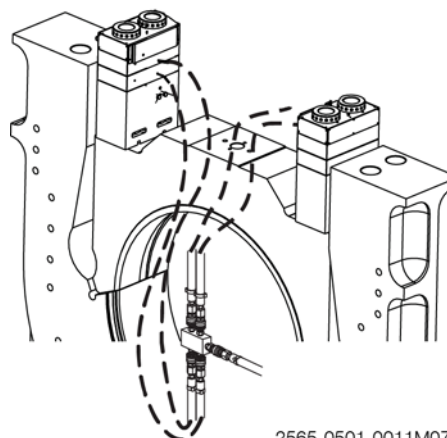
6. Nuts and spacer rings

Remove the lifting tools.

Install the nuts, the spacer rings, the hydraulic jacks, and tighten the nuts.
See Data.

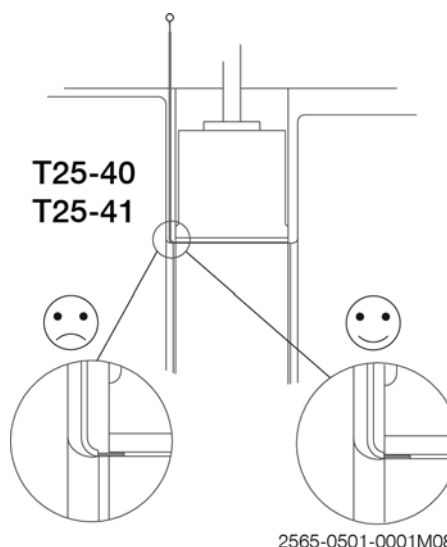
For operation of the hydraulic tools, see work card 7665-0101.

T76-01



7. Check Clearance

Before removing the hydraulic jacks, check the top clearance between the upper bearing shell and the journal.

T25-40
T25-41

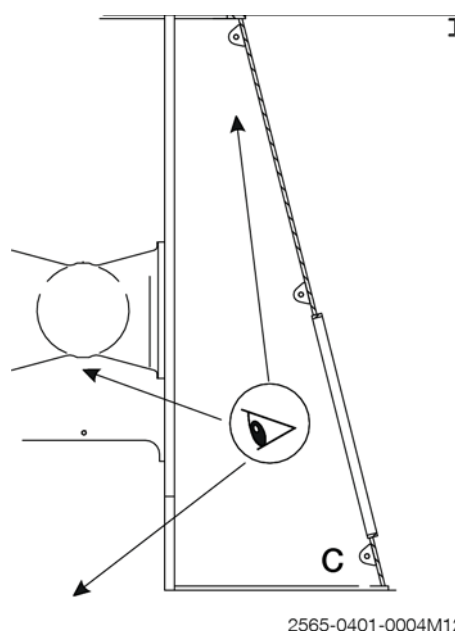
8. Tools

Remove all tools from the engine.

NOTICE**Bearing wear monitoring**

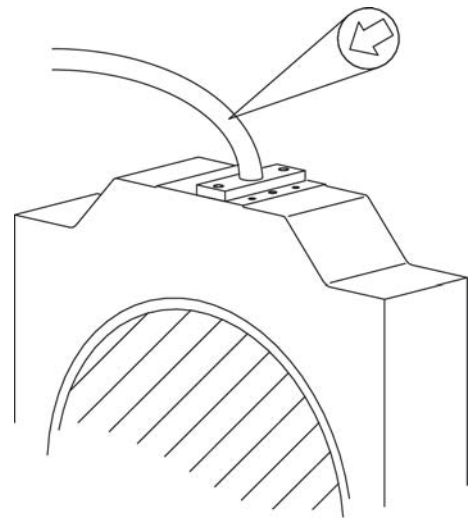
The engine may be equipped with a bearing wear monitoring (BWM) system.

If the bracket for the BWM probe has been dismantled, re-mount the bracket and re-adjust the BWM system according to the BWM system manufacturer's instructions.



9. Finally

Reconnect all disassembled piping, and mount the end cover for the chain housing.



2565-0401-0004M13

Safety**Precautions**

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T25-48	Thrust bearing segment	50	kg
T25-49	Segment stopper	30	kg
T25-54	Segment stopper tightening torque	1650	Nm
T25-60	Segment stopper tightening torque + angle	150+45	Nm+°

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
2570-0010	104	Tool for turning out segments
7670-0200	-	Torque spanners
7670-0300	-	Lifting tools, etc
7670-0410	054	Feeler gauge set

**WARNING**

Observe safety precautions when working in the crankcase.
See description 0545-0100.

The clearance in the thrust bearing was measured during testbed trials of the engine and noted down in the Adjustment Sheet.

See description 6345-0100.

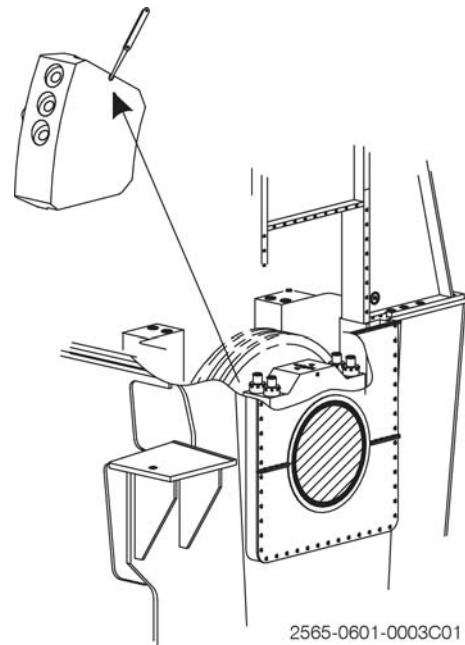
For a new engine the clearance is 0.5-1.0 mm, and for an engine in service it must not exceed 2.0 mm.

In service it is only necessary to measure the wear of the thrust bearing pads, and to inspect for white metal below the thrust bearing.

1. Wear groove

To measure the wear in the thrust bearing, it is necessary to dismount the foremost segment stopper.
See dismantling procedure.

A wear groove of 1 mm is positioned in the uppermost thrust segment. (The segment with thermometers).

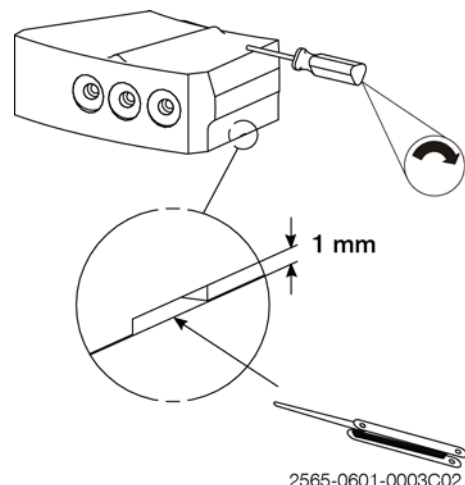


2565-0601-0003C01

2. Measuring

To measure the wear, the thrust segment has to be pressed against the thrust cam, to eliminate any gap, i.e. by using a suitable crowbar on the back of the segment.

If a feeler gauge of 0.1 mm is not able to enter the groove (the wear is more than 0.9 mm), the thrust bearing must be overhauled.



2565-0601-0003C02

3. Remember!
- Note down the wear for later reference.

AUTOLOG + CLEARANCES									
CYL 1									
CYL 2									
CYL 3	0,0	0,0	0,0	0,0	0,0				
CYL 4									
CYL 5									
CYL 6									
CYL 7									
CYL 8									

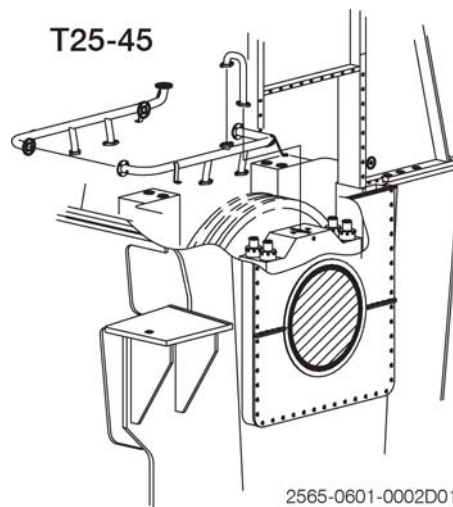
2565-0601-0003C03

1. Lube oil pipes

Remove the end cover of the engine.

Remove the lube oil pipe from the aftmost main bearing shell.

Remove the lube oil pipe above the thrust segments.



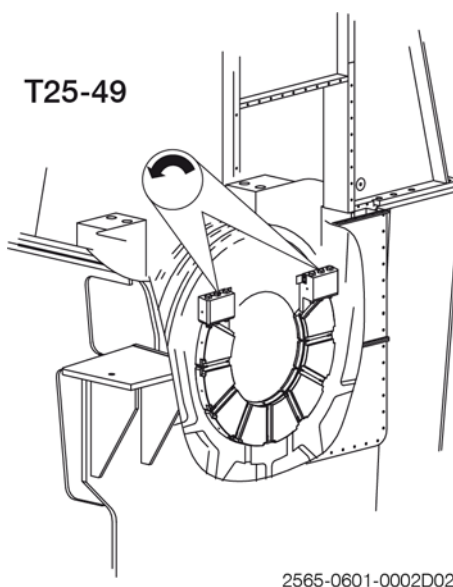
2. Segment stopper

Loosen and remove the screws from the segment stoppers.

Screw an eyebolt into the stoppers that are to be removed.

Suspend a tackle above each stopper and hook the tackle on to the eyebolt.

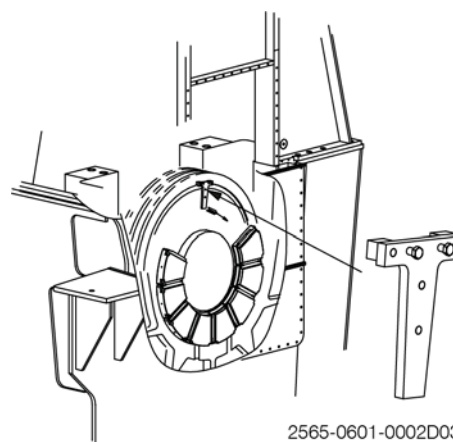
Remove the stoppers from the chain drive above the thrust segments (AHEAD or ASTERN) that are to be taken out.



3. Segment tool

Suspend a tackle from the chain tightener bracket above the segments bearing cap to be removed.

For turning-up the thrust segments, mount the segment tool on the chain wheel.

**WARNING****Safe working load (SWL)**

Always use lifting gear with sufficient SWL.

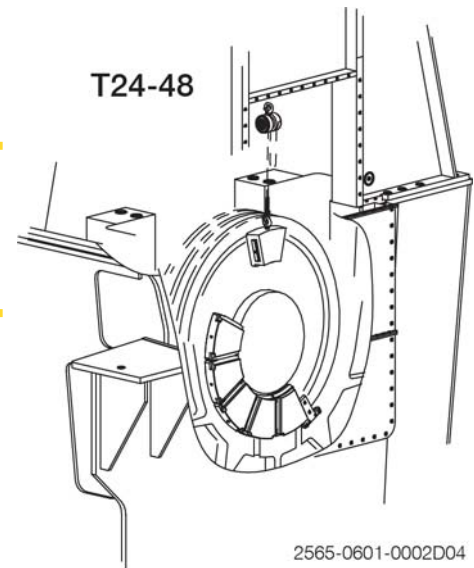
See data.

4. Inspect the segment Turn up the segments, one at a time, by turning the engine, and remove the segment from the chain casing.

NOTICE

Do not remove all the segments from the bearing at the same time.

Inspect the segment and remount it before turning up the next segment.
See mounting procedure.



2565-0601-0002D04

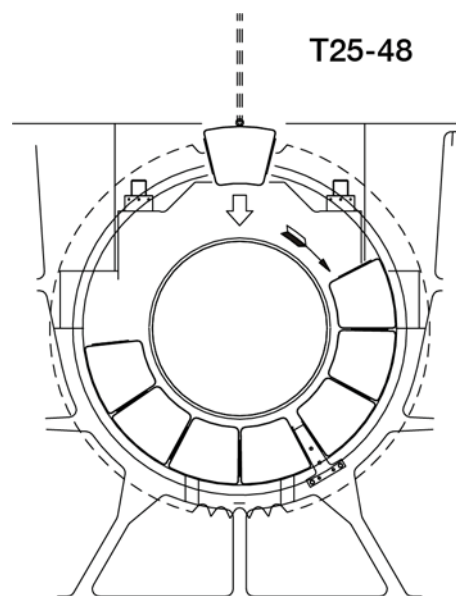
1. Mounting the segment

Suspend a tackle from the crossbar above the segments which are to be mounted.

Mount the segment tool on the chain wheel.

Land the segment on the journal and remove the eye bolt from the segment.

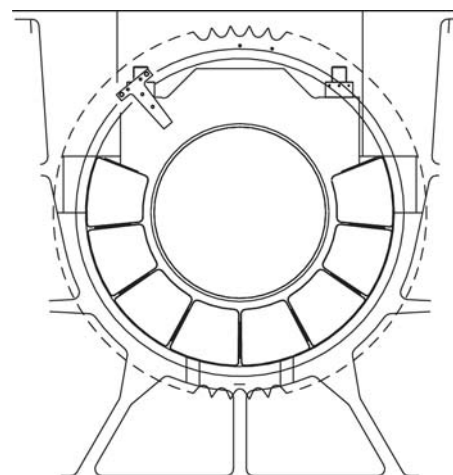
Carefully slide the segment on to the segment tool. Turn the engine to dismantle the next segment.
See dismantling procedure.



2565-0601-0002M01

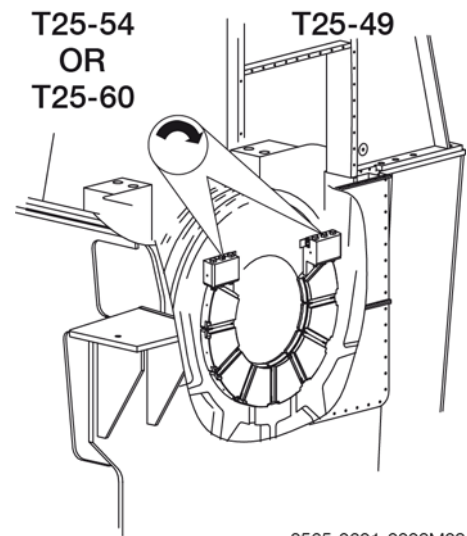
2. Removing the segment tool

After the last segment has been mounted, turn the segment tool up and dismount it.



3. Segment stoppers Mount the segment stoppers.

Mount and tighten the segment stopper bolts. *See data.*



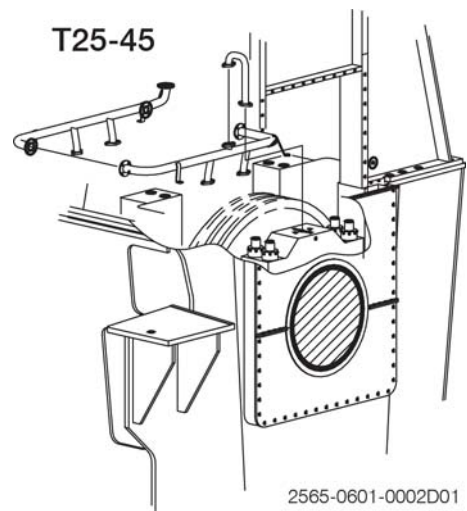
2565-0601-0003M03

4. Protective shield Mount the protective shield.

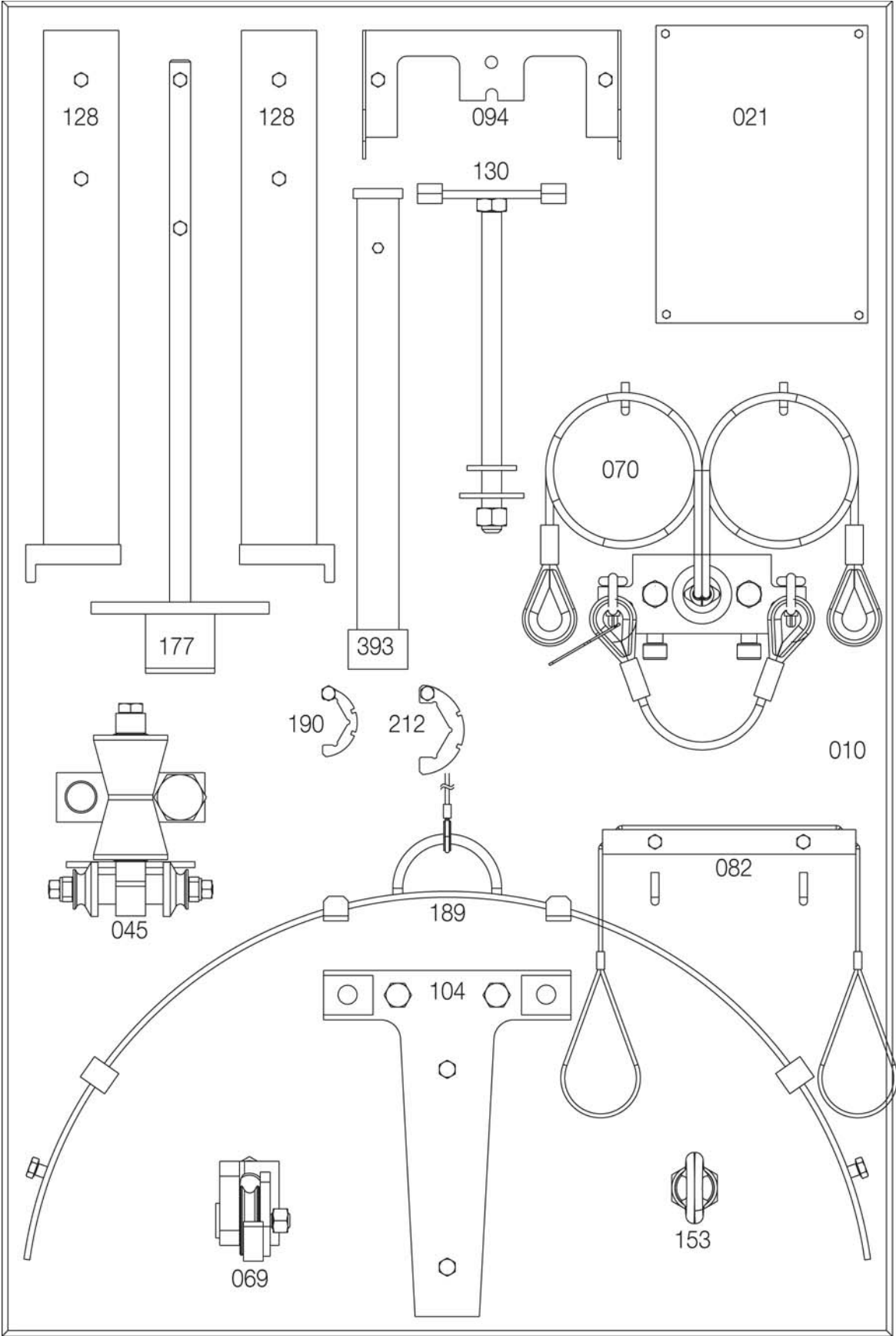
Mount the lube oil pipe for the thrust segments.

Mount the lube oil pipe for the aft-most main bearing.

Mount the end cover.



2565-0601-0002D01

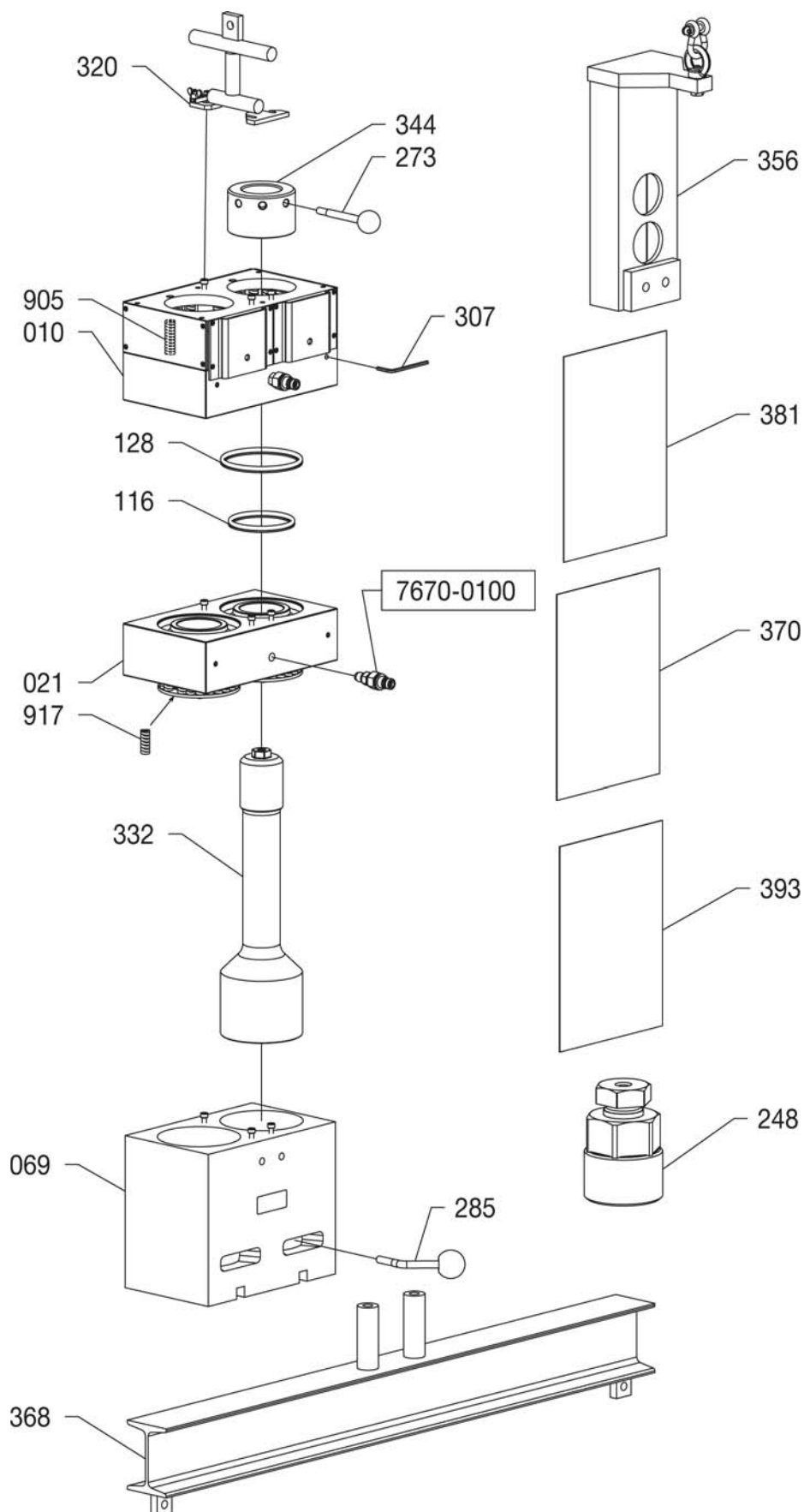


Bearing Panel Tools

Plate

2570-0010-0025

Item No.	Qty	Item Designation
010	-	Panel for tools
021	-	Name plate
045	-	Pulley wire for main bearing
069	-	Pulley wire for main bearing
070	-	Lifting tool for main bearing cap
082	-	Dismantling tool for main bearing shell
094	-	Mounting tool for thin bearing shell
104	-	Tool for turning out segment
128	-	Retaining tool for main bearing shell
130	-	Lifting tool for relief valve
153	-	Eye bolt
177	-	Mounting tool for thin bearing shell
189	-	Lifting tool for main bearing shell
190	-	Tightening template for axial vibration damper
212	-	Tightening gauge for segment stopper
393	-	Extractor complete

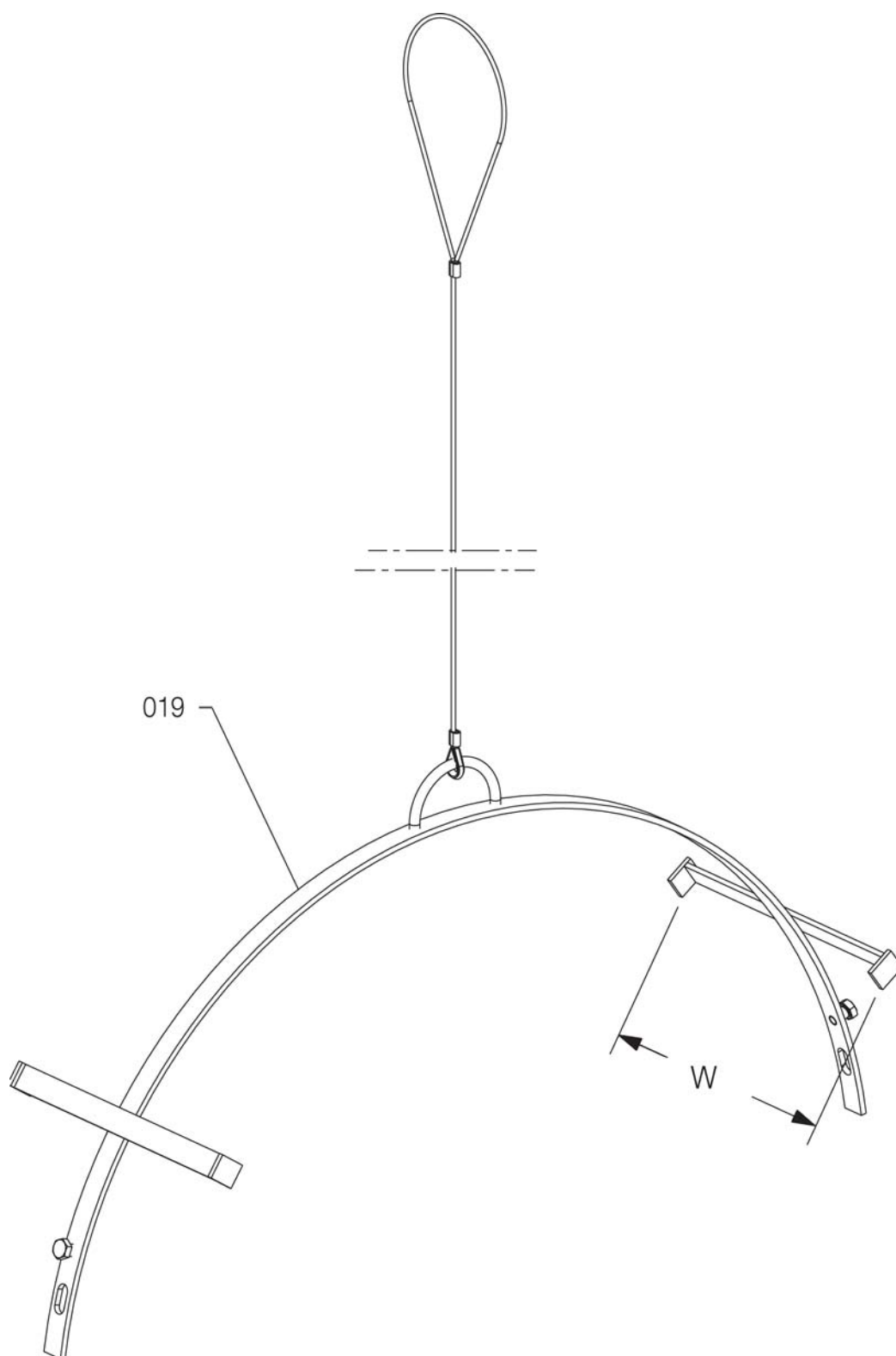


Main Bearing Hydraulic Tools

Plate

2570-0400-0028

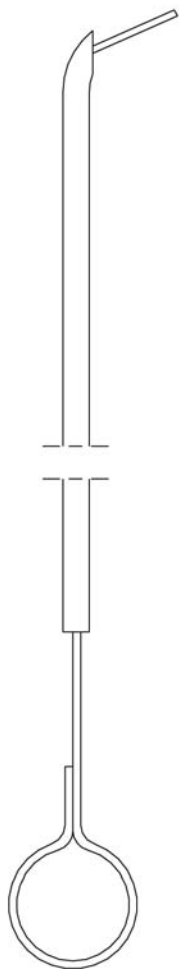
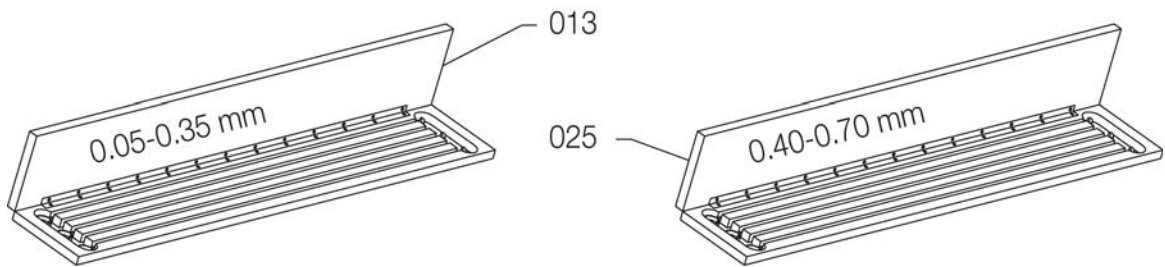
Item No.	Qty	Item Designation
010	-	Hydraulic jack, complete
021	-	Hydraulic jack, complete
069	-	Support for hydraulic jack
116	-	Sealing and back-up ring
128	-	Sealing and back-up ring
248	-	Stud setter
273	-	Ball handle
285	-	Ball handle
307	-	Hex key
320	-	Lifting tool
332	-	Extension stud for hydraulic jack
344	-	Nut
356	-	Lifting attachment
368	-	Lifting tool
370	-	Instruction plate
381	-	Instruction plate
393	-	Instruction plate
905	-	Spring
917	-	Spring



Item No.	Qty	Item Designation
019	-	Lifting tool for main bearing shell ¹⁾

Note: ¹⁾ * When ordering, please state the width "W" of the tool.





- 062
- 074
- 086
- 098
- 108
- 121
- 133
- 145
- 157
- 169
- 170
- 182
- 194
- 204



- 300
- 312
- 324
- 336
- 348
- 361
- 373
- 385
- 397
- 407
- 419
- 420
- 432
- 444

2010-08-29 - en

Preface Chapter	Lubricating Oil System	3040-0100-0001
Description	Cylinder Lubrication	3045-0110-0010
	Circulating Oil and Oil System	3045-0120-0003
	Maintenance of Circulating Oil System	3045-0130-0005
	Turbocharger Lubrication	3045-0140-0002
Drawing	Circulating Oil System – Outside Engine (Engines with Uni-Lube System)	3055-0115-0002
	Circulating Oil System – Inside Engine	3055-0125-0003
	Flushing of Main Lubricating Oil System – Location of Checkbag and Blank Flanges	3055-0130-0003
	Cleaning System – Stuffing Box Drain Oil (Option)	3055-0135-0002
	Turbocharger Lubricating Oil Pipes	3055-0155-0002
Work Card	Lubricating Oil, Data	3065-0150-0001
	Lubricating Oil	3065-0151-0001
	Cylinder Lubricator, Data	3065-0600-0001
	Cylinder Lubricator	3065-0601-0010

Cylinder Lubricators

The engine is equipped with electronically controlled cylinder lubricators for lubrication of the running surface of liners and rings.

See chapter 3045-0110.

1 Lubricators

Each cylinder liner has a number of lubricating quills, through which oil is introduced from the lubricators.

For the ME engines the lubricators are integrated with the ECS system.

For the specific lubricator system installed, *see work card 3065-0601*. The oil is pumped into the cylinder (via non-return valves) when the piston rings pass the lubricating orifices, during the upward stroke.

A overview of the cylinder lubricating oil system is shown on *drawing 3055-0110*.

2 Cylinder lubricating oil film

The purpose of cylinder lubrication is as follows:

1. To create a hydrodynamic oil film separating the piston rings from the liner. The oil amount needed to create an oil film is more or less independent of the fuel being used. Measurements of the oil film have also revealed that when the feed rate for optimum oil film is reached no further increase of the oil film is obtained from an increase of the feed rate, the optimum is kept safely down to a feed rate of 0.60 g/kWh.
2. To clean the piston rings, ring lands and ring grooves. Cleaning of piston rings, ring lands and grooves is essential, and relies on the detergency properties of the cylinder oil. All approved cylinder oils fulfil the requirements, even at a feed rate as low as 0.60 g/kWh.
3. Control of cylinder liner corrosion, i.e. neutralisation of sulphuric acid. The combustion process creates highly corrosive sulphuric acids depending on the sulphur content in the fuel. To obtain an optimal corrosive level of the cylinder liner, the ACC factor for the cylinder oil feed rate must be set according to instructions. The ACC (Adaptive Cylinder oil Control) concept ensures a correct cylinder oil feed rate level in relation to the fuel oil Sulphur content.

If a satisfactory cylinder condition is to be achieved, it is of vital importance that the oil film is intact. Therefore, the following conditions must be fulfilled:

1. The cylinder lubricators must be correctly timed.
2. The cylinder oil type and BN must be selected in accordance with the fuel being burned.
3. New liners and piston rings must be carefully run-in, *see drawing 2255-0125*.
4. The oil feed-rate (dosage) under normal service must be in accordance with the engine builder's recommendations. Furthermore, the dosage feed rate must be adjusted in accordance with the service experience for the actual trade (obtained from the scavenge port inspections).

3 Cylinder lubricating oils

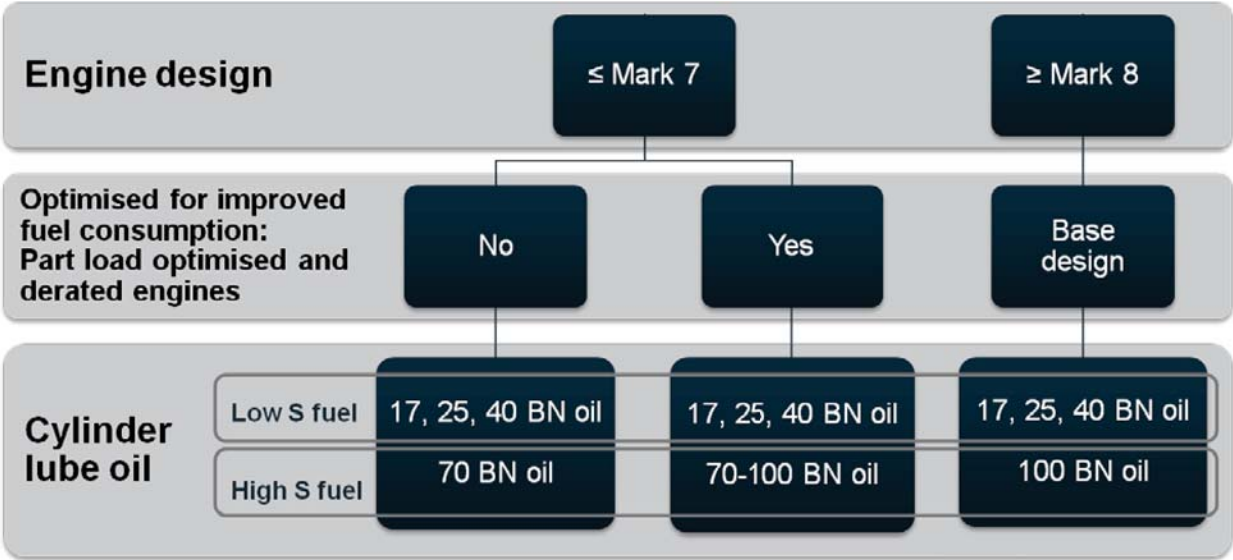
The tables below indicates international brands of cylinder oils that have been tested in service with acceptable results, and some of the oils have also given long term satisfactory service during heavy fuel operation in MAN B&W engines.

Do not consider the list complete, as oils from other companies can be equally suitable. Further information can be obtained by contacting the engine builder or MAN Diesel & Turbo, Copenhagen.

MAN Diesel & Turbo recommend the use of cylinder oils with the following main properties:

- SAE 50 viscosity
- High detergency
- Alkalinity (BN) must be chosen according to the applied fuel sulphur content and engine design

Below a general overview of cylinder lube oils and how to choose. Low S fuel = low-sulphur fuel incl. LNG, methanol, ethane and LPG. High S fuel = high-sulphur fuel.



For Mark 8.1 engines and higher the following oils are recommended:

Cylinder oils		
Oil company	Oil name	Specified BN level
Aegean	Alfacylo 540 LS	40
	Alfacylo 570	70
	Alfacylo 100 HS	100
Castrol	Cyltech 40SX	40
	Cyltech 70	70
	Cyltech 80 AW	80
	Cyltech 100	100
Chevron	Taro Special HT LF	25
	Taro Special HT LS 40	40
	Taro Special HT 70	70
	Taro Special HT 100	100
ExxonMobil	Mobilgard 525	25
	Mobilgard 570	70
	Mobilgard 5100	100
Gulf Oil Marine	GulfSea Cylcare ECA 50	17

Cylinder oils		
Oil company	Oil name	Specified BN level
	GulfSea Cylcare DCA 5040H	40
	GulfSea Cylcare EHP 5070	70
	GulfSea Cylcare 8550	85
	GulfSea Cylcare 50100	100
Indian Oil Corp.	Servo Marine LB 1750	17
	Servo Marine ME 7050	70
JX Nippon Oil & Energy	Marine C405	40
	Marine C705	70
	Marine C1005	100
Lukoil	Navigo 40 MCL	40
	Navigo 70 MCL	70
	Navigo 100 MCL	100
Shell	Alexia S3	25
	Alexia 50	70
	Alexia S5	80
	Alexia S6	100
Sinopec	Marine Cylinder Oil 5040	40
	Marine Cylinder Oil 5070E	70
	Marine Cylinder Oil 50100	100
Total	Talusia LS 25	25
	Talusia LS 40	40
	Talusia HR 70	70
	Talusia Universal 100	100

1 Circulating Oil

For lubricating and cooling oil, rust and oxidation inhibited engine oils of the SAE 30 viscosity grade, should be chosen.

In order to keep the crankcase and piston cooling space clean of deposits, the oils should have adequate dispersancy and detergency properties and also adequately corrosion and oxidation inhibited.

Alkaline circulating oils are generally superior in this respect.

The international brands of oils listed below have all given satisfactory service in one or more MAN diesel engine installation(s).

Company	Circulating oil SAE 30, BN 5-10
Aegean	EnerAlfasys 305
Castrol	CDX 30
Chevron	Veritas 800 Marine 30
Exxon Mobil	Mobilgard 300
Gulf Oil Marine	GulfSea Superbear 3006
Indian Oil Corp.	Servo Marine 0530
JX Nippon Oil & Energy	Marine S30
Lukoil	Navigo 6 SO
Shell	Melina S 30
Sinopec	System Oil 3005
Total	Atlanta Marine D3005

The list must not be considered complete, and oils from other companies may be equally suitable.

Further information can be obtained by contacting the engine builder or MAN Diesel & Turbo.

2 Circulating Oil System

(See Drawing 3055-0115)

One of the pumps (1) draws the oil from the bottom tank and forces it through the lub. oil cooler (2), the filter (3) with an absolute fineness of minimum 50 µm (0.05 mm) (40 µm, 0.04 mm for AlSn40 bearings) corresponding to a nominal fineness of approx. 30 µm at a retaining rate of 90%) and thereafter delivers it to the engine via the flange RU.

RU The main part of the oil is, via the telescopic pipe, sent to the piston cooling manifold, where it is distributed between piston cooling and bearing lubrication. From the crosshead bearings, the oil flows through bores in the connecting rods, to the crankpin bearings.

The remaining oil goes to lubrication of the main bearings, thrust bearing, camshaft (not ME/ME-C engines) and turbocharger.

The relative amounts of oil flowing to the piston cooling manifold, and to the main bearings, are regulated by a butterfly valve, or an orifice plate. The oil distribution inside the engine is shown on *Drawing 3055-0125*.

Circulating Oil Pressure: *See 7045-0100*.

3 Circulating Oil Failure

3.1 Cooling Oil Failure

The piston cooling oil is supplied via the telescopic pipe fixed to a bracket on the crosshead. From here it is distributed to the crosshead bearing, guide shoes, crankpin, bearing and to the piston crown.

Failing supply of piston cooling oil, to one or more pistons, can cause heavy oil coke deposits in the cooling chambers. This will result in reduced cooling, thus increasing the material temperature above the design level.

In such cases, to avoid damage to the piston crowns, the cylinder loads should be reduced immediately (see slow-down below), and the respective pistons pulled at the first opportunity, for cleaning of the cooling chambers.

Cooling oil failure will cause alarm and slow-down of the engine. *See 7045-0100*.

For CPP-plants with a shaft generator coupled to the grid, an auxiliary engine will be started automatically and coupled to the grid before the shaft generator is disconnected and the engine speed reduced. *See Drawing 6655-0120, 'Sequence Diagram'.*

After remedying a cooling oil failure, it must be checked (with the circulating oil pump running) that the cooling oil connections in the crankcase do not leak, and that the oil outlets from the crosshead, crankpin bearings, and piston cooling, are in order.

3.2 Lubricating Oil Failure

If the lube oil pressure falls below the pressures stated in 7045-0100, the engine's safety equipment shall reduce the speed to slow down level, respectively stop the engine when the SHUT DOWN oil pressure level has been reached.

For CPP-plants with a shaft generator coupled to the grid, an auxiliary engine will be started automatically and coupled to the grid before the shaft generator is disconnected and the engine speed reduced. *See 6655-0120, 'Sequence Diagram'.*

Find and remedy the cause of the pressure drop.

NOTICE

A likely cause of pressure drop, is worn-out bearings, causing the filters to clog.

Check for traces of melted white metal in the crankcase and oil pan. *See also Section 6645-0100.*

“Feel over” 15-30 minutes after starting, again one hour later, and finally also after reaching full load (*see also Section 6645-0120*).

1 Oil System Cleanliness

In a new oil system, as well as in a system which has been drained owing to repair or oil change, the utmost care must be taken to avoid the ingress and presence of abrasive particles, because filters and centrifuges will only remove these slowly, and some are therefore bound to find their way into bearings etc.

For this reason - prior to filling-up the system - careful cleaning of pipes, coolers and storage tank is strongly recommended.

2 Cleaning the Circulating Oil System

The recommendations below are based on our experience, and laid out in order to give the contractor/supplier and operators the best possible advice regarding the avoidance of mishaps to a new engine, or after a major repair.

The instruction given in this book is an abbreviated version of our flushing procedure used prior to shoptrial. A copy of the complete flushing procedure is available through MAN Diesel & Turbo or the engine builder.

2.1 Cleaning before filling-up

In order to reduce the risk of bearing damage, the normal careful manual cleaning of the crankcase, oil pan, pipes and storage tank, is naturally very important.

However, it is equally important that the system pipes and components, *between the filter(s) and the bearings*, are also carefully cleaned for removal of "welding spray" and oxide scales.

If the pipes have been sand blasted, and thereafter thoroughly cleaned or "acid-washed", then this ought to be followed by "washing-out" with an alkaline liquid, and immediately afterwards the surfaces should be protected against corrosion.

In addition, particles may also appear in the circulating oil coolers, and therefore we recommend that these are also thoroughly cleaned.

2.2 Flushing Procedure, Main Lube Oil System

Regarding flushing of the camshaft lube oil pipes:

Engines with Uni-lube system, see *Description 3045-0160*.

Experience has shown that both during and after such general cleaning, airborne abrasive particles can still enter the circulating oil system. For this reason it is necessary to flush the whole system by continuously circulating the oil - while bypassing the engine bearings, etc.

This is done to remove any remaining abrasive particles, and, before the oil is again led through the bearings, **it is important** to definitely ascertain that the system and the oil have been cleaned adequately.

During flushing (as well as during the preceding manual cleaning) the bearings must be effectively protected against the entry of dirt.

The methods employed to obtain effective particle removal during the oil circulation depend upon the actual plant installations, especially upon the filter(s) type, lube oil centrifuges and the bottom tank layout.

Cleaning is carried out by using the lube oil centrifuges and by pumping the oil through the filter. A special flushing filter, with fineness down to 10 µm, is often used as a supplement to or replacement of the system filter.

The following items are by-passed by blanking off with special blanks:

- a. The main bearings
- b. The crossheads
- c. The thrust bearing
- d. The turbocharger(s)
- e. The axial vibration damper.
- f. The torsional vibration damper (if installed)
- g. The moment compensators (if installed)
- h. The chain drive

See also Drawing 3055-0130 page 1.

It is possible for dirt to enter the crosshead bearings due to the design of the open bearing cap. It is therefore essential to cover the bearing cap with rubber shielding throughout the flushing sequence.

As the circulating oil cannot by-pass the bottom tank, the whole oil content should partake in the flushing.

During the flushing, the oil should be heated to 60-65°C and circulated using the full capacity of the pump to ensure that all protective agents inside the pipes and components are removed.

It is essential to obtain an oil velocity which causes a turbulent flow in the pipes that are being flushed.

Turbulent flow is obtained with a Reynold number of 3000 and above.

$$R_e = \frac{V \times D}{\nu} \times 1000, \text{ where}$$

R_e = Reynold number

V = Average flow velocity (m/s)

ν = Kinematic viscosity (cSt)

D = Pipe inner diameter (mm)

The preheating can be carried out, for instance, by filling the waterside of the circulating oil cooler (between the valves before and after the cooler) with fresh water and then leading steam into this space. During the process the deaerating pipe must be open, and the amount of steam held at such a level that the pressure in the cooler is kept low.

In order to obtain a representative control of the cleanliness of the oil system during flushing, "control bags" are used (e.g. 100 mm wide by 400 mm long, but with an area of not less than 1000 cm², and made from 0.050 mm filter gauze). Proposals for checkbag housings are shown on *Drawing 3055-0130 page 2*.

To ensure cleanliness of the oil system after the filter, two bags are placed in the system, one at the end of the main lube oil line for the telescopic pipes, and one at the end of the main lube oil line for the bearings.

To ensure cleanliness of the oil itself, another bag is fed with circulating oil from a connection stub on the underside of a horizontal part of the main pipe between circulating oil pump and main filter. This bag should be fitted to the end of a 25 mm plastic hose and hung in the crankcase.

At intervals of approx. two hours, the bags are examined for retained particles, where after they are cleaned and suspended again, without disturbing the oil circulation in the main system.

The oil flow through the "control bags" should be sufficient to ensure that they are continuously filled with oil. The correct flow is obtained by restrictions on the bag supply pipes.

The max. recommended pressure differential across the check bag is 1 bar, or in accordance with information from the check bag supplier.

On condition that the oil has been circulated with the full capacity of the main pump, the oil and system cleanliness is judged sufficient when, *for two hours, no abrasive particles have been collected*.

As a supplement, and for reference during later inspections, we recommend that in parallel to using the checkbag, the cleanliness of the lube oil is checked by particle counting, in order to find particle concentration, size and type of impurities. When using particle counting, flushing should not be accepted as being complete until the cleanliness is found to be within the range in ISO 4406 level $\leq 19/15$ (corresponding to NAS 1638, Class 10).

In order to improve the cleanliness, it is recommended that the circulating oil centrifuges are in operation during the flushing procedure. The centrifuge preheaters ought to be used to keep the oil heated to the proper level.

NOTICE

If the centrifuges are used without the circulating oil pumps running, then they will only draw relatively clean oil, because, on account of low oil velocity, the particles will be able to settle at different places within the system.

A portable vibrator or hammer should be used on the outside of the lube oil pipes during flushing in order to loosen any impurities in the piping system. The vibrator is to be moved one metre at least every 10 minutes in order not to risk fatigue failures in piping and welds.

A flushing log, *see Drawing 3055-0130 page 3*, is to be used during flushing and for later reference.

As a large amount of foreign particles and dirt will normally settle in the bottom tank during and after the flushing (low flow velocity), it is recommended that the oil in the bottom tank is pumped to a separate tank via a 10 µm filter, and then the storage tank is again cleaned manually. The oil should be returned to the tank via the 10 µm filter.

If this storage tank cleaning is not carried out, blocking up of the filters can frequently occur during the first service period, because settled particles can be dispersed again:

- a. due to the oil temperature being higher than that during flushing,
- b. due to actual engine vibrations.

Important: When only a visual inspection of the lube oil is carried out, it is important to realise that the smallest particle size which is detectable by the human eye is approx. 0.04 mm.

During running of the engine, the lube oil film thickness in the bearings becomes as low as 0.005 mm or even lower. Consequently, visual inspection of the oil *cannot* protect the bearings from ingress of harmful particles. It is recommended to inspect the lube oil in accordance with ISO 4406.

3 Circulating Oil Treatment

3.1 General

Circulating oil cleaning, during engine operation, is carried out by means of an inline oil filter, the centrifuges, and possibly by-pass filter, if installed, as illustrated on *Drawing 3055-0115*.

The engine as such consumes about 0.1 g/kWh of circulating lub. oil, which must be compensated for by adding new lub. oil.

It is this continuous and necessary refreshing of the oil that will control the BN and viscosity on an acceptable equilibrium level as a result of the fact that the oil consumed is with elevated figures and the new oil supplied has standard data.

In order to obtain effective separation in the centrifuges, it is important that the flow rate and the temperature are adjusted to their optimum, as described in the following.

3.2 The Centrifuging Process

Efficient oil cleaning relies on the principle that - provided the through-put is adequate and the treatment is effective - an equilibrium condition can be reached, where the engine contamination rate is balanced by the centrifuge separation rate i.e.:

Contaminant quantity added to the oil per hour = contaminant quantity removed by the centrifuge per hour.

It is the purpose of the centrifuging process to ensure that this equilibrium condition is reached, with the oil insolubles content being as low as possible.

Since the cleaning efficiency of the centrifuge is largely dependent upon the flow-rate, it is very important that this is optimised.

The above considerations are further explained in the following.

3.3 The System Volume, in Relation to the Centrifuging Process

As mentioned above, a centrifuge working on a charge of oil will, in principle, after a certain time, remove an amount of contamination material per hour which is equal to the amount of contamination material produced by the engine in the same span of time.

This means that the system (engine, oil and centrifuges) is in equilibrium at a certain level of oil contamination (P_{eq}) which is usually measured as pentane insolubles %.

In a small oil system (small volume), the equilibrium level will be reached sooner than in a large system (Fig. 1) - but the final contamination level will be the same for both systems - because in this respect the system oil acts only as a carrier of contamination material.

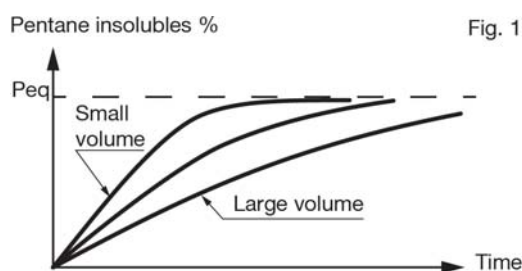


Fig. 1

A centrifuge can be operated at greatly varying flow rates (Q).

Practical experience has revealed that the content of pentane insolubles, before and after the centrifuge, is related to the flow rate as shown in Fig. 2.

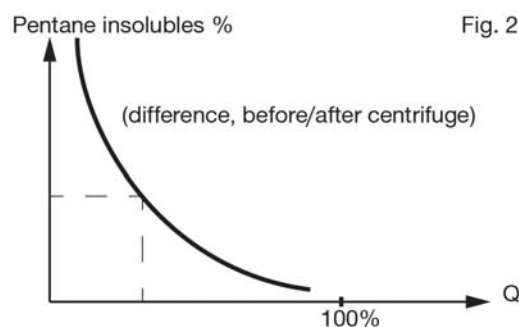


Fig. 2

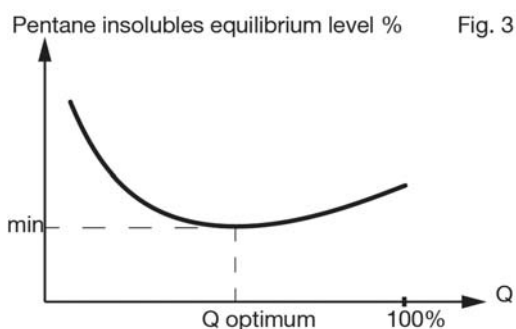
Fig. 2 illustrates that the amount of pentane insolubles removed will decrease with rising Q .

It can be seen that:

- At low Q , only a small portion of the oil is passing the centrifuge/hour, but is being cleaned effectively.
- At high Q , a large quantity of oil is passing the centrifuge/hour, but the cleaning is less effective.

Thus, by correctly adjusting the flow rate, an optimal equilibrium cleaning level can be obtained (Fig. 3).

This minimum contamination level is obtained by employing a suitable flow rate that is only a fraction of the stated maximum capacity of the centrifuge (see the centrifuge manual).



3.4 Guidance Flow Rates

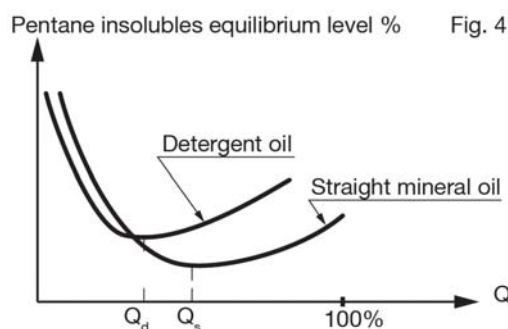
The ability of the system oil to “carry” contamination products is expressed by its detergency/dispersancy level.

This means that a given content of contamination - for instance 1 % pentane insolubles - will, in a detergent oil, be present as smaller, but more numerous particles than in a straight oil.

Furthermore, the particles in the detergent oil will be surrounded by additives, which results in a specific gravity very close to that of the oil itself, thereby hampering particle settling in the centrifuge.

This influences the position of the minimum in Fig. 3, as illustrated in Fig. 4.

As can be seen, the equilibrium level in a detergent oil will be higher than in a straight oil, and the optimum flow rate will be lower.



However, since the most important factor is the particle size (risk of scratching and wear of the bearing journals), the above-mentioned difference in equilibrium levels is of relatively minor importance, and the following guidance figures can be used:

In general,

- a. the optimum centrifuge flow rate for a detergent oil is about 20-25% of the maximum centrifuge capacity,
- b. whereas, for a *straight oil*, it is about 50-60%.
- c. This means that for most system oils of today, which incorporate a certain detergency, the optimum will be at about 30-40% of the maximum centrifuge capacity.

The *preheating* temperature should be about 90°C.

4 Oil Deterioration

4.1 General

Oil seldom loses its ability to lubricate, i.e. to form an oil film which reduces friction, but it can become corrosive.

If this happens, the bearing journals can be attacked, such that their surfaces become too rough, and thereby cause wiping of the white metal.

In such cases, not only must the bearing metal be renewed, but also the journals (silvery white from adhering white metal) will have to be re-polished.

Lubricating oil corrosiveness is either due to advanced oxidation of the oil itself (Total Acid Number, TAN) or to the presence of inorganic acids (Strong Acid Number, SAN). *See further on in this Section.*

In both cases the presence of water will multiply the effect, especially an influx of salt water.

4.2 Oxidation of Oils

At normal service temperature the rate of oxidation is insignificant, but the following three factors will accelerate the process:

4.2.1 High Temperature

The temperature level will generally increase if the coolers are not effective.

Local high-temperature areas will arise in pistons, if circulation is not continued for about 15 minutes after stopping the engine.

The same will occur in electrical preheaters, if circulation is not continued for 5 minutes after the heating has been stopped, or if the heater is only partly filled with oil (insufficient venting).

4.2.2 Air Admixture

Good venting of the bottom tank should be arranged.

The total oil quantity should be such that it is not circulated more than about 15-18 times per hour. This ensures that sufficient time exists for deaeration during the period of "rest" in the bottom tanks.

It is important that the whole oil content takes part in the circulation, i.e. stagnant oil should be avoided.

4.2.3 Catalytic Action

Oxidation will be considerably accelerated if oxidation catalysts are present in the oil.

In this respect, wear particles of copper are especially bad, but also ferrous wear particles and rust are active.

In addition, lacquer and varnish-like oxidation products of the oil itself have an accelerating effect. Therefore, continuous cleaning is important to keep the "sludge" content low.

As water will evaporate from the warm oil in the bottom tank, and condense on the tank ceiling, rust is apt to develop here and fall into the oil, thereby tending to accelerate oxidation. This is the reason for advocating the measures mention in *Section 6645-0100*, concerning cleaning and rust prevention.

4.3 Signs of Deterioration

If oxidation becomes grave, prompt action is necessary because the final stages of deterioration can develop and accelerate very quickly, i.e. within one or two weeks.

Even if this seldom happens, it is prudent to be acquainted with the following signs of deterioration, which may occur singly or in combinations.

- The sludge precipitation in the centrifuge multiplies.
- The smell of the oil becomes bad (acid or pungent).
- Machined surfaces in crankcase become coffee-brown (thin layer of lacquer).
- Paint in crankcase peels off, or blisters.
- Excessive carbon deposits (coke) are formed in piston cooling chambers.

In serious cases of oil deterioration, the system should be cleaned and flushed thoroughly, before fresh oil is filled into it.

4.4 Water in the Oil

Water contamination of the circulating oil should always be avoided.

The presence of water, especially salt water, will:

- accelerate oil oxidation (tend to form organic and inorganic acids)
- tend to corrode machined surfaces and thereby increase the roughness of bearing journals and piston rods, etc. (*see e.g. Section 2545-0100*)
- tend to form tin-oxide on white metal (*see Section 2545-0100*).

In addition, freshwater contamination can enhance the conditions for bacteriological attack.

For alkaline oils, a minor increase in the freshwater content is not immediately detrimental, as long as the engine is running, although it should, as quickly as possible, be reduced again to *below* 0.2% water content.

If the engine is stopped with excess water in the oil, then once every hour, it should be turned a little more than 1/2 revolution (to stop in different positions), while the oil circulation and centrifuging (at preheating temperature) continue to remove the water. This is particularly important in the case of salt water ingress.

Water in the oil may be noted by “dew” formation on the sight glasses, or by a *milky* appearance of the oil.

Its presence can also be ascertained by heating a piece of glass, or a soldering iron, to 200-300°C and immersing it in an oil sample. If there is a hissing sound, water is present.

If a large quantity of (sea) water has entered the oil system, it may be profitable to suck up sedimented water from the bottom of the tank. Taste the water for salt.

In extreme cases it may be necessary to remove the oil/water mixture, and clean and/or flush the system, before filling up again with the cleaned oil, or the new oil.

4.5 Check of Oil Condition

As described in items 4.3 and 4.4, the on site surveillance of oil condition involves keeping a check of:

- alterations in separated sludge amount
- appearance and smell of the oil
- “dew” on sight glasses
- lacquer formation on machined surfaces
- paint peeling and/or blistering
- “hissing” test
- carbon deposits in piston crown.

In addition to the above, oil samples should be sent ashore for analysis at least every three months. The samples should be taken while the engine is running, and from a test cock on a main pipe through which the oil is circulating.

Kits for rapid on-board analyses are available from the oil suppliers. However, such kits can only be considered as supplementary and should not replace laboratory analyses.

5 Circulating Oil: Analyses and Characteristic Properties

The system/circulating oil cleanliness level for ME-engines in service is recommended to be kept at level according to ISO 4406 Code xx/16/13

Used-oil analysis is most often carried out at oil company laboratories. It is normal service for these to remark upon the oil condition, based upon the analysis results. The report usually covers the following characteristics:

Property	Remarks	Guiding Limits for used oils
Oil Type	Alkaline detergent (for 2-stroke engines)	
Specific Gravity	Usually 0.90-0.98. Mainly used for identification of the oil.	±5% (of initial value)
Viscosity	The viscosity increases with oil oxidation, and also by contamination with cylinder oil, heavy fuel, or water. A decrease in the viscosity may be due to dilution with diesel oil.	max. + 40% min. -15% (of initial value)
Flash Point (open cup)	Lowest temperature at which the oil gives off a combustible vapour. Gives an indication of possible fuel oil contamination.	min. 180°C
TAN (Total Acid Number)	This expresses the total content of organic and inorganic acids in the oil. Organic (or weak) acids are due to oxidation. TAN = SAN + Weak acid number.	max. 2
SAN (Strong Acid Number)	This expresses the amount of inorganic (or strong) acids in the oil. These are usually sulphuric acid from the combustion chamber, or hydrochloric acid arising from salt water (ought to be stated in the analysis). SAN makes the oil corrosive (especially if water is present) and should be zero.	0
Alkalinity/BN (Base Number)	Gives the alkalinity level in oils containing acid neutralizing additives. Increase in BN can influence the ability of the oil to reject water. It will then be difficult for the centrifuge to remove water. Deposits built up by water and Calcium (Ca) can build up lacquer on the bearings. Another effect is increased sludge formation.	max.+ 100% min.-30% (of initial values)
Water	Risky if TAN and SAN are high. Salt water has a higher corrosive effect than freshwater. <i>See previous point 4.4. Also refer to SL05-460/NHN</i>	fresh: 0.2% (0.5% for short periods) Saline: trace

Property	Remarks	Guiding Limits for used oils
Conradson Carbon	Residue from incomplete combustion, or cracked lubricating and cylinder oil.	max. + 3%
Ash	Some additives leave ash, which may thereby be used to indicate the amount of additives in the oil. The ash can also consist of wear particles, sand and rust. The ash content of a used oil can only be evaluated by comparison with the ash content of the unused oil.	max. + 2%
Insolubles	Usually stated as pentane/heptane and benzene insolubles. The amount of insoluble ingredients in the oil is checked as follows: Equal parts of the oil sample are diluted with benzene (C ₆ H ₆) and normal pentane (C ₅ H ₁₂) or heptane (C ₇ H ₁₄). As oxidized oil (lacquer and varnish-like components) is only soluble in benzene, and not in pentane or heptane, the difference in the amount of insolubles is indicative of the degree of oil oxidation. The benzene insolubles are the solid contaminants.	Non-coagulated pentane insolubles max. 2% Non-coagulated benzene insolubles max. 1%

The above limiting values are given for reference/guidance purposes only.

The assessment of oil condition can seldom be based on the value of a single parameter, i.e. it is usually important, and necessary, to base the evaluation on the overall analysis specification.

For qualified advice, we recommend consultation with the oil company or engine builder.

6 Cleaning of Drain Oil from Piston Rod Stuffing Boxes

See Drawing 3055-0135.

The oil which is drained off from the piston rod stuffing boxes is mainly circulating oil with an admixture of partly-used cylinder oil and, as such, it contains sludge from the scavenge air space. In general, this oil can be re-used if thoroughly cleaned.

Drawing 3055-0135 shows the cleaning installations. (Option)

The drain oil is collected in tank No. 1. When the tank is nearly full, the oil is transferred, via the centrifuge, to tank No. 2, and thereafter, via the centrifuge, recirculated a number of times.

When centrifuging the stuffing box drain oil, the flow-rate should be decreased to about 50% of what is normally used for the circulating oil, and the preheating temperature raised to about 90°C. This is because, in general, the drain oil is a little more viscous than the circulating oil, and also because part of the contamination products consist of oxidized cylinder oil, with a specific gravity which does not differ much from that of the circulating oil itself.

Water-washing should only be carried out if recommended by the oil supplier. Finally, the centrifuged oil in tank No. 2, should be filtered a number of times through the cellulose fine filter, at a temperature of 60-80°C.

This will remove any very fine soot and oxidation products not taken out by the centrifuging, and thus make the oil suitable for returning to the circulating system.

Provided that the *circulating oil is an alkaline detergent type*, it is not necessary to analyse each charge of cleaned drain oil before it is returned to the system. Regular sampling and analysis of the circulating oil and drain oil will be sufficient.

If, however, the *circulating oil is not alkaline*, all the cleaned drain oil should be checked for acidity, for instance by means of an analysis kit, before it is returned to the system.

The "total acid number" (TAN) should not exceed 2. *See also Item 5, 'Circulating Oil: Analyses & Characteristic Properties'*. If the TAN exceeds 2, the particular charge of drain oil should be disposed of.

1 MAN Diesel & Turbo T/C, System Details

The lube oil system for the MAN Diesel & Turbo type of turbocharger is shown separately on *Drawing 3055-0155*.

The system is supplied from the main lube oil system.
See also Drawing 3055-0125.

The oil is discharged to the main lube oil system. The discharge line is connected to the venting pipe, E, which leads to open air.
See also Drawing 3055-0115.

In case of failing lube oil supply from the main lube oil system, e.g. due to a power black-out or defects in the system, the engine will stop due to shut-down. Lubrication of the turbocharger bearings is ensured by a separate tank.

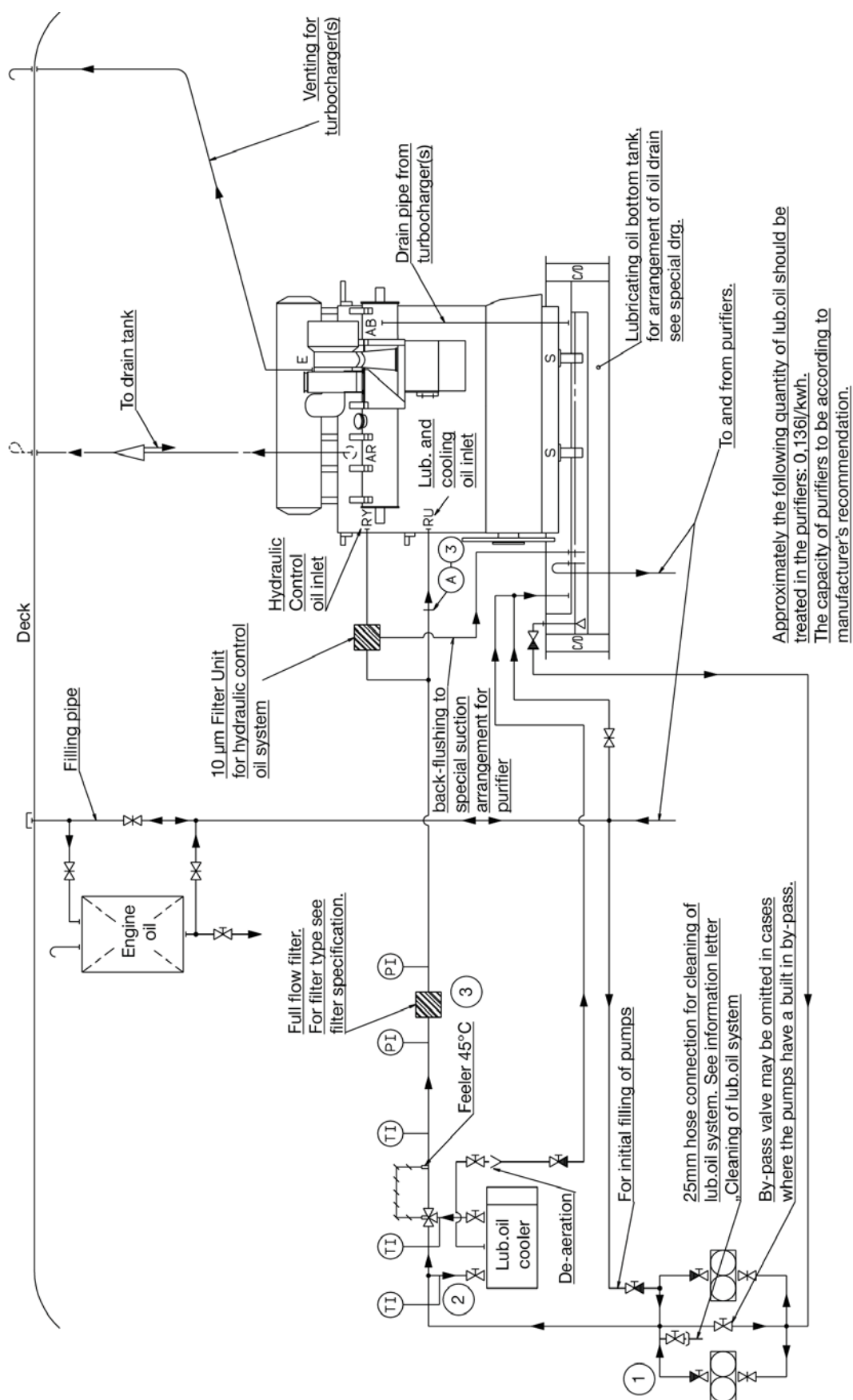
The tank is mounted on top of the turbocharger, and is able to supply lube oil until the rotor is at a standstill, or until the lube oil supply is re-established.

2 MET T/C, System Details

The MET turbochargers are also lubricated via the main lube oil system. *See description of turbocharger lube oil system in Item 1 'MAN Diesel & Turbo T/C, System Details'.*

3 ABB TPL T/C, System Details

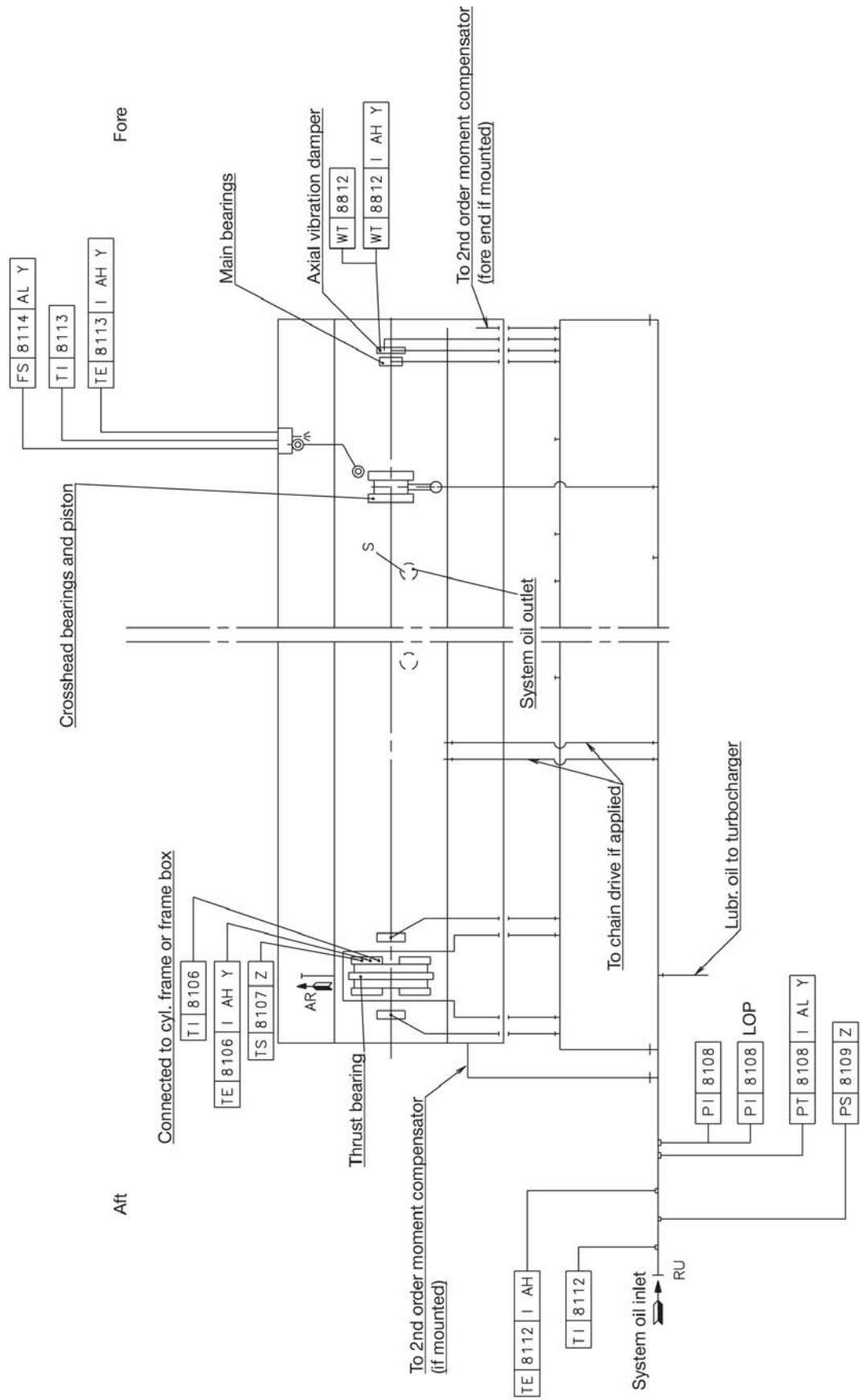
The ABB TPL turbochargers are designed either with an integrated lube oil system or with a similar system as MDT TC. Please refer to the relevant ABB TPL-instruction manual.



Circulating Oil System (Outside Engine)

Drawing

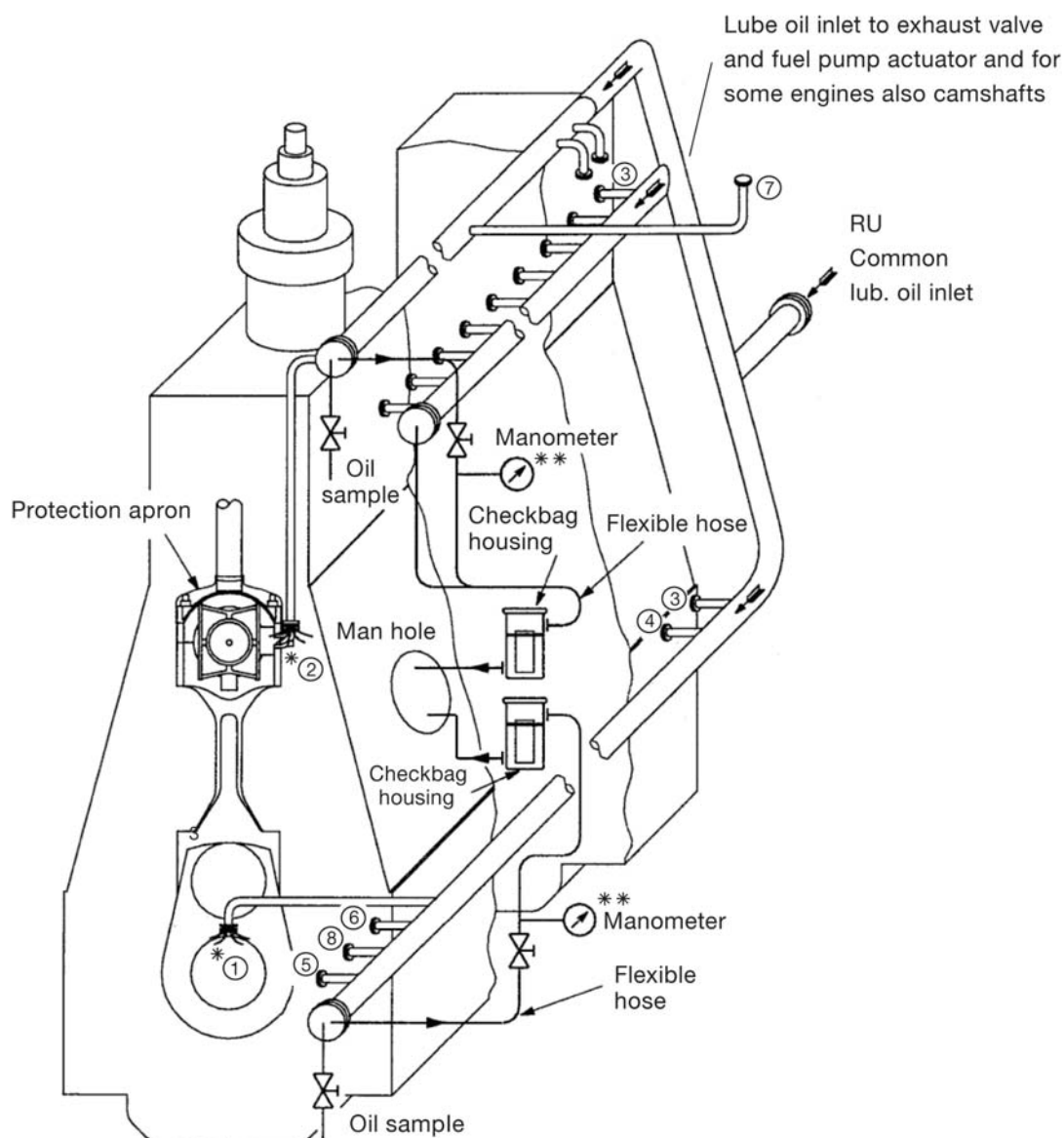
3055-0115-0002



Circulating Oil System (Inside Engine)

Drawing
3055-0125-0003

Location of Checkbag and Blank Flanges



Blanking off pipes:

1. Main bearing by-pass blanks
2. Crosshead bearings by-pass blanks
3. Blank-off Thrust bearing
4. Blank-off or by-pass axial vibration damper
5. Blank-off torsional vibration damper
6. Blank-off forward moment compensator chain drive
7. Blank-off or by-pass turbocharger
8. Blank-off PTO-PTI power gear

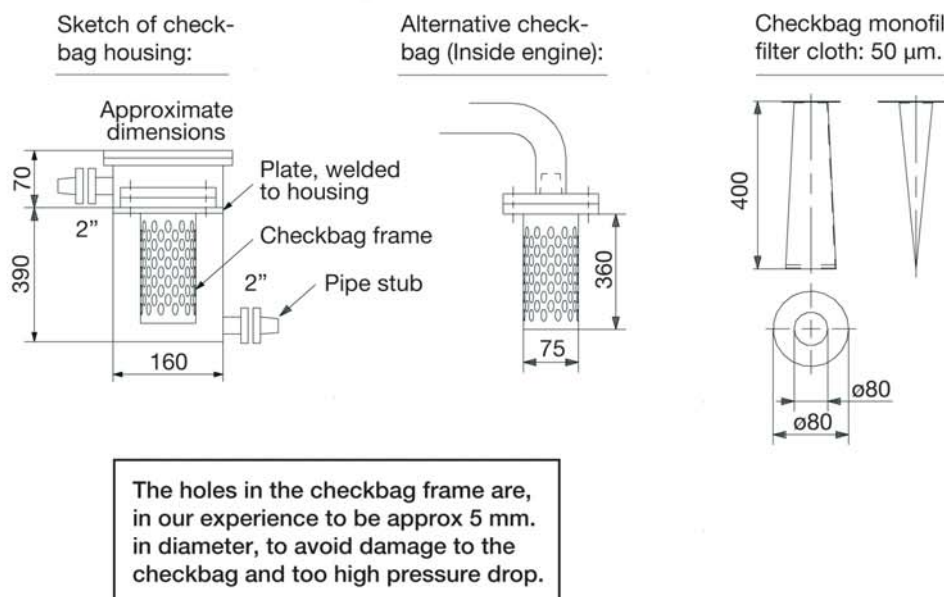
* See Page 2.

** Manometer, max. recommended pressure before checkbag: 1 bar o. or in accordance with information from the checkbag supplier.

Flushing of Main Lubricating Oil System

Drawing
3055-0130-0003

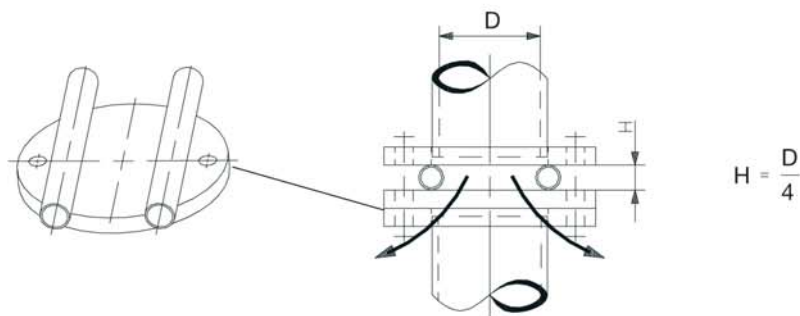
Dimension of Checkbag and Blank Flanges



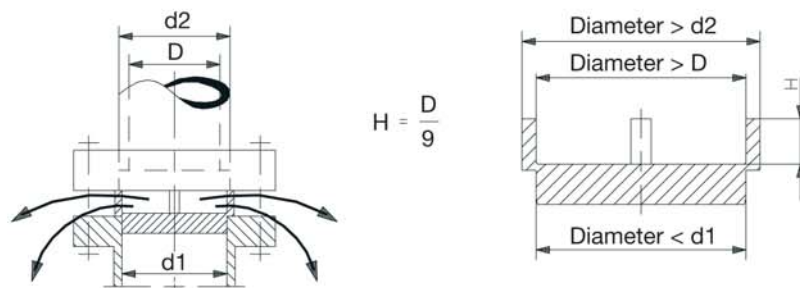
The above filter components can be delivered from MAN Diesel & Turbo

Blank flanges for flushing:

A) Blank at main bearings

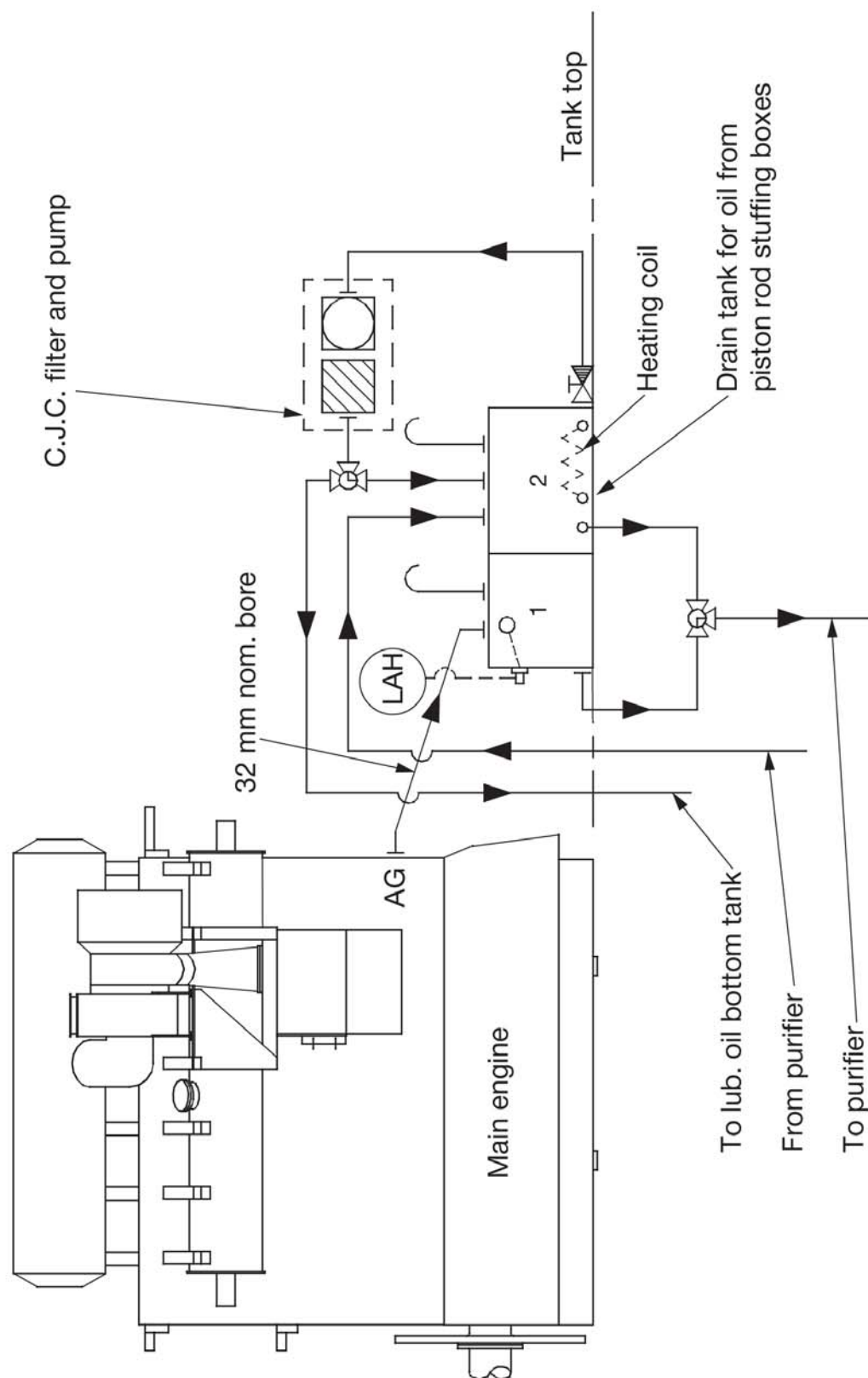


B) Blank between telescopic pipes and crossheads



Flushing of Main Lubricating Oil System

Drawing
3055-0130-0003

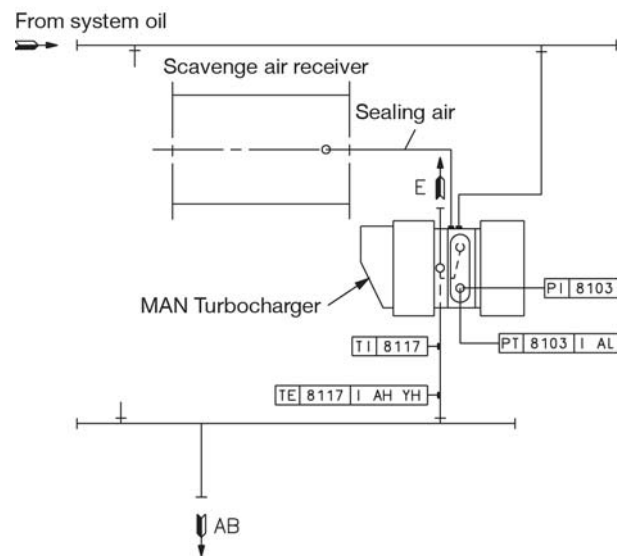


Cleaning System, Stuffing Box Drain Oil (Option)

Drawing

3055-0135-0002

MAN Turbocharger



MET Turbocharger

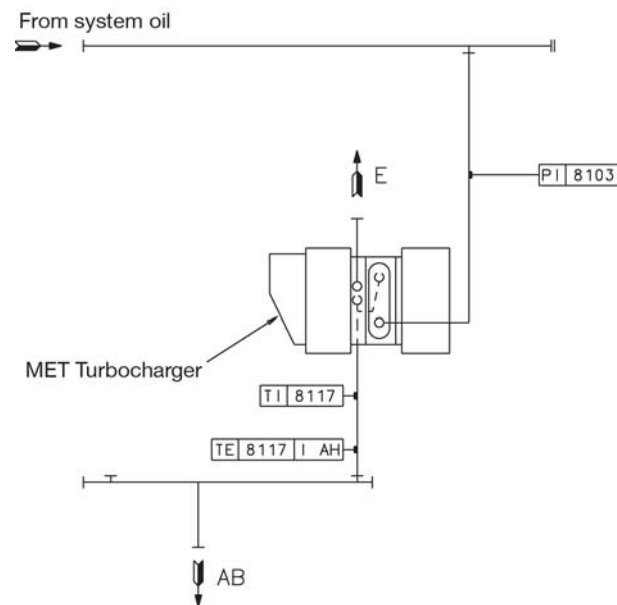
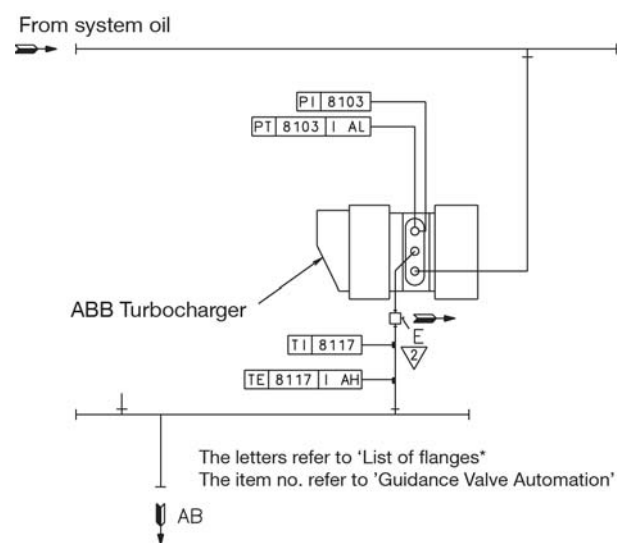


ABB TPL Turbocharger



Safety**Precautions**

*for detailed sketch
see 0545-0100*

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off safety air supply - Not ME Engines
☐	Shut off control air supply
☐	Shut off air supply to exhaust valve - Only when stopped lubricating oil pumps
☐	Engage turning gear
☐	Shut off cooling water
☐	Shut off fuel oil
☐	Stop lubricating oil supply
☐	Lock the turbocharger rotors

Data

Ref.	Description	Value	Unit
T30-08	Maximum water content lub.oil	0.2	%

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.



1. Lub. oil checking Lubricating oil is to be checked for water content and other contaminants weekly.

2. Lub. oil samples In addition to the on board surveillance of the lubricating oil condition.

See description 3045-0130.

Oil samples must be sent ashore for analysis at least every three months.

The samples should be taken while the engine is running, and from a test cock on a main pipe through which the oil is circulating.



3065-0151-0001C02

Safety**Precautions**

for detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
-	Table is empty on purpose. No Data needed.	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
2270-0400	171	Pushing tool for seals
4570-0540	126	Special screw

1. The MOP control panel
 Activate the prelub.-function on the MOP and check that all lubricators are operating correctly.

For use of the MOP, see description 6645-0190.
2. Inspection
 If the cylinder cover or the exhaust valve is removed, check inside the liner that all lubricating points are working properly.

 Otherwise, remove the covers for scavenge port inspection.

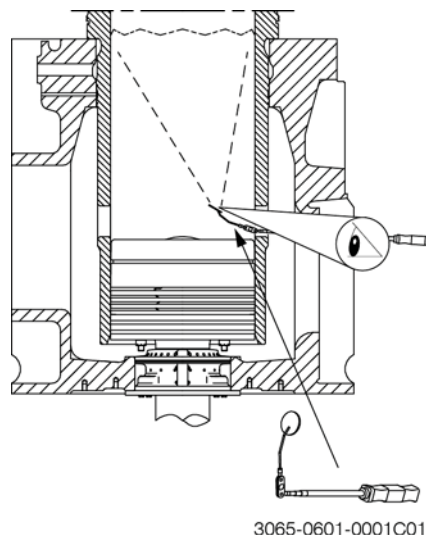
 Turn the piston to BDC and check inside the liner with a mirror and a powerful light source that all lubrication points are working properly.
3. Check all lubricators on LEDs
 With running engine:

 Check that all lubricators are operating correctly by watching the LEDs on the intermediate boxes for each lubricator.

 The LEDs give signal when oil is injected.

 Check the pressure shocks from the injection of the lubricators on each lubricator pipe by feeling with a hand.

 If in doubt, disconnect the pipe at the cylinder liner to observe the oil flow.



Oil spray risk and hot exhaust gas leak

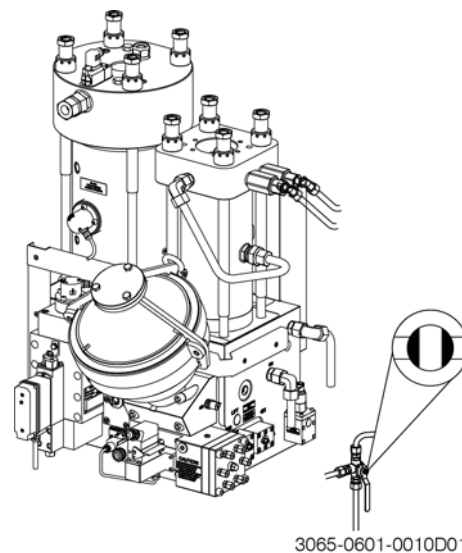
Use eye protection and gloves when disconnecting the lubrication pipes.

1. Dismantling of lubricators

Normally, the engine must be stopped and blocked before dismantling a lubricator.

2. The supply valve

Close the supply valve for cylinder lubricating oil.



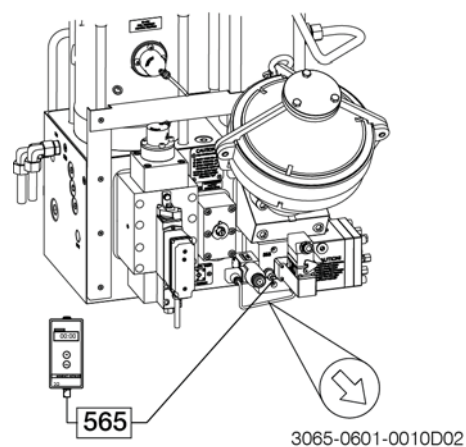
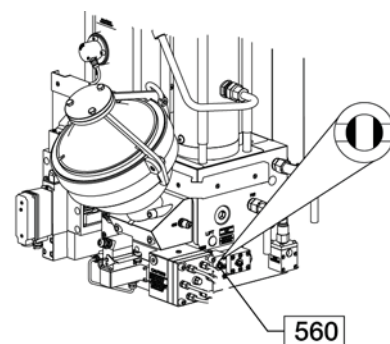
3. Pressure check

Mount a pressure gauge at minimess point 565.

Check the pressure.

Close valve 560. Check that the cylinder lubricator is pressure free. If pressure is still present, activate the prelub. function on the MOP to remove the pressure.

Disconnect the electrical plug on the side of the lubricator.

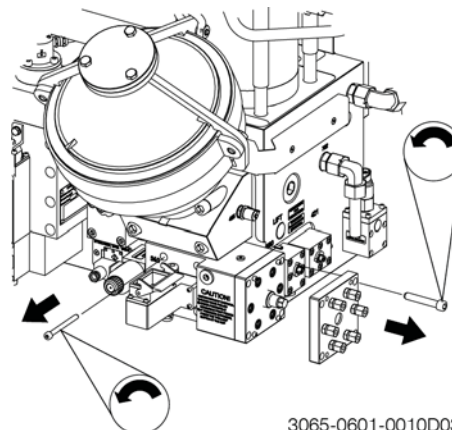


1. Remove the cover of the lubricator

Unscrew the four screws in the aft side of the lubricator and disconnect the cover with pertaining pipes.

Unscrew the four screws on the side that secure the lubricator to the hydraulic cylinder unit.

Pull the pipe flange to one side and pull the lubricator out and clear of the guide pins.



3065-0601-0010D03

2. Special running

It is possible to change a lubricator while the engine is running if a spare lubricator with O-rings and the necessary tools is available. The change should be done in a maximum of 15 minutes.

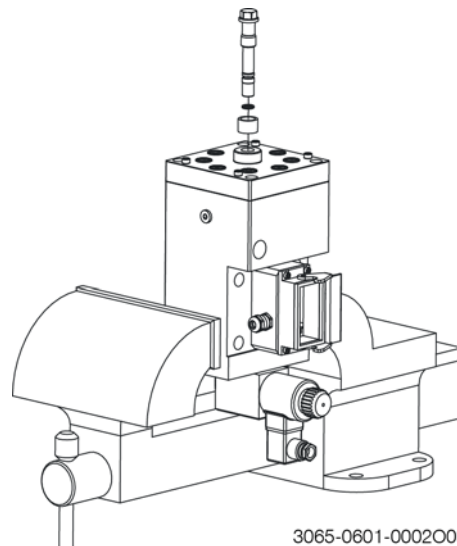
- Reduce the engine rpm to below 40% of MCR-rpm.
- Dismount the lubricator as described in steps 1-3.
- Mount a spare lubricator, *see work card 2265-0601*.

3. Remove the O-ring

Place the lubricator in a bench vice with soft jaws.

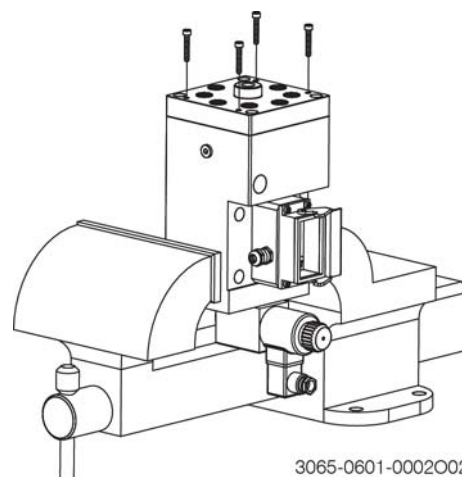
Remove the adjusting screw with bushings.

Discard the O-ring from the adjusting screw.



3065-0601-0002O01

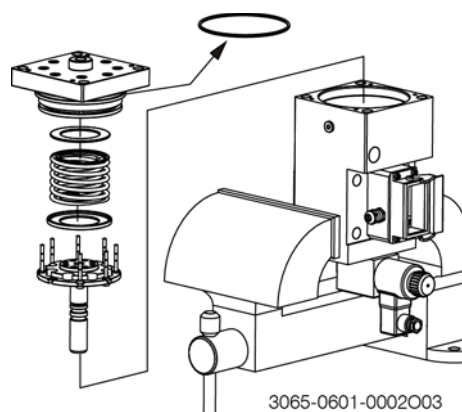
4. The cylinder block Push down the cylinder block and remove the four screws from the cylinder block.



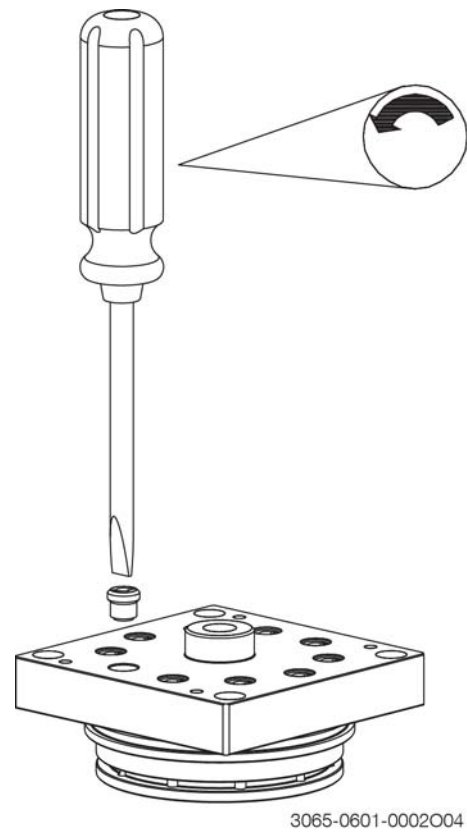
5. Overhaul dismantling Pull up the cylinder block.

Remove the springs, spring disc and actuator piston with plungers.

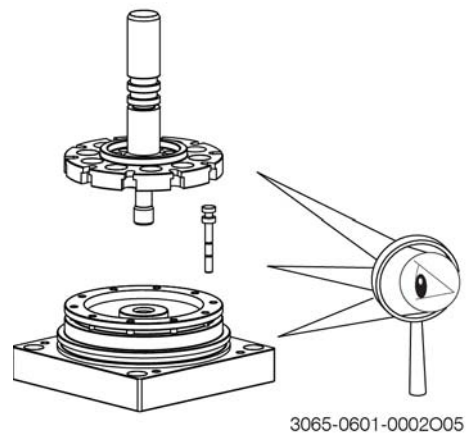
Remove and discard the O-ring from the cylinder block.



6. Non-return valves Screw out the non-return valves and remove and discard the O-rings.
- Clean the valves and check them with compressed air.

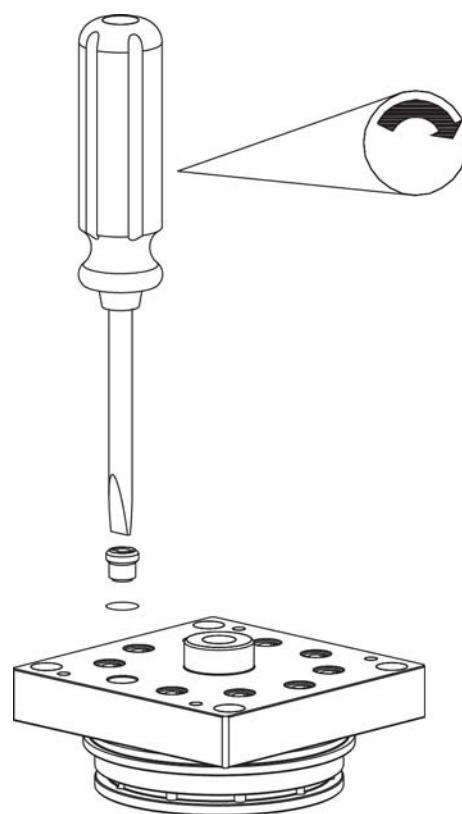


7. General inspections Inspect the plungers, actuator piston and cylinder block for wear, using a magnifying glass.



8. Mount the non-return valve with new O-rings.

Mount the non-return valves in the cylinder block.

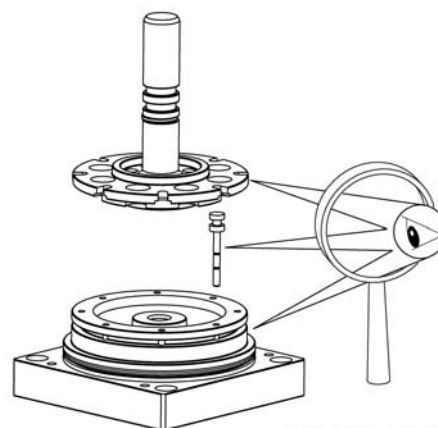


3065-0601-0002Q06

9. Inspection

Inspect the plungers, actuator piston sealing ring and cylinder block for wear, using a magnifying glass.

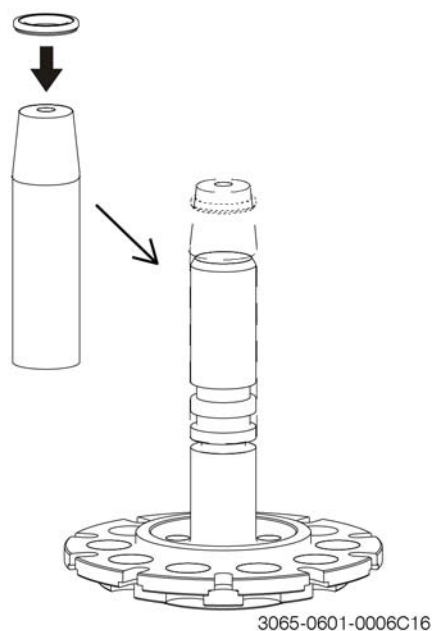
If the sealing ring needs to be replaced, proceed as follows:



3065-0601-0006C15

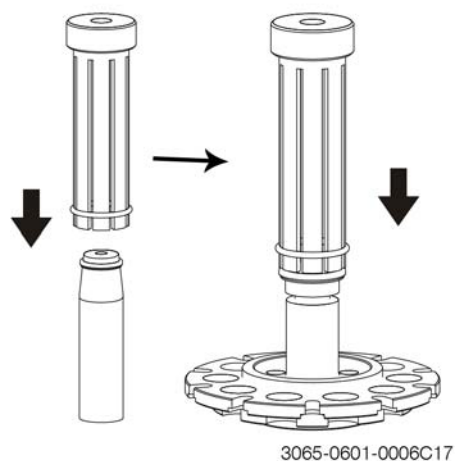
10. Place new sealing ring on the cone

Slide the cone for the sealing ring onto the actuator piston so that only the lowermost groove is exposed. place a new sealing ring on the uppermost part of the cone.



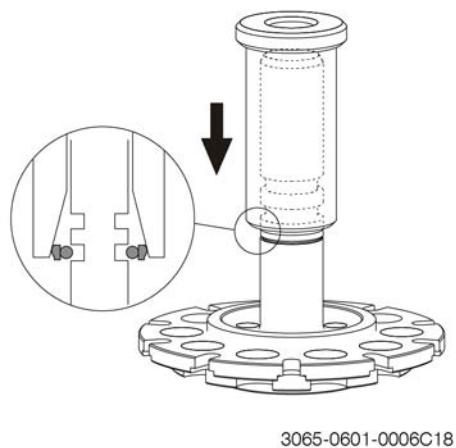
11. Use the pushing tool

Push the pushing tool over the cone thus pushing the sealing ring down to the lowest groove, then remove both tools.



12. Mount the non-return valve

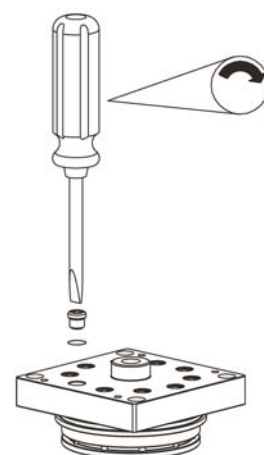
Push the compressor over the ring so that the sealing ring goes back to its original form and into the groove.



13. Non-return valve

Mount the non-return valve with new O-rings.

Mount the non-return valves in the cylinder block.

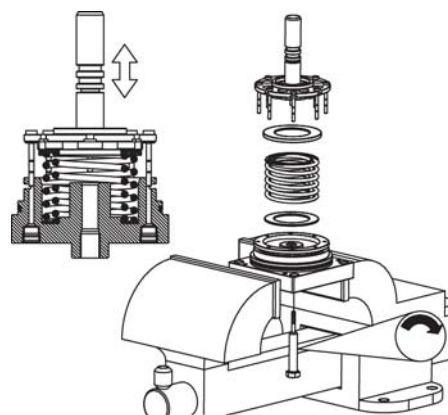


3065-0601-0006C19

14. The cylinder block

Mount the cylinder block with a new O-ring. Pre-assemble the cylinder block with the actuator piston and plungers to ensure correct guidance of the plungers, before finally assembling the cylinder block unit.

Mount the springs and spring disc and press down the actuator piston with plungers. Mount the special screw, supplied with the test equipment for accumulators to keep the spring compressed.



3065-0601-0002O07

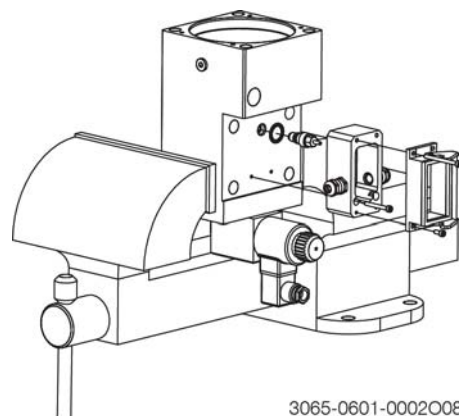
15. The terminal box

Remove the cover from the terminal box, and disconnect the wires for the feedback (pick-up) sensor.

Remove the terminal box.

Carefully unscrew the feedback sensor and remove and discard the O-ring.

Clean the housing with diesel oil or kerosene and dry with a non-fluffy cloth.



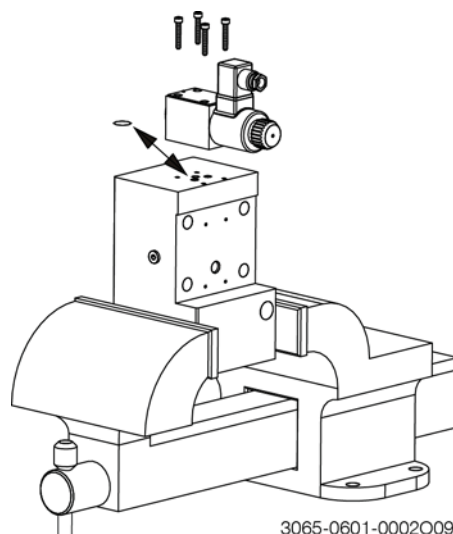
3065-0601-0002O08

16. Solenoid valve

Turn the lubricator upside down in the vice.

Unscrew the solenoid valve.

Discard the O-rings.

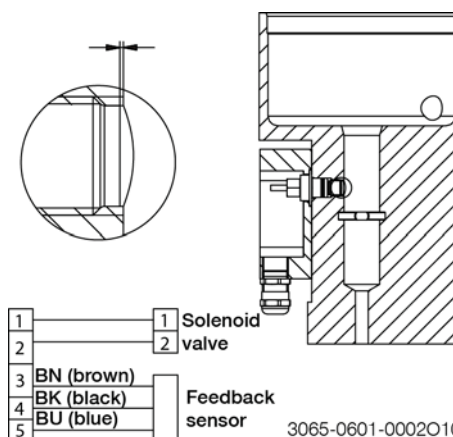


17. Remember !

Before mounting the feedback sensor, check that the sensor is flush with the sensor housing.

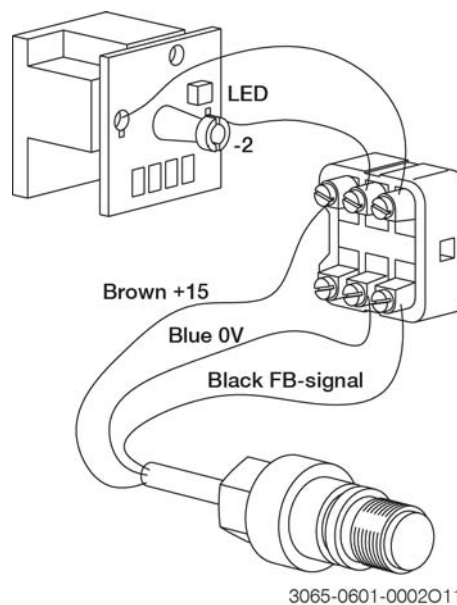
Mount the feedback sensor or a new one, if necessary, with a new O-ring.

Check with an object with a straight edge (e.g. the end of a calliper) that the end of the feedback sensor does not protrude into the actuator piston cylinder.



18. Mount the terminal box

Connect the wires and mount the cover on the terminal box.



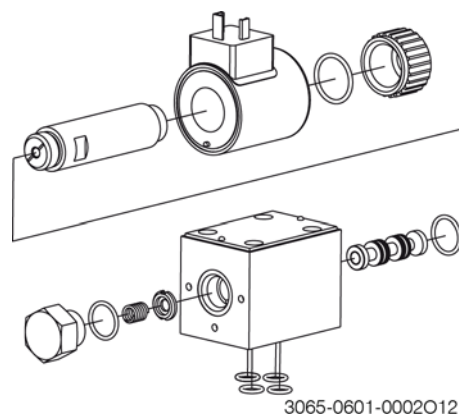
19. Solenoid Valve

Disassemble and clean the valve.

Check the slide for wear. If the slide is scratched or scuffed, the valve must be replaced by a new one.

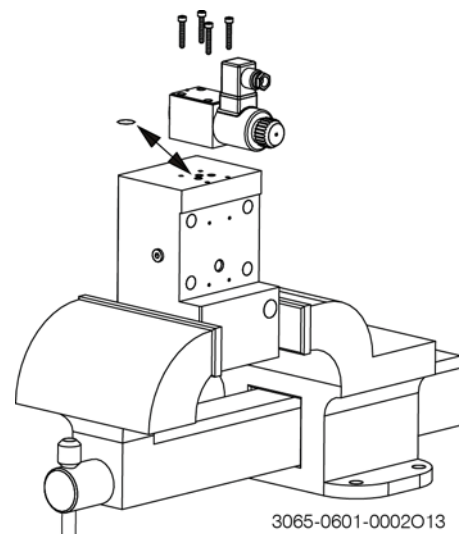
Lubricate the slide with oil and check that the slide can move lightly with a good fit in the housing.

Assemble the valve.



20. Mounting the solenoid valve

Mount the solenoid valve fitted with new O-rings. Coat the O-rings with a little grease to keep the rings in place during mounting.



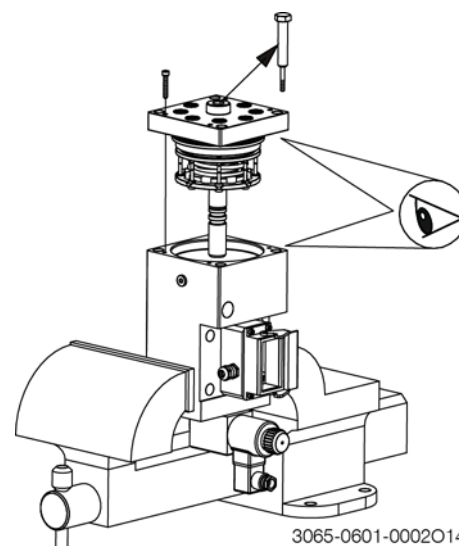
21. Cylinder block assembly and cylinder housing

Mount the cylinder block assembly in the cylinder housing.

Check that the spring pin engages correctly with the cylinder block assembly.

Mount the screws and tighten the block to the housing.

Remove the special screw.



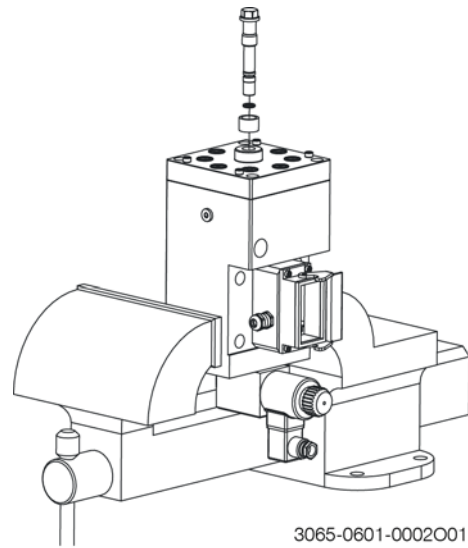
22. New O-ring and distance bushing

Mount the adjusting screw fitted with a new O-ring and the distance bushing.

23. Remember !

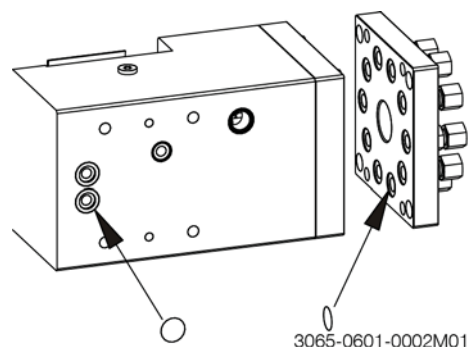
If the lubricator is not to be mounted on the engine immediately after overhauling, cover all openings with plastic to prevent dirt from entering the lubricator during storage.

Cover all surfaces with a thin layer of oil.



1. New O-ring on the lubricator

Mount new O-rings on the lubricator and on the cover with pipes.

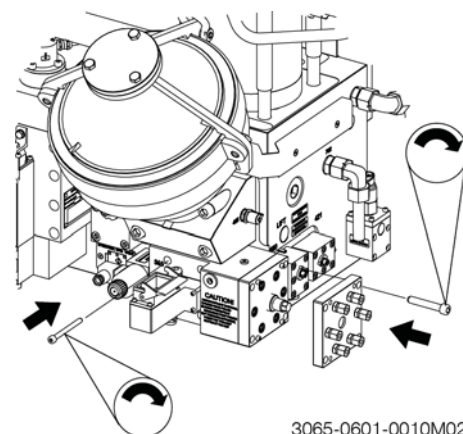


2. Mounting the lubricator and cylinder oil supply pipe

Mount the lubricator and tighten the screws on the hydraulic cylinder unit.

Tighten the screws in the aft end of the lubricator to the pipe connection.

Mount the cylinder oil supply pipe.

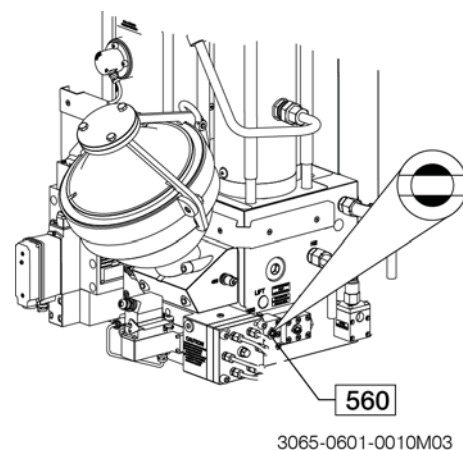


3. Finally

Mount the electrical plug. Check the injection of cylinder oil on the feedback LED on the terminal box for the specific lubricator.

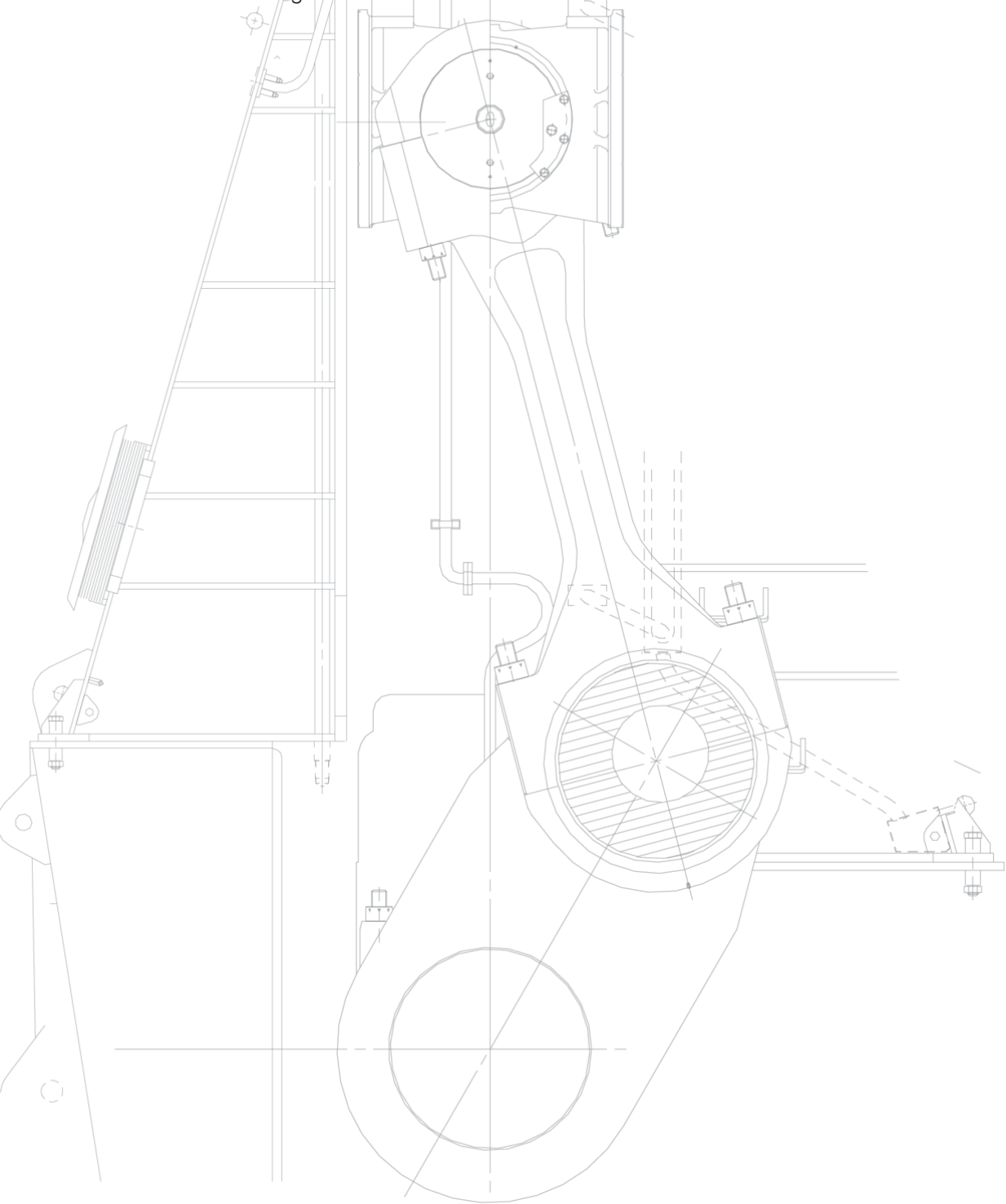
Open valve 560 for hydraulic oil supply.

Open the valve for cylinder lubricating oil supply.



Preface Chapter
Drawing
Work Card

Compressed Air System	3440-0100-0002
Starting Air System	3455-0100-0002
Starting Air Valve, Data	3465-0200-0004
Starting Air Valve	3465-0201-0006



Starting Air System

The starting air system consists of the manoeuvring system and the starting air components, which comprise:

- Main Starting Valve
- Solenoid Valves
- Starting Valves

The manoeuvring system is of electric/pneumatic design. See also *Drawing 7055-0150*.

Main Starting Valve

The main starting valve is interposed in the starting air main pipe. The main starting valve consists of a large ball valve and, optionally, a smaller ball valve for slow-turning prior to starting the engine, which is fitted as a by pass for the large valve. Both valves are operated by pneumatic actuators.

If the smaller ball valve is installed, an adjusting screw will be mounted for setting the slow-turning speed.

Furthermore, a non-return valve is incorporated to prevent blowback in the event of excessive pressure in the starting air line.

The main starting valve is equipped with a blocking device consisting of a plate which by means of a hand-wheel, can be made to block the actuators.

The ball valves and their actuators are, together with the non-return valve and blocking device, built together to form a unit.



WARNING

During all inspections of the engine, the blocking device of the main starting valve must be in the BLOCKED position.

The only exception is when the starting valves are being tested for tightness, in which case the blocking device of the main starting valve must be in the WORKING position and the shutoff valve for the starting air distributor must be in the CLOSED position. See *Drawing 7055-0150*.

Solenoid Valve

The Engine Control System controls the opening and closing of the starting valves, via one solenoid pilot valve fitted for each cylinder. When actuated by the ECS, the solenoid valve leads control air from the control air system to the starting valve on the individual cylinder cover.

Starting Valves

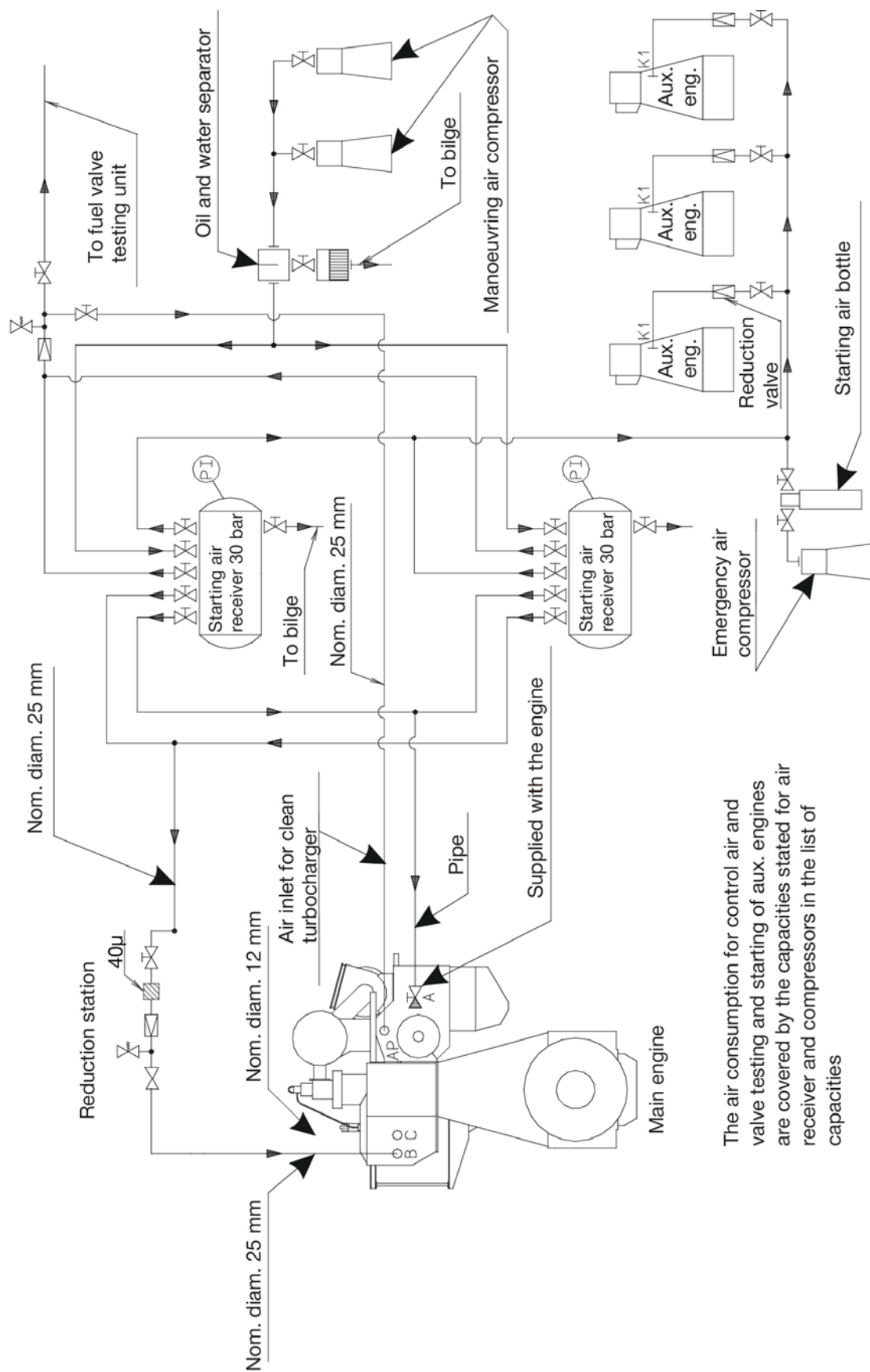
One starting valve (spring-loaded) is fitted on each cylinder cover. They are controlled by control air from the control air system.

When the main starting valve is open, the chamber below the piston of the starting valve is pressurised through the starting air pipe.

The starting valve is kept closed by the spring. When the chamber above the starting valve piston is pressurised with control air from the control air system, the starting valve opens, and starting air now flows from the starting air pipe to the cylinder.

When the starting period is finished, the chamber above the piston is vented through the vent pipe of the solenoid valve, and the starting valve will close.

The starting air in the chamber below the piston and the starting air pipe is vented slowly through small holes in the starting air pipe.



Starting Air System

Drawing

3455-0100-0002

Safety

Precautions

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Engage turning gear
○	Shut down hydraulic power supply



Data

Ref.	Description	Value	Unit
T34-03	Valve tightening angle	60	°
T34-04	Starting air valve	35	kg

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

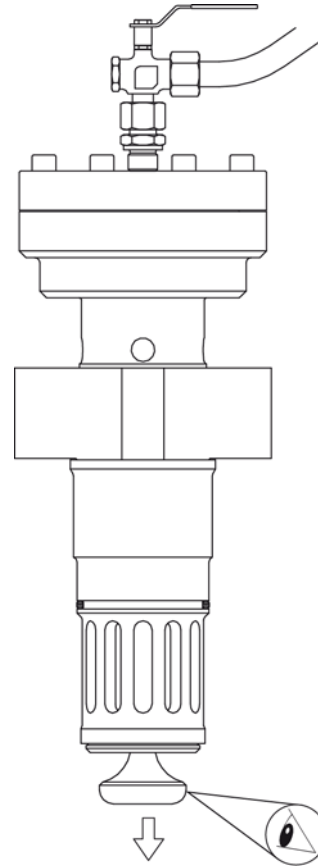
Tools

Plate	Item No.	Description
2270-0300	083	Handle for sundry types
2270-0300	095	Grinding ring for starting valve
7670-0200	-	Torque spanners

1. Air supply on

When the starting air valve has been overhauled, connect a supply of working air to the control air inlet at the top of the valve.

Check that the valve opens approx. 15-20 mm.



3465-0201-0002C01

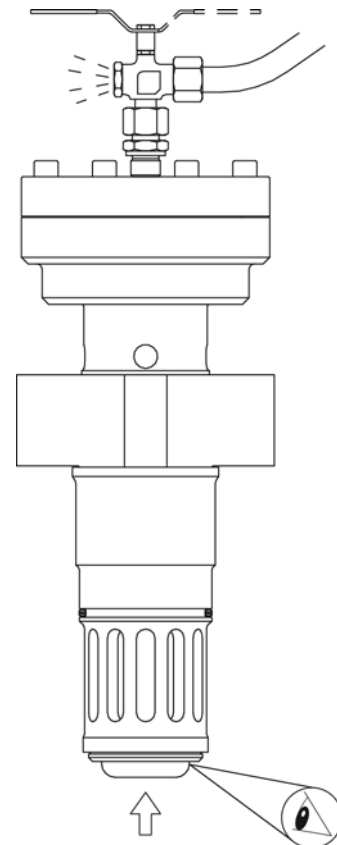
Starting Air Valve • Checking

Work Card
3465-0201-0006

2. Air supply off

Shut off the air supply.

Check that the valve closes fully.



3465-0201-0002C02

3. Repeat

Repeat steps 1 and 2 a couple of times.

1. Air pipes

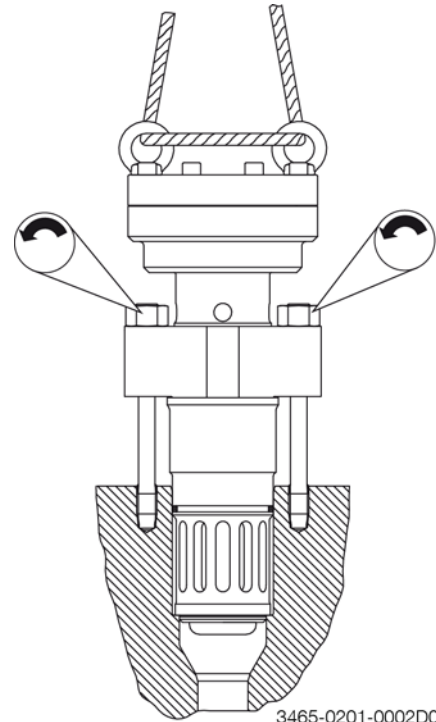
Shut off the starting air and control air inlet.

Dismount the control air pipes.

Mount two eye bolts in the top cover of the valve.

Hook a lifting wire on to the eye bolts.

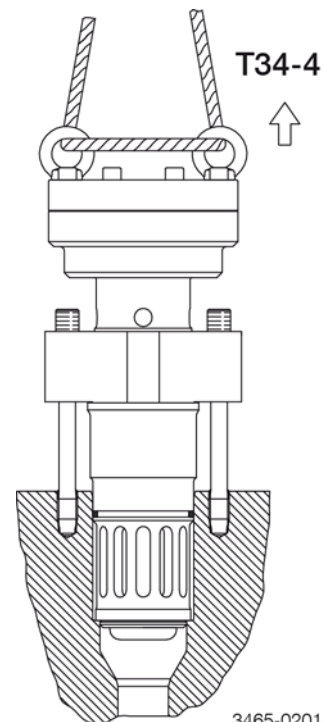
Unscrew the fixing nuts of the starting valve flange.



3465-0201-0002D01

2. Starting valve

Lift away the starting valve.

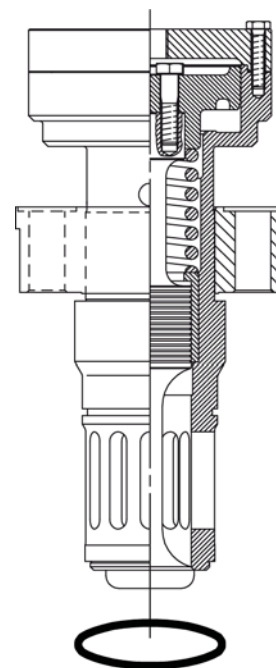


3465-0201-0002D02

1. O-ring

Place the starting air valve horizontally in a bench vice provided with "soft" jaws.

Remove and discard the O-ring from the valve housing.

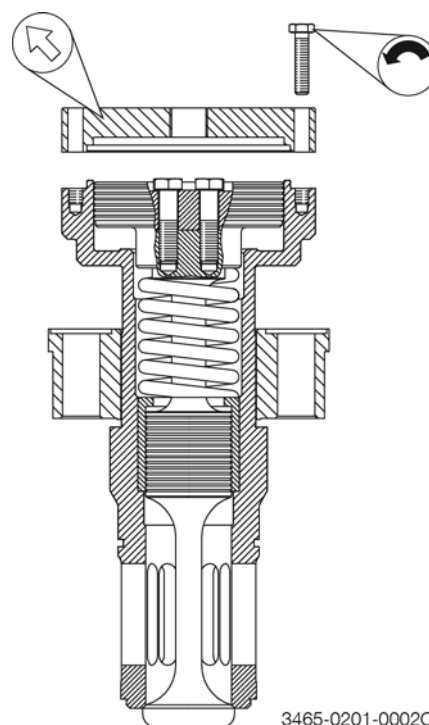


3465-0201-0002O01

2. Top cover

Loosen and remove the screws from the top cover.

Dismount the top cover.

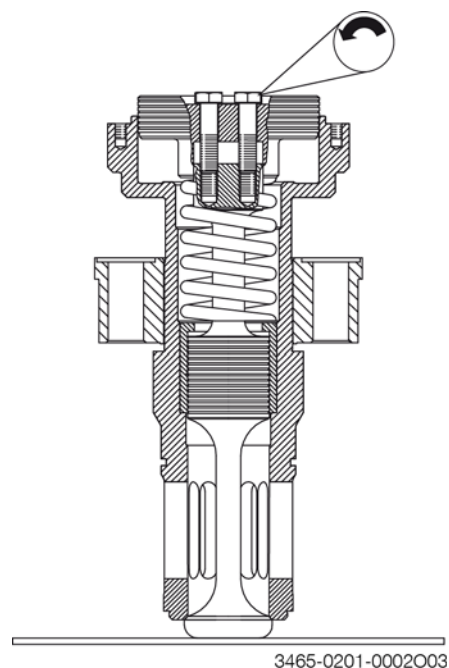


3465-0201-0002O02

3. Piston and spindle Use the face wrench for the spindle as a back-stop when loosening the two screws which tighten the piston to the spindle.

Remove the screws and discard the locking device.

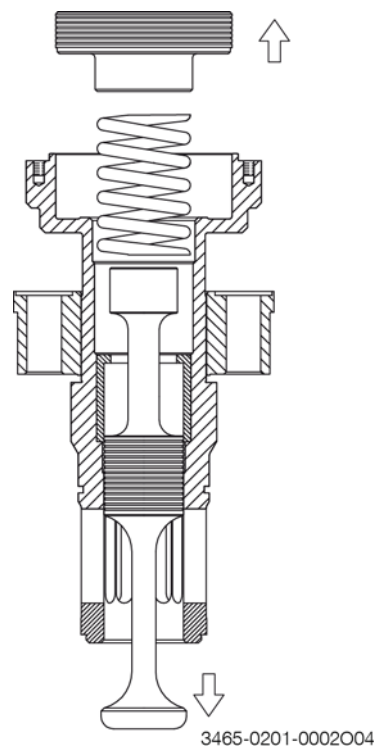
When unscrewing, the piston will partially be pressed out of the valve housing due to the spring force.



4. Remove the spring from the top end of the housing Remove the piston from the top end of the valve housing.

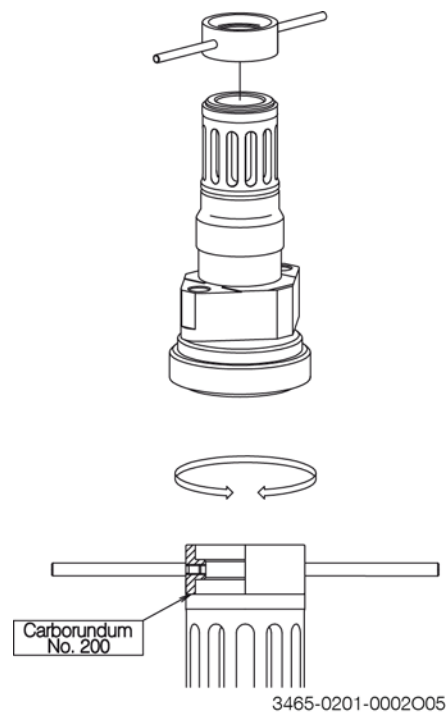
Take out the spindle from the bottom end of the valve housing.

Remove the spring from the top end of the housing.



5. Grind the valve housing seating

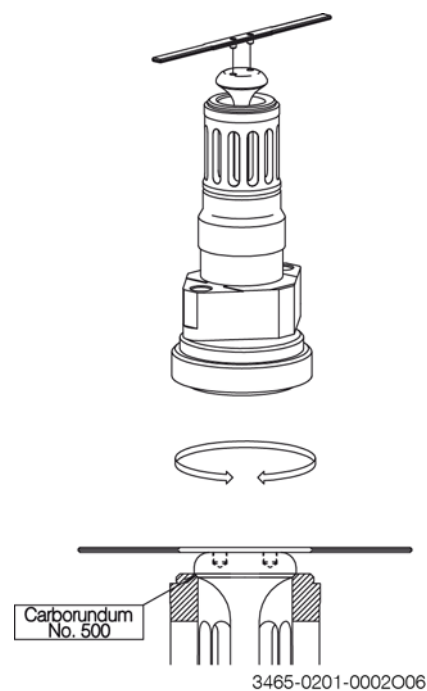
Apply grinding paste, e.g. carborundum No. 200. Grind the valve housing seating with the grinding ring.



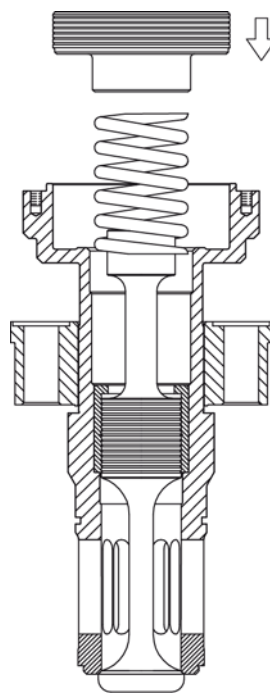
6. Match the seatings

When lapping the seatings of the spindle and valve housing to match, use the face wrench to rotate the spindle.

As grinding paste, use e.g. carborundum No. 500.



7. Assemble the valve housing parts
- Thoroughly clean the valve housing and all the parts in diesel oil or kerosene.
- Lubricate all internal parts and sliding surfaces with, e.g., Molybdenum Disulphide, MoS_2 .
- Insert the spindle in the valve housing. Then mount the spring in the housing around the spindle and, finally, place the piston on top of the spindle.



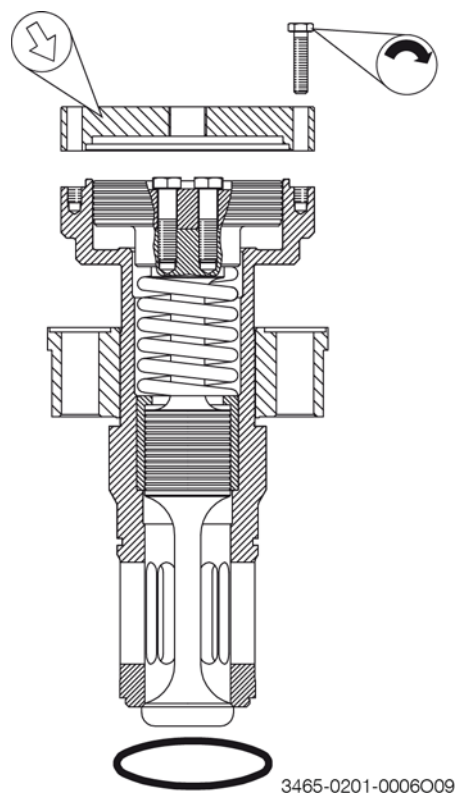
3465-0201-0002007

8. Tighten and lock the screws
- Mount the discs and the two screws.
- When tightening the screws, the piston will compress the spring.
- Tighten the screws continuously until the piston faces tightly against the spindle.

9. Top cover

Mount and tighten the top cover.

Mount a new O-ring on the valve housing.



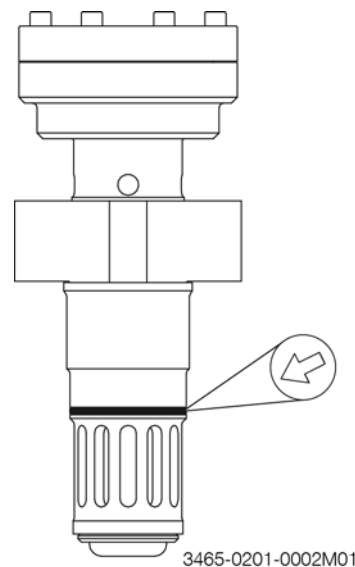
10. Starting air valve

Check the starting air valve.

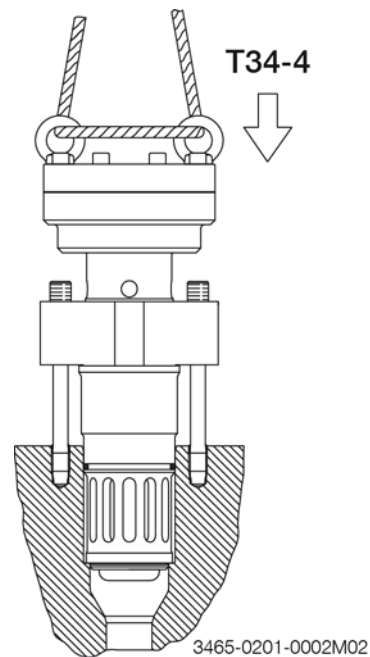
If the valve is not to be mounted in the engine immediately, cover all openings with plastic to prevent dirt from entering the valve during storage.

1. Starting valve bore Carefully clean the starting valve bore in the cylinder cover and, if necessary, recondition the seat for the starting valve in the bore.
See work card 2265-0301.

If not already done, replace the O-ring on the overhauled valve and lubricate with Neverseize or Molybdenum Disulphide, MoS₂.

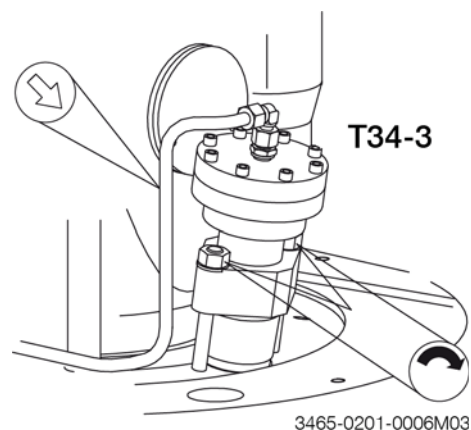


2. Mount the valve Mount the valve in the cylinder cover.



3. Control air pipe Mount the nuts and tighten up in at least three steps, to reach the full tightening angle.
See data.

Mount the control air pipe and turn on starting air and control air.



Preface Chapter	Fuel System	4240-0100-0002
Description	Fuel Specification	4245-0100-0003
	Pressurised Fuel Oil System	4245-0110-0005
	Fuel Treatment	4245-0120-0003
Drawing	Residual Fuel Oil Standards	4255-0100-0003
	Fuel Oil System	4255-0105-0004
	Fuel Pipes on Engine	4255-0110-0002
	Fuel Oil Centrifuges – Mode of Operation	4255-0115-0003
	Centrifuge Flow Rate and Separation Temperature – Preheating	4255-0120-0002
	Preheating of Heavy Fuel Oil (Prior to Injection)	4255-0125-0002
Work Card	Fuel Oil High-Pressure Pipe, Data	4265-0100-0015
	Fuel Oil High-Pressure Pipe	4265-0101-0037
	Fuel Oil Injection Valve, Data	4265-0200-0013
	Fuel Oil Injection Valve	4265-0201-0018
	Fuel Oil Injection Valve Spindle Guide, Data	4265-0300-0001
	Fuel Oil Injection Valve Spindle Guide	4265-0301-0001
	Fuel Oil Injection Valve Non-Return valve, Data	4265-0400-0001
	Fuel Oil Injection Valve Non-Return valve	4265-0401-0002
	Fuel Oil Pressure Booster, Data	4265-0500-0007
	Fuel Oil Pressure Booster	4265-0501-0013
	Fuel Oil Pressure Booster Top Cover, Data	4265-0600-0010
	Fuel Oil Pressure Booster Top Cover	4265-0601-0012
	Fuel Oil Pressure Booster Suction Valve, Data	4265-0700-0003
	Fuel Oil Pressure Booster Suction Valve	4265-0701-0009
	Fuel Oil, Data	4265-1800-0001
	Fuel Oil	4265-1801-0001
Tool Plate	Fuel Oil System Panel Tools	4270-0010-0045
	Fuel Oil Injection Valve Nozzle Tools	4270-0210-0002
	Fuel Oil Injection Valve Nozzle Tools	4270-0210-0003
	Fuel Oil Injection Valve Testing Tools	4270-0220-0001
	Fuel Oil Injection Valve Inspection Tools	4270-0230-0001
	Fuel Oil Pump Top Cover Tools	4270-0900-0004

Fuel Injection Valve Actuator

The electronically controlled fuel injection system consists of the hydraulically controlled fuel oil pressure booster, its controlling valve, i.e. FIVA (Fuel Injection Valve Actuator) valve and the fuel injection valves. The FIVA valve (controlled by the ECS) ensures fast and precise control of the oil flow to the fuel oil pressure booster. The oil flow pushes the hydraulic piston and fuel injection plunger, thus generating the injection pressure and hence the injection.

After the injection has finished, the plunger and piston are returned to their starting positions by the piston being connected to a drain and letting the pressure in the fuel supply drive the plunger back. The fuel oil pressure booster is then filled and ready for the next injection sequence. The fuel system permits continuous circulating of heated heavy fuel oil through the fuel oil pressure booster and fuel valves to keep the system heated during engine standstill.

Fuel Oil High Pressure Pipes

All high-pressure pipes in the system are provided with a protective outer pipe. The space between the pipe and the protective outer pipe communicates, through bores in the union nipples, with a drain bore in the fuel oil pressure pump top cover.

Fuel Valve

The fuel valve consists of a valve head and a valve housing. Fitted within the valve housing are a non-return valve combined with a spindle and spindle guide with a pressure spring, and a nozzle.

The spindle is provided with a cut-off slide. When the fuel valve is fitted in the cylinder cover, the valve parts are tightened together by the pressure from the securing nuts.

Fuel Valve Function

The function of the fuel valve is as follows:

The electrically driven fuel oil primary pump circulates preheated oil through the fuel oil pressure booster and fuel valve. The fuel oil passes through the fuel valve, and leaves the fuel valve through a circulation bore on the valve head and flows through the return oil pipe.

When the pressure at the beginning of the fuel oil pressure booster's delivery stroke has reached the predetermined pressure, the circulating bores are closed.

When the pressure has reached the predetermined opening value for the fuel valve, the spindle will be lifted and oil injected through the nozzle into the combustion chamber of the engine .

On completion of the fuel oil pressure booster's delivery stroke, the pressure will drop. The valve spindle is pressed against its seat and the injection will cease. Then the circulating bore is uncovered, and oil starts to circulate through the valve.

1 Diesel fuel oil

Diesel fuel fulfilling:

ISO 8217, CIMAC no. 21, British Standard MA 100 Class M2, ASTM Classification of Diesel fuel oil D975 grade No. 4-D, or similar; may be used. If deviating qualities are applied, the engine must be prepared for this.

2 Heavy fuel oil

Most commercially available fuel oils with a viscosity below 700 cSt. at 50°C (7000 sec. Redwood I at 100°F) can be used.

For guidance on purchase, reference is made to ISO 8217, BS6843 and to CIMAC recommendations no. 21 regarding requirements for heavy fuel for diesel engines, edition 2003. From these, the maximum accepted grades are RMG 700 and RMK 700. The mentioned ISO and BS standards supersede BS MA 100 in which the limit is M9.

For reference purposes, an extract from relevant standards and specifications is shown in *drawing 4255-0100*.

The data in the above fuel standards and specifications refer to fuel as delivered to the plant, i.e. before cleaning.

In order to ensure effective and sufficient cleaning of the fuel oil – i.e. removal of water and solid contaminants – the fuel oil specific gravity at 15°C (60°F) should be below 1.010 for e.g. ALCAP.

Higher densities can be allowed if special treatment systems are installed.
See description 4245-0120.

Current analysis information is not sufficient for estimating the combustion properties of the oil.

This means that service results depend on oil properties which cannot be known beforehand. This especially applies to the tendency of the oil to form deposits in combustion chambers, gas passages and turbines. It may therefore be necessary to rule out some oils that cause difficulties.

If the plant has been out of service for a long time without circulation of fuel oil in the tanks (service and settling), the fuel must be circulated before start of the engine.

Before starting the pump(s) for circulation, the tanks are to be drained for possible water settled during the stop.

The risk of concentration of dirt and water in the fuel to the engines caused by long time settling is consequently considerably reduced.
For treatment of fuel oil, *see description 4245-0120*.

3 Fuel oil sampling

3.1 Sampling

To be able to check whether the specification indicated and/or the stipulated delivery conditions have been complied with, we recommend that a minimum of one sample of each received fuel lot be retained. In order to ensure that the sample is representative for the oil received, a sample should be drawn from the transfer pipe at the start, in the middle, and at the end of the receiving period.

3.2 Analysis of samples

The samples received from the oil supply company are frequently not identical with the heavy fuel oil actually received. It is also appropriate to verify the heavy fuel oil properties stated in the delivery note documents, such as density, viscosity, and pour point. If these values deviate from those of the heavy fuel oil received, there is a risk that the heavy fuel oil separator and the preheating temperature are not set correctly for the given injection viscosity.

3.3 Sampling equipment

Several suppliers of sampling and fuel test equipment are available on the market, but for more detailed and accurate analyses, a fuel analysing institute should be contacted.

4 Guiding fuel oil specification

4.1 Heavy fuel oil specifications

Based on our general service experience we have, as a supplement to the above-mentioned standards, drawn up the guiding fuel oil specification shown in the table below.

Fuel oils limited by this specification have, to the extent of the commercial availability, been used with satisfactory results on MAN Diesel & Turbo two-stroke low speed diesel engines, as well as MAN Diesel & Turbo auxiliary engines.

Guiding specification (maximum values)	Unit	Fuel Oil
Density at 15°C	kg/m ³	1010 ¹
Kinematic viscosity at 100°C	cSt	55
Kinematic viscosity at 50°C	cSt	700
Flash point	°C	≥60
Pour point	°C	30
Carbon residue	%(m/m)	20
Ash	%(m/m)	0.15
Total sediment after ageing	%(m/m)	0.10
Water	%(v/v)	0.5
Sulphur	%(m/m)	Statutory requirements
Vanadium	mg/kg	450

Guiding specification (maximum values)	Unit	Fuel Oil
Aluminium + Silicon	mg/kg	60
Equal to ISO 8217 RMK 700/CIMAC H700		

1) 991 if older centrifuges are installed.

NOTICE

The heavy fuel oil data refers to the fuel as supplied, i.e. before any onboard cleaning.

If fuel oils with analysis data exceeding the above figures are to be used, especially with regard to viscosity and specific gravity, the engine builder should be contacted for advice regarding possible fuel oil system changes.

On account of the relatively low commercial availability, only limited service experience has been accumulated on fuels with data exceeding the following:

Conradson Carbon	18 %
Sulphur	4 %
Vanadium	400 mg/kg

Therefore, in the case of fuels with analysis data exceeding these figures, a close watch should be kept on engine performance.

1 System Layout

The system is normally arranged such that both diesel oil and heavy fuel oil can be used as fuel.

See drawing 4255-0105 (Fuel Oil System).

See drawing 4255-0110 (Fuel Oil Pipes on Engine).

From the storage tanks, the oil is pumped to an intermediate tank, from which the centrifuges can deliver it to the respective service tanks ("day-tank").

To obtain the most efficient cleaning, the centrifuges are equipped with preheaters, so that the oil can be preheated to 98°C.

Regarding the cleaning, *see description 4245-0120*. Also refer to *SL 05-452/KEA*.

From the particular service tank in operation, the oil is led to one of the two electrically driven supply pumps.

These pumps deliver the oil, under a pressure of about 4 bar, through an automatic filter and a flow-meter.

Thereupon the oil continues to the low pressure side of the fuel oil system.

Standard 50 µm filter.

The oil is thereafter drawn to one of two electrically driven circulating pumps, which passes it through the preheater, the filter, and on to the fuel injection pumps.

The filter mesh shall correspond to an absolute fineness of 50 µm.

See drawing 4255-0105 page 1.

Optional 10 µm filter.

The filter mesh shall correspond to an absolute fineness of 10 µm. The absolute fineness corresponds to a nominal fineness of approximately 5 µm, at a retaining rate of 90 %.

The oil is thereafter drawn to one of two electrically driven circulating pumps, which passes it through the preheater, the viscosity regulator, the filter, and on to the fuel injection pumps.

The filter mesh shall correspond to an absolute fineness of maximum 150 µm.

See drawing 4255-0105 page 2.

NOTICE

Actual system layout may vary slightly from the examples shown on drawing 4555-0105.

The return oil from the fuel valves and pumps is led back, via the venting pipe, to the suction side of the circulating pump.

In order to maintain a constant pressure in the main line at the inlet to the fuel pumps, the capacity and delivery rate of the circulating pump exceeds the amount of fuel consumed by the engine.

In addition, a spring-loaded overflow valve is fitted, which functions as a by-pass between the fuel oil inlet to the fuel injection pumps and the fuel oil return, thus ensuring a constant pressure in the fuel oil inlet line.

The fuel oil drain pipes are equipped with heat tracing, through which hot jacket cooling water flows. The drain pipe heat tracing must be in operation during running on heavy fuel.

See drawing 5055-0110.

To ensure an adequate flow of heated oil through the fuel pumps, housings and fuel valves at all loads (including stopped engine), the fuel valves are equipped with a slide and circulating bore.

By means of the "built-in" circulation of preheated fuel oil, the fuel pumps and fuel valves can be maintained at service temperature, also while the engine is stopped.

Consequently, it is not necessary to change to diesel oil when the engine is stopped, provided that the circulating pump is kept running and preheating of the circulated fuel oil is maintained.

See description 4245-0120.

If, during long standstill periods, it is necessary to stop the circulating pump or the preheating, the fuel oil system must first be emptied of the heavy oil.

This is carried out by:

- Changing to diesel oil in due time before the engine is stopped,
See description 4245-0120, or
- Stopping the preheating, and pumping the heavy oil back to the service tank, through the change-over valve mounted at the top of the venting pipe.
See description 4245-0120.

2 Fuel Oil Pressure

Carry out adjustment of the fuel oil pressure, during engine standstill, in the following way:

1. Adjust the valves in the system as for normal running, thus permitting fuel oil circulation.
2. Start the supply and circulating pumps, and check that the fuel oil is circulating.
3. **Supply Pumps:**
Adjust the spring-loaded safety valve at supply pump No. 1 to open at the maximum working pressure of the pump.
The pressure must not be set below 4 bar, due to the required pressure level in the supply line, see point 4.
Make the adjustment gradually, while slowly closing and opening the valve in the discharge line, until the pressure, with closed valve, has the above-mentioned value.

Carry out the same adjustment with supply pump No. 2.

4. Regulate the fuel oil pressure, by means of the over-flow valve between the supply pump's discharge and suction lines. Adjust so that the pressure in the low pressure part of the fuel system is 4 bar.
5. **Circulating Pumps:**
With the supply pumps running at 4 bar outlet pressure, secure that the spring-loaded relief by-pass valves for each circulating pump (the valve is preset from the valve manufacturer) open at the maximum working pressure of the circulation pumps involved, about 10 bar.
If adjustments have to be made, regulate the spring tension in the relief bypass valve(s), see valve maker's instruction.
6. **Fuel Line:** Regulate the fuel oil pressure by means of the spring-loaded overflow valve installed between the main inlet pipe to the fuel injection pumps and the outlet pipe on the engine. Adjust the overflow valve so that the pressure in the main inlet pipe is 7-8 bar.
See description 7045-0100.
7. With the engine running, the pressure will fall a little. Re-adjust to the desired value at MCR.

1 Cleaning

1.1 General

Fuel oils are always contaminated and must therefore, before use, be thoroughly cleaned for solid as well as liquid contaminants.

The solid contaminants are mainly rust, sand and refinery catalytic fines ("cat fines"); the main liquid contaminant is water, – i.e. either fresh or salt water.

These impurities can:

- cause damage to fuel pumps and fuel valves.
- result in increased cylinder liner wear.
- be detrimental to exhaust valve seatings.
- give increased fouling of gasways and turbocharger blades.

1.2 Centrifuging

Effective cleaning can only be ensured by means of centrifuges.

The ability to separate water depends largely on the specific gravity of the fuel oil relative to the water – at the separation temperature. In addition, the fuel oil viscosity (at separation temp.) and flow rate, are also influencing factors.

The ability to separate abrasive particles depends upon the size and specific weight of the smallest impurities that are to be removed; and in particular on the fuel oil viscosity (at separation temp.) and flow rate through the centrifuge.

To obtain optimum cleaning, it is of the utmost importance to:

- a. operate the centrifuge with as low a fuel oil viscosity as possible.
- b. allow the fuel oil to remain in the centrifuge bowl for as long as possible.

Re a.

The optimum (low) viscosity, is obtained by running the centrifuge preheater at the maximum temperature recommended for the fuel concerned.

NOTICE

It is especially important that, in the case of fuels above 1500 Sec. RW/ 100°F (i.e. 180 cSt/50°C), the highest possible preheating temperature – 98°C – should be maintained in the centrifuge preheater. *See Drawing 4255-0120. Also refer to SL 05-452/KEA.*

The centrifuge should operate for 24 hours a day except during necessary cleaning.

Re 2.

The fuel is kept in the centrifuge as long as possible, by adjusting the flow rate so that it corresponds to the amount of fuel required by the engine, without excessive re-circulation.

The ideal output should thus correspond to the normal amount of fuel required by the engine, plus the amount of fuel consumed during periods when the centrifuge is stopped for cleaning.

The nominal capacity of the installed centrifuges must be according to the maker's instructions.

For efficient removal of water by means of a conventional purifier, the correct choice of gravity disc is of special importance. The centrifuge manual states the disc which should be chosen, corresponding to the specific gravity of the fuel in question.

Centrifuge Capacity: Series or Parallel Operation

It is normal practice to have at least two centrifuges available for fuel cleaning.
See Drawing 4255-0115

Regarding centrifuge treatment of today's residual fuel qualities, the latest experimental work has shown that, the best mode of operating modern centrifuges with no gravity disc, is when the centrifuges are operated in parallel.

Experiments have shown, that when running the centrifuges i series, particles which are not removed during treatment in the first centrifuge are not removed during treatment in the second centrifuge either. Therefore, running the centrifuges i parallel, provides the opportunity of decreasing the flow through the centrifuges, as the amount of fuel that need be treated per hour, is shared by two centrifuges, thus increasing the cleaning quality.

However, it is recommended to follow the maker's specific instructions,
see item 1.3.

Regarding the determination/checking of the centrifuging capacity, we generally advise that the recommendations of the centrifuge maker are followed, but the curves shown on *Drawing 4255-0120* can be used as a guidance.

1.3 High Density Fuels

To cope with the trend towards fuels with density exceeding 991 kg/m³ at 15°C, the centrifuging technology has been further developed.

Improved centrifuges, with automatic de-sludging provides adequate separation of water and particles from the fuel, up to a density of 1010 kg/m³ at 15°C.

The centrifuges should be operated in parallel or in series according to the maker's instructions and recommendations.

1.4 Homogenisers

As a supplement only (to the centrifuges), a homogeniser may be installed in the fuel oil system, to homogenise possible water and sludge still present in the fuel after centrifuging. A homogenizer should always be installed AFTER the centrifuges.

1.5 Fine Filter

As a supplement only (to the centrifuges), a fine filter with very fine mesh may be installed, to remove possible contaminants present in the fuel after centrifuging.

A homogeniser should be inserted before a possible fine filter in order to minimise the risk of blocking by agglomeration of asphaltenes.

1.6 Super Decanters

As a supplement only, a super decanter may be installed. This is, in principle, a "horizontal" clarifier. The aim is to remove sludge before normal centrifuging and thus minimize the risk of blocking of the centrifuges.

2 Fuel oil stability

Fuel oils of today are produced on the basis of widely varying crude oils and refinery processes. Practical experience has shown that, due to incompatibility, certain fuel types may occasionally tend to be unstable when mixed.

As a consequence, fuel mixing should be avoided to the widest possible extent.

A mixture of incompatible fuels, in the storage tanks and the settling tanks, may lead to stratification, and also result in rather large amounts of sludge being taken out by the centrifuges, in some cases even causing centrifuge blocking.

Stratification can also take place in the service tank, leading to a fluctuating preheating temperature, when this is controlled by a viscorator.

Service tank stratification can be counteracted by recirculating the contents of the tank through the centrifuge. This will have to be carried out at the expense of the previously mentioned benefits of low centrifuge flow rate.

3 Preheating before Injection

In order to ensure correct atomization, the fuel oil has to be preheated before injection.

The necessary preheating temperature is dependent upon the specific viscosity of the oil in question.

Inadequate preheating (i.e. too high viscosity):

- will influence combustion,
- may cause increased cylinder wear (liners and rings),
- may be detrimental to exhaust valve seatings,
- may result in too high injection pressures, leading to excessive mechanical stresses in the fuel oil system.

In most installations, preheating is carried out by means of steam, and the resultant viscosity is measured by a viscosity regulator (viscorator), which also controls the steam supply.

Depending upon the viscosity/temperature relationship, and the viscosity index of the fuel oil, an outlet temperature of up to 150°C will be necessary. This is illustrated in the diagram on *Drawing 4255-0125*, which indicates the expected preheating temperature as a function of the fuel oil viscosity.

Recommended viscosity meter setting is 10-15 cSt.

As opposed to a too high viscosity, experience from service has shown that a higher viscosity of the fuel oil than the above recommended, before the fuel oil pump, is not a too strict parameter, for which reason we allow a viscosity of up to 20 cSt after the preheater.

In order to avoid too rapid fouling of the preheater, a temperature of 150°C should not be exceeded.

3.1 Precaution

Caution must be taken to avoid heating the fuel oil pipes by means of the heat tracing when changing from heavy fuel to diesel oil, and during running on diesel oil.

Under these circumstances excessive heating of the pipes may reduce the viscosity too much, which will involve the risk of the fuel pumps running hot, thereby increasing the risk of sticking of the fuel pump plunger and damage to the fuel oil sealings. (*See item 4.2*).

3.2 Fuel Preheating during engine standstill

During engine standstill, the circulation of preheated heavy fuel oil (HFO) does not require the viscosity to be as low as is recommended for injection. Thus, in order to save energy, the preheating temperature may be lowered some 20°C, giving a viscosity of about 30 cSt.

3.3 Starting after engine standstill

If the engine has been stopped on HFO, and the HFO has been circulated at a reduced temperature during standstill, the preheating and viscosity regulation should be made operative about one hour before starting the engine, so as to obtain the required viscosity, *see Item 3., 'Preheating before Injection'*.

4 Other Operational Aspects

4.1 Circulating Pump Pressure

The fuel oil pressure measured on the engine (at fuel pump level) should be 7-8 bar, equivalent to a circulating pump pressure of up to 10 bar. This maintains a pressure margin against gasification and cavitation in the fuel system, even at 150°C.

The supply pump may be stopped when the engine is not in operation.
See Drawing 4255-0105.

4.2 Fuel change-over

The engine is equipped with uncooled, "all-symmetrical", light weight fuel valves – with built-in fuel circulation. This automatic circulation of the preheated fuel (through the high-pressure pipes and the fuel valves) during engine standstill, is the background for MAN Diesel & Turbo recommending *constant operation on heavy fuel*.

However, change-over to diesel oil can become necessary if, for instance:

- the vessel is expected to have a prolonged inactive period with cold engine, e.g. due to:
 - a major repair of the fuel oil system etc.
 - a docking
 - more than 5 days' stop (incl. laying-up)
- environmental legislation requiring the use of low-sulphur fuels.

Change-over can be performed at any time:

- during engine running
- during engine standstill

In order to prevent:

- fuel pump and injector sticking/scuffing
- poor combustion
- fouling of the gasways

it is very important to carefully follow the temperature / load requirements of the change-over procedures.

4.3 Change-over between heavy fuel oil (HFO) and distillate fuel (DFO) during running

Before the intended change-over from HFO to DFO and vice versa, we recommend checking the compatibility of the two fuels – preferably at the bunkering stage. The compatibility can be checked either by an independent laboratory or by using test kits onboard.

As incompatible fuels may lead to filter blockage, there should be extra focus on filter operation in case of incompatibility.

Change-over of fuel can be somewhat harmful for the fuel equipment, because hot HFO is mixed with relatively cold DFO. The mixture is not expected to be immediately homogeneous, and some temperature/viscosity fluctuations are to be expected. The process therefore needs careful monitoring of temperature and viscosity.

In general, only the viscosity controller should control the steam valve for the fuel oil heater. However observations of the temperature/viscosity must be the factor for manually taking over the control of the steam valve to protect the fuel components.

During change-over two factors are to be kept under observation:

- The viscosity must not drop below 2 cSt and not exceed 20 cSt.
- The rate of temperature change of the fuel inlet to the fuel pumps must not exceed 2°C/min to protect the fuel equipment from thermal shock (expansion problems) resulting in sticking.

It should be noticed that when operating on low-viscosity fuel internal leakages in the fuel equipment will increase. With worn pump elements this can result in starting difficulties, and an increased start index might be necessary. The wear in the fuel pumps should be monitored by comparing the fuel index for the new engine and during service. At a 10% increase of the fuel index for the same load the plunger/barrels can be considered as worn out and should be replaced.

A change-over of the main engine's fuel will result in a dilution of the fuel already in the booster circuit. The fuel feed to the system will mix with fuel in the system, and the main engine's consumption from the system will be a mixture of the fuels. A complete change of fuel (only DFO in the system) can therefore take several hours, depending on engine load, system layout and volume of fuel in the booster-circuit.

Before manoeuvring in port, it should be tested that the engine is able to start on DFO.

We do not recommend reducing the temperature difference between the HFO and the DFO by preheating the DFO in the service tank. This will reduce the cooling capacity of the oil and might result in a too low viscosity during change-over.

4.3.1 Manual change-over

4.3.1.1 Distillate fuel oil to heavy fuel oil

- Ensure that the HFO in the service tank is at normal service temperature (80- 100°C)
- Reduce the engine load.
The load should be 25-40% MCR during this process to ensure a slow heatup to normal HFO service temperature at engine inlet (up to 150°C), maximum change gradient 2°C/min.
- Carry out change-over by turning the three-way valve.
The load can, based on experience with the individual system, be changed to a higher level – up to 75% MCR, as long as the change gradient is kept below 2°C/min.

- Slowly stop the cooler (if installed) when the viscosity exceeds 5 cSt .
A slow stop of the cooler can be done by controlling the oil flow through the cooler, the cooling medium flow or a combination of both.
The temperature change gradient at engine inlet is still to be kept below 2°C/min.
- Open for steam to pre-heater and check that the set point is at normal level (10-15 cSt).
Manual control of the heater might be necessary if it is observed that the viscosity control exceeds the maximum temperature change gradient of 2°C/min at engine inlet.
- Open for steam tracing when the pre-heater is operating normally.

4.3.1.2 Heavy fuel oil to distillate fuel oil

- Ensure that the temperature of the DFO in the service tank is at an acceptable level.
The following must be taken into consideration:
 - Viscosity at engine inlet must not drop below 2 cSt.
 - Heat transmission from metal parts in the system to the fuel will occur.
 - Cooling capacity in the system, if any
- Reduce the pre-heating of the fuel, by increasing the set point of the viscosity controller to 18 cSt.
 - Manual control of the heater might be necessary if it is observed that the viscosity control exceeds the maximum temperature change gradient 2°C/ min. at engine inlet
- Reduce the engine load when the fuel reaches a temperature corresponding to 18 cSt.
 - During this change-over the load should be 25-40% MCR to ensure a slow reduction of the temperature at engine inlet, max. change gradient 2°C/min.
- Stop steam tracing.
Carry out change-over by turning the three-way valve.
 - The load can, based on experience with the individual system, be changed to a higher level – up to 75% MCR, as long as the change gradient is kept below 2°C/min.
- Stop steam to pre-heater when the regulating valve has closed completely.
Depending on system layout and condition, it might be necessary to open the heater bypass.
- Slowly start the cooler (if installed) when viscosity is below 10 cSt.
 - To obtain slow start of the cooler control the oil flow through the cooler, the cooling medium flow or a combination of both.
 - Keep the temperature change gradient at engine inlet below 2°C/min.

4.4 Change-over during standstill

When change-over is to be carried out during standstill of the engine there is no consumption from the fuel system and thus, no replacement of the oil. It is therefore necessary to return the oil to the HFO service tank. This will cause some DFO to be returned to the HFO service tank. However this is better than contaminating the DFO service tank with HFO.

When change-over is performed at standstill the engine should not be started until all the components in the fuel oil system have had sufficient time to adapt to the new temperature.

4.4.1 Heavy fuel oil to distillate fuel oil

- Stop the preheating and heat tracing.
- Start the supply and circulating pumps (if they are not already running).
- Change position of the change-over valve at the venting pipe, so that the fuel oil is pumped to the HFO service tank.
- Temperature in the system should now drop to the same level as the HFO service tank temperature.
- Change position of the change-over valve at the fuel tanks, so that DFO is led to the supply pumps.
- When the HFO is replaced with DFO, turn the change-over valve at the venting pipe back to its normal position. The HFO in the venting pipe is now mixed with DFO.
- Stop the circulating pumps.
- Stop the supply pumps.

4.4.2 Distillate fuel oil to heavy fuel oil

- Start the supply pumps.
- Start the circulating pumps (if they are not already running).
- Change position of the change-over valve at the fuel tanks so that HFO is led to the supply pumps.
- Change position of the change-over valve at the venting pipe, so that the fuel oil is pumped to the HFO service tank.
- Temperature in the system should now rise to the same level as the HFO service tank temperature.
- When the DFO is replaced with HFO turn the change-over valve at the venting pipe back to its normal position. The DFO in the venting pipe is now mixed with HFO.
- Stop the supply pumps.
- Start the preheating and heat tracing.

Recommendations for residual fuels for diesel engines (as received)

Note: This table is derived from CIMAC official document no. 21

Characteristics ¹⁾	Unit	Limit	CIMAC A30	CIMAC B30	CIMAC D80	CIMAC E180	CIMAC F180	CIMAC G380	CIMAC H380	CIMAC K380	CIMAC H700	CIMAC K700	Test method reference
Density at 15 °C	Kg/m ³	Max.	960.0	975.0	980.0	991.0	991.0	991.0	991.0	1010.0	991.0	1010.0	ISO 3675 or ISO 12185 (see also 6.1)
Kinematic viscosity at 50 °C	mm ² /s ²⁾	Max. ³⁾ Min.	30.0 22.0	-	80.0	180.0	-	-	380.0	-	700.0	-	ISO 3104
Flash point	°C	Min.	60	60	60	60	60	60	60	60	60	60	ISO 2719 (see also 6.2)
Pour point (upper)	°C												
1. Winter quality		Max.	0	24	30	30	30	30	30	30	30	30	ISO 3016
2. Summer quality		Max.	6	24	30	30	30	30	30	30	30	30	ISO 3016
Carbon residue	% (m/m)	Max.	10	10	14	15	20	18	22	22	22	22	ISO 10370
Ash	% (m/m)	Max.	0.10	0.10	0.10	0.10	0.15	0.15	0.15	0.15	0.15	0.15	ISO 6245
Water	% (V/V)	Max.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	ISO 3733
Sulphur ⁴⁾	% (m/m)	Max.	3.50	3.50	4.00	4.50	4.50	4.50	4.50	4.50	4.50	4.50	ISO 14596 or ISO 8754 (see also 6.3)
Vanadium	mg/kg	Max.	150	150	350	200	500	300	600	600	600	600	ISO 14597 or IP 501 (see also 6.8)
Total sediment potential	% (m/m)	Max.	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	ISO 10307-2 (see also 6.6)
Aluminium plus silicon ⁵⁾	mg/kg	Max.	80	80	80	80	80	80	80	80	80	80	ISO 10478
Used lubricating oil (ULO)			The fuel must be free of ULO. A fuel shall be considered free of ULO, if one or more of the elements Zinc, Phosphorus and Calcium is below or at the specified limit. All three elements must exceed the same limits before a fuel is to be deemed to contain ULO.										
Zinc	mg/kg	-											IP 501 or IP 470
Phosphorus	mg/kg	-											IP 501 or IP 500
Calcium	mg/kg	-											IP 501 or IP 470 (see also 6.7)

1) See General Recommendations paragraph 3 for additional characteristics not included in this table.

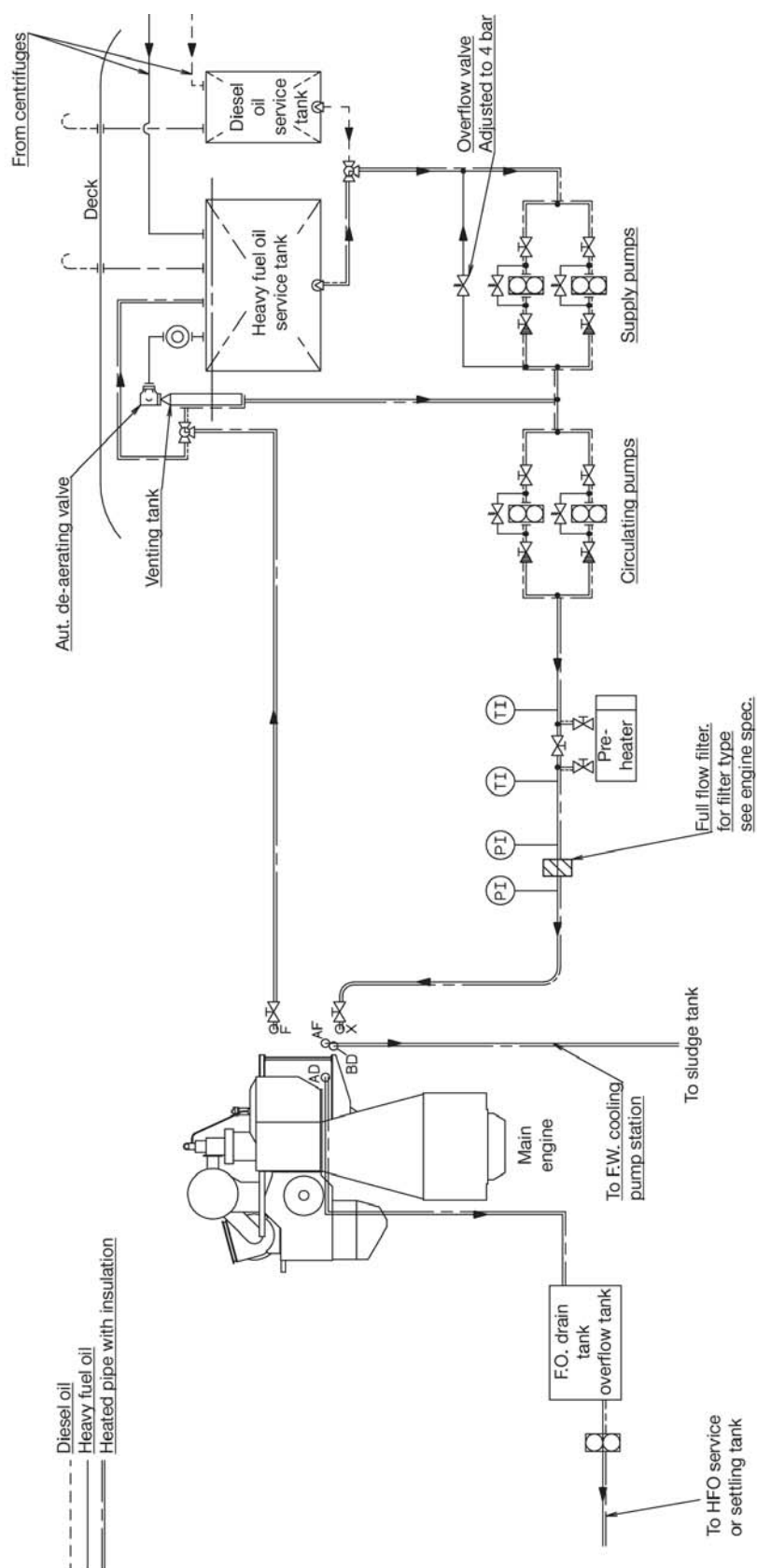
2) 1 mm²/s = 1 cSt.

3) Fuels with density close to the *maximum*, but with very low viscosity, may exhibit poor ignition quality, see Annex 6.

4) A sulphur limit of 1.5% m/m, will apply to SOx Emission Control Areas designated by the IMO, when its relevant protocol comes into force. There may be local variations.

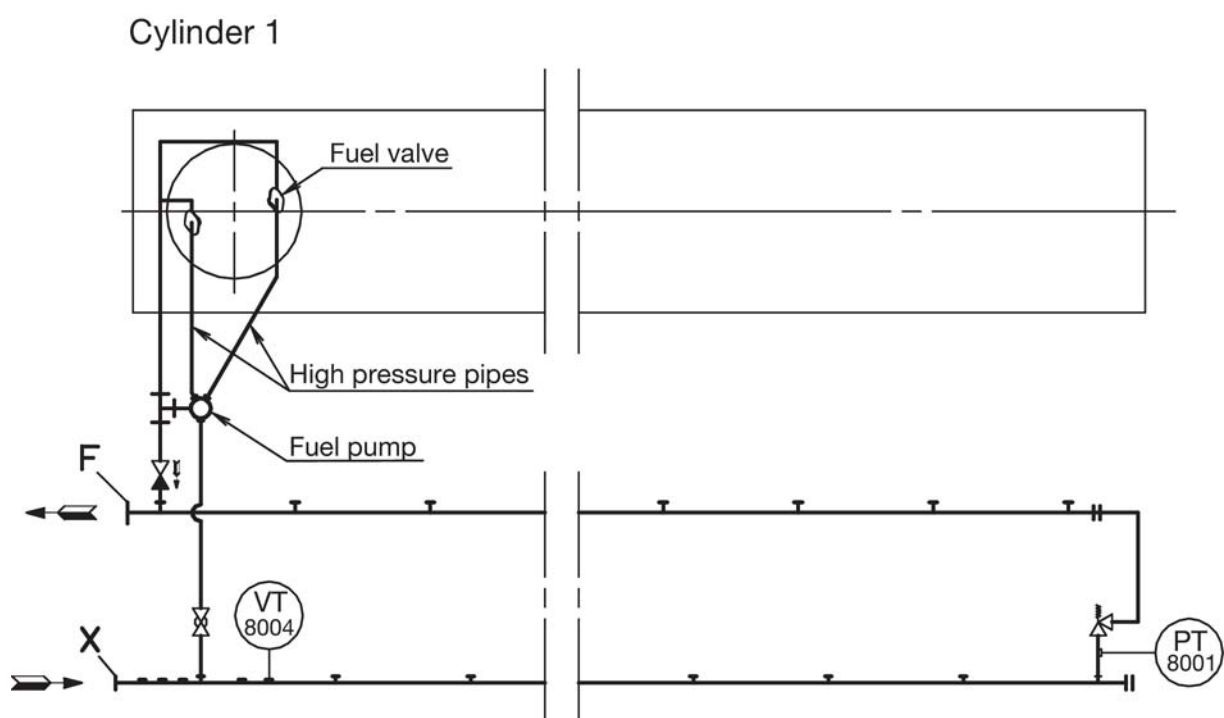
5) See Annex 3.

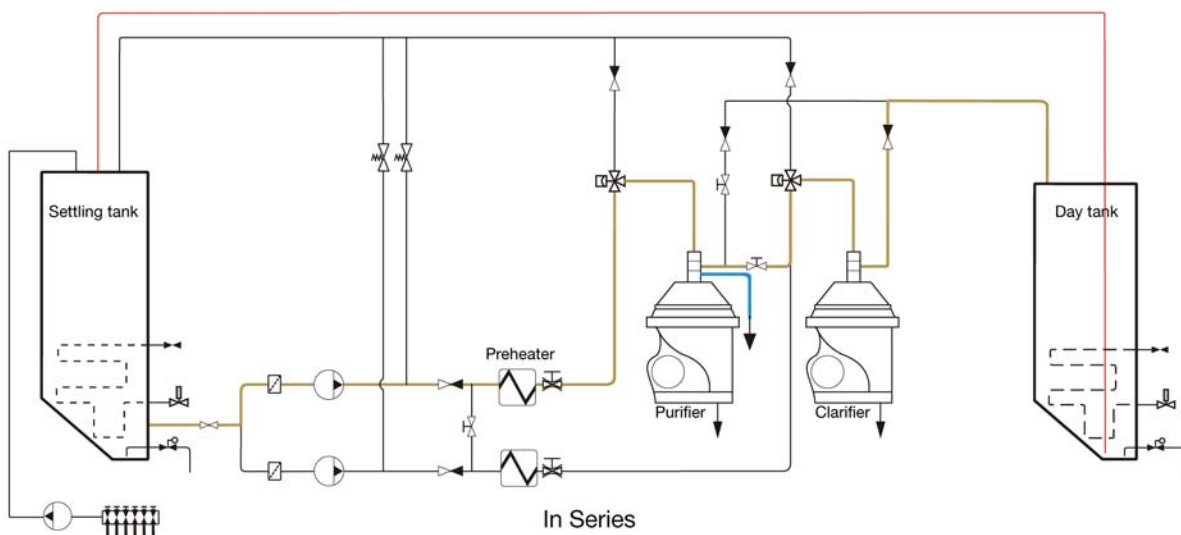
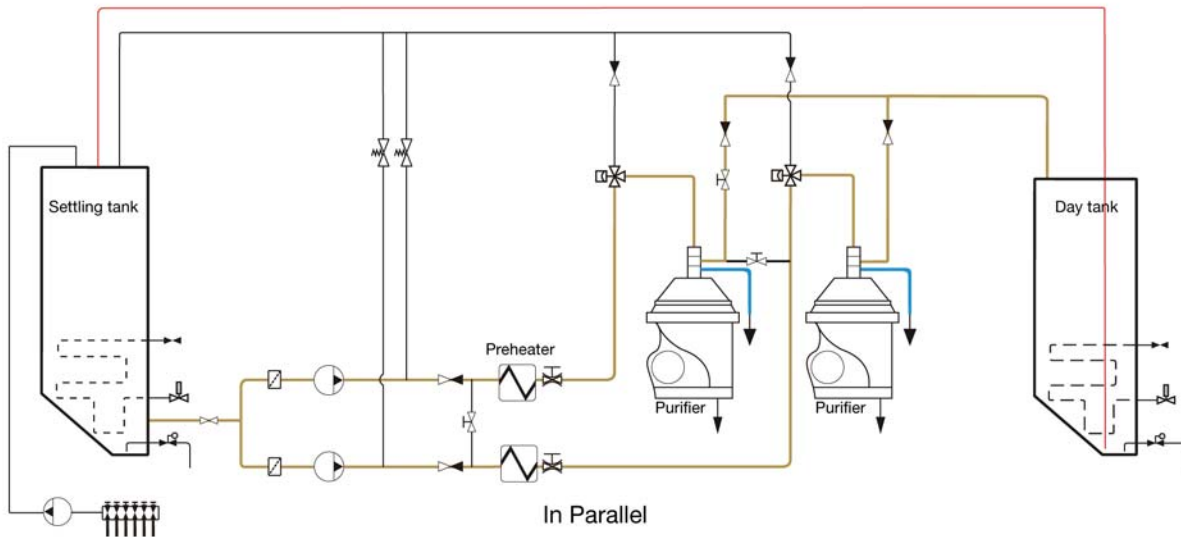
Standard



Fuel Oil System

Drawing
4255-0105-0004

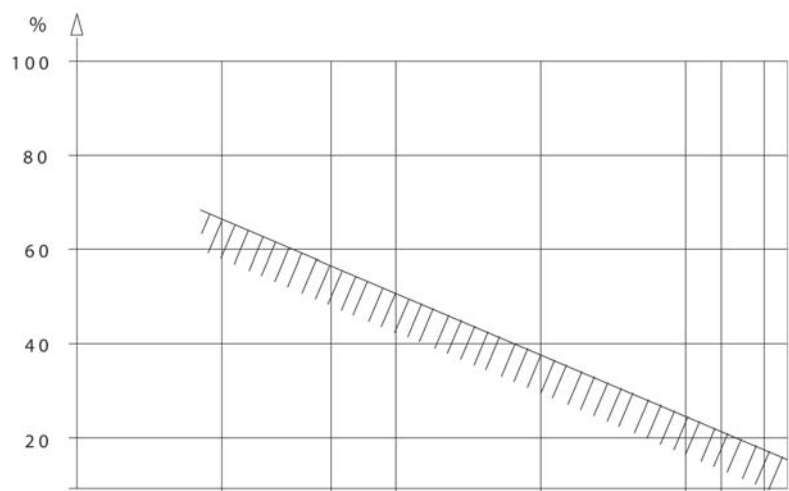




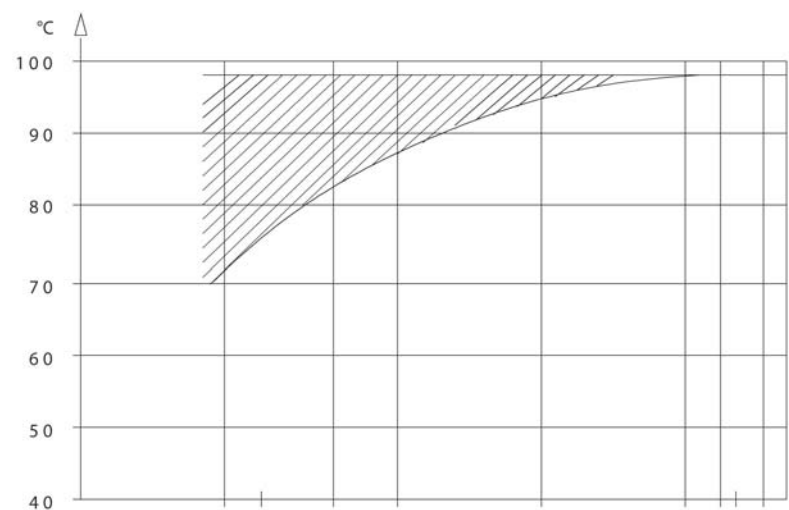
By courtesy of Alfa-Laval

Rate of Flow

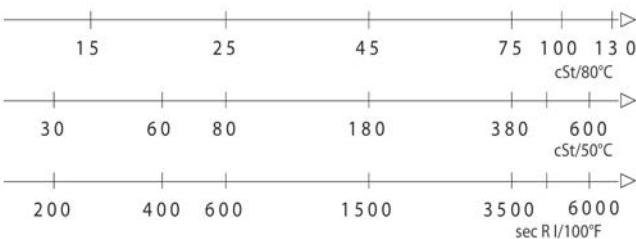
Related to rated capacity of centrifuge

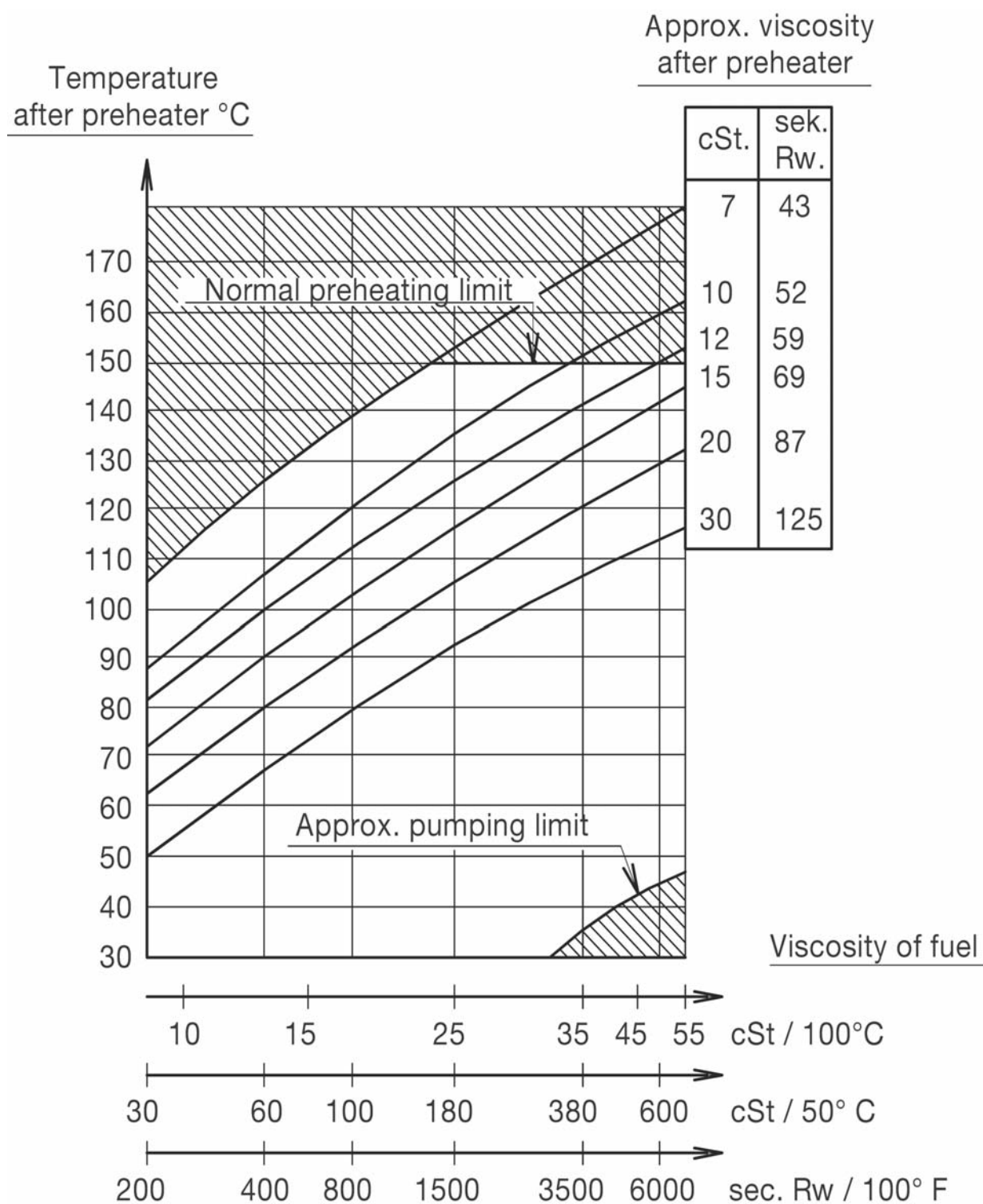


Separation Temperature



Log Scales





This chart is based on information from oil suppliers regarding typical marine fuels with viscosity index 70-80. Since the viscosity after the preheater is the controlled parameter, the preheating temperature may vary, dependent on the viscosity and the viscosity index of the fuel.

Recommended viscosity meter setting is 10-15 cSt.

Safety**Precautions**

for detailed sketch
see 0545-0100

	Stop the Engine
	Shut off starting air supply - At starting air receiver
	Block the main starting valve
	Shut off starting air distributor/distributing system supply
	Shut off safety air supply - Not ME Engines
	Shut off control air supply
	Engage turning gear
	Shut off fuel oil
	Stop lubricating oil supply
	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T42-04	Union nuts, tightening torque (small pipes)	300	Nm
T42-07	Fuel oil high-pressure pipe, tightening torque (fuel oil pressure booster - fuel oil distributor block)	450	Nm
T42-08	Fuel oil high-pressure pipe, tightening torque (fuel oil distributor block - fuel valves)	300	Nm
T42-16	Union nuts, tightening torque (large pipe)	340	Nm
T42-80	Mounting screws, tightening torque	190	Nm
T42-81	Fuel oil inlet seat, max. grinding diameter	30	mm
T42-82	Fuel oil outlet seat, max. grinding diameter	26	mm
T42-83	Fuel oil distributor block	100	kg
T42-86	Fuel oil pipe, pressure booster - distributor block	30	kg
T42-87	Fuel oil pipe, distributor block - fuel valves	20	kg

T42-05/88	Distance from pipe end to thrust bushing lower edge		
	For pipe connecting to fuel valve and distributor block	14	mm
	For pipe connecting to fuel pump and distributor block	16	mm

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
4270-0010	095	Milling tool for fuel oil pipe seat (outlet)
4270-0010	105	Milling tool for fuel oil pipe (Dist. block - F.O. valves)
4270-0010	453	Milling tool for fuel oil pipe seat (inlet)

Plate	Item No.	Description
4270-0010	465	Milling tool for fuel oil pipe (FOPB - Dist. block)
4270-0010	-	Crowfoot wrench head - sundry types

! WARNING**Secure the engine and depressurise the HCU**

Make sure the engine is stopped and blocked according to the safety precautions.
See data.

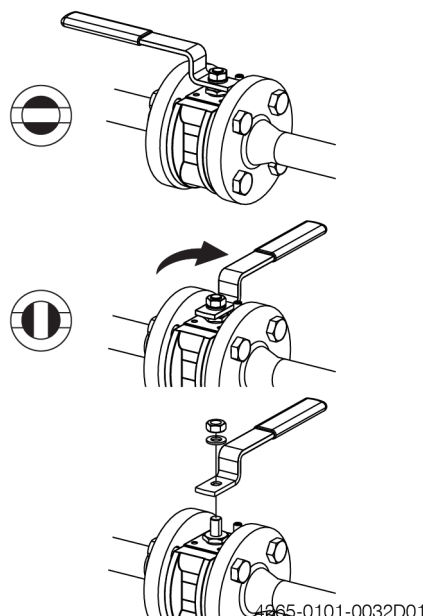
Close the fuel oil supply and depressurise the HCU.
See work card 4565-0501.

1. Remove the fuel oil inlet valve handle

Fully relieve the pressure from the fuel oil high-pressure pipes.

! WARNING**For safety reasons**

Remove the fuel oil inlet valve handle.

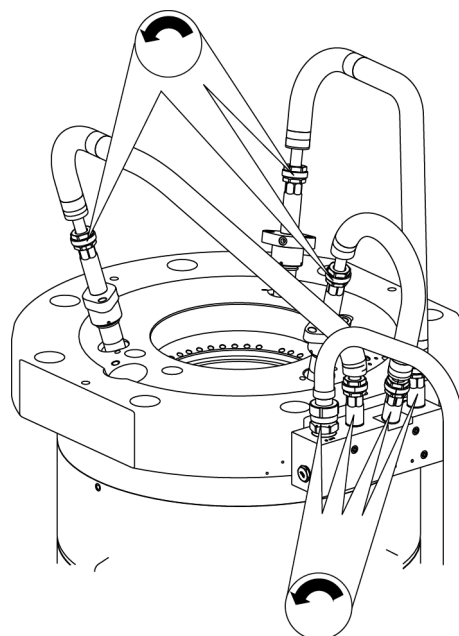


2. Remove the union nuts and outer cones

Unscrew the outermost union nuts at the fuel valve end and at the distributor block end of the small high-pressure pipes.

Pull the union nuts clear of the unions.

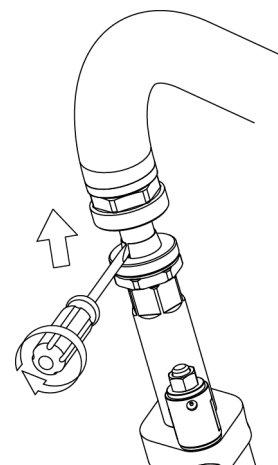
Lift the outermost cone rings clear of the unions.



3. Remove the inner cones

By means of a screwdriver, carefully increase the gap (and hereby the diameter) of the innermost cones.

Lift the cones clear of the innermost union nuts.

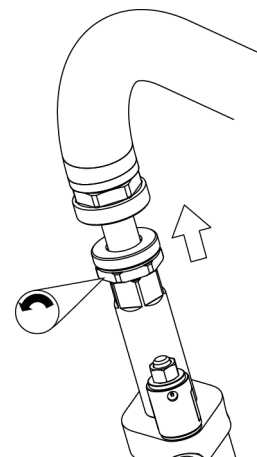


4265-0101-0012D03

4. Remove the Inner union nuts and sealing ring housings

Unscrew the innermost union nuts from the union nipples and lift them away from the union nipples.

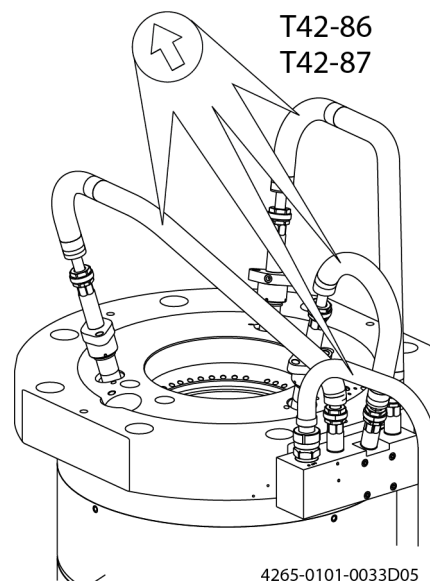
Lift the sealing ring housings with sealing rings clear of the union nipples and unscrew the union nipples from the fuel oil injection valves and distributor block.



4265-0101-0012D04

5. Remove the small pipes (Dist. block - Inj. valves)

Lift the pipe ends clear of the fuel oil injection valve/distributor block and remove the high-pressure pipes from the engine.



4265-0101-0033D05

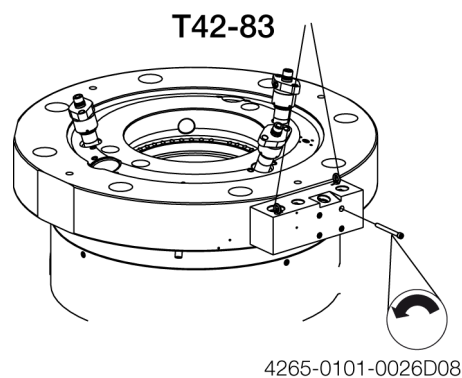
6. Remove the large pipe (FOPB - Dist. block)
- Using a hook spanner, unscrew the union nuts at the fuel oil pressure booster end and at the distributor end. Remove the high-pressure pipe clear from the engine.

NOTICE

It is recommended always to overhaul the high-pressure pipe before remounting it on the engine. *See overhaul procedure.*

The overhaul should preferably take place immediately after the high-pressure pipe has been dismantled.

7. Loosen the distributor block
- Mount two eye bolts, shackles and round sling in the distributor block.
- Hook the round sling on to the engine room crane.
- Tighten up the round sling / engine room crane slightly.
- Loosen and remove the four screws securing the distributor block to the cylinder cover



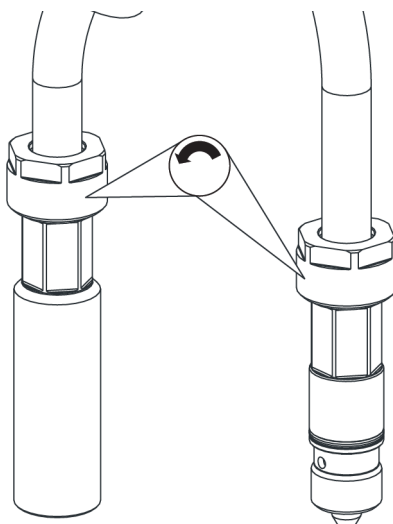
Whenever the fuel oil high-pressure system has been dismantled, it is necessary, before remounting the high-pressure pipes, to carefully inspect the tapered contact surfaces of the pipe ends, together with their seats in the fuel oil injection valves and the fuel oil pressure booster top cover.

Both the tapered contact surfaces and the seats in injection valves and top cover must be smooth without any grooves or ridges.

After the pipes have been removed from the engine, proceed as follows.

1. Union nuts

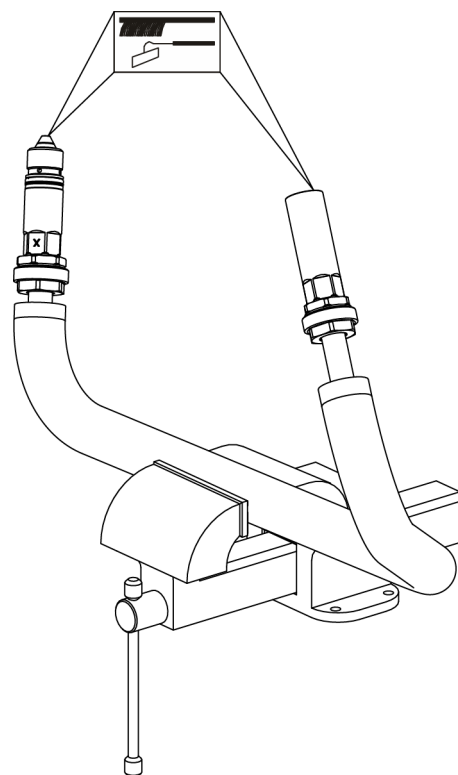
If still in place, unscrew the union nuts from the union nipples.



4265-0101-0029001

2. Clean pipe ends

Carefully clean both ends of the high-pressure pipe in clean diesel oil. If any of the pipe ends require reconditioning, to do this carefully mount the high-pressure pipe in a bench vice.

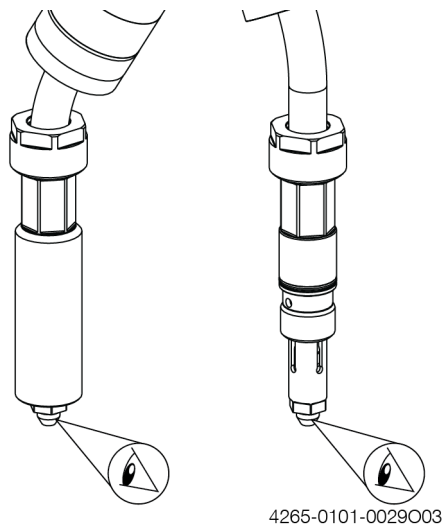


4265-0101-0027002

3. Examination

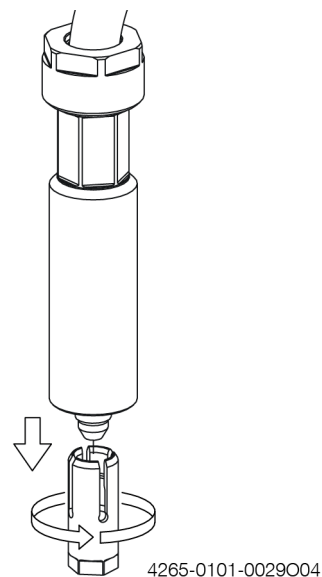
Carefully examine the sealing surfaces on both pipe ends. If necessary lift up the union nipples.

The pipe ends must be smooth without grooves or marks. If grooves or marks are found the sealing surfaces must be reconditioned.



4. Recondition

For reconditioning of the sealing surfaces of the high-pressure pipe unscrew the thrust bushing. (left-hand thread)



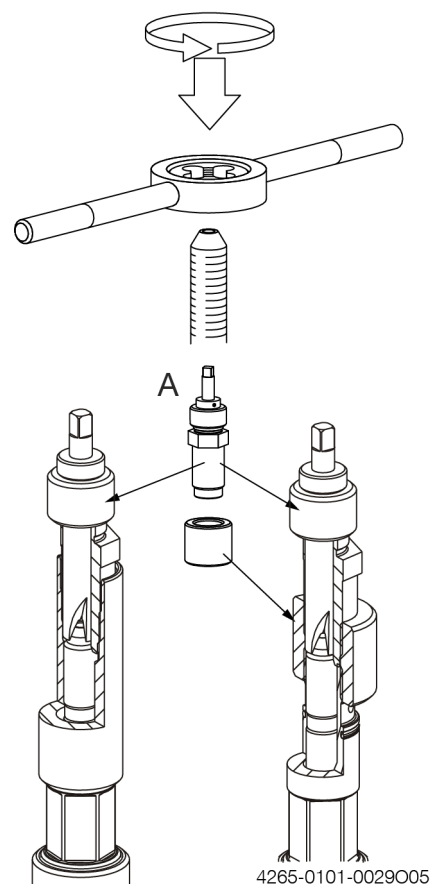
5. Milling

Shape-up the threads on the pipe ends with the nut die. (left-hand thread).

Add drilling oil emulsion and mount the cutting tool.

Turn the miller clockwise with, for instance, a tap wrench while lightly tightening the upper tightening ring A to provide a suitable pressure between the miller and the pipe end.

During the milling process, remove the cutting tool at intervals, clean the pipe end and add drilling oil emulsion. Continue until a smooth surface has been achieved.



6. Clean

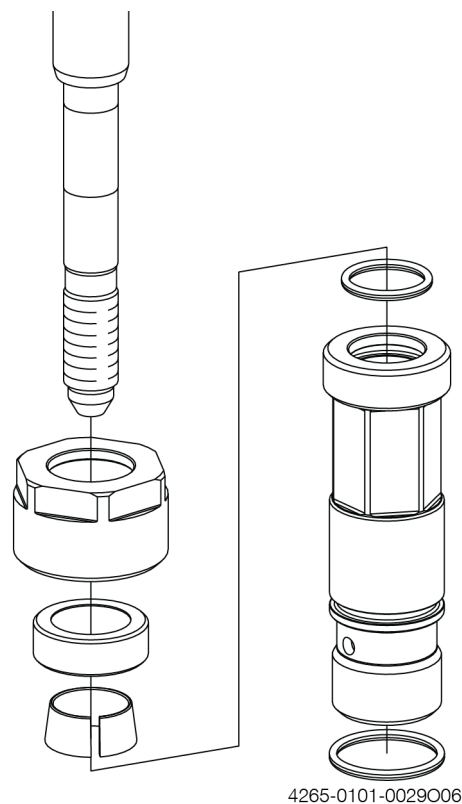
When the reconditioning of the sealing surfaces has been completed remove the cutting tool from the pipes.

Remove the union nipples and union nuts from the pipe ends.

Blow through the pipes with compressed air.

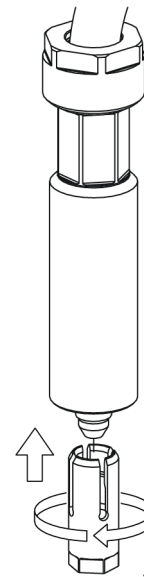
Clean all parts and replace the O-rings.

Mount the union nipples and union nuts on the pipe ends.



7. Thrust bushing

Mount the thrust bushing on both ends of the high-pressure pipes.



4265-0101-0029007

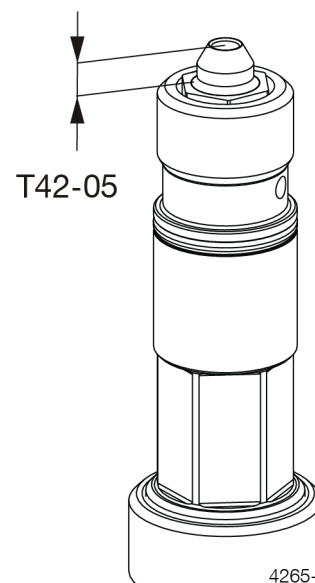
8. Adjustment

Adjust the position of the thrust bushings on both ends of the high-pressure pipes so that the distance between the pipe end and the bottom edge of the thrust bushing is as stated in data.

If the high-pressure pipe is not to be mounted on the engine immediately after the overhaul, cover the ends of the pipe with cloth and/or plastic for protection during storage.

For reconditioning of the seat in the fuel oil injection valve, see work card 4265-0201.

For reconditioning of the seat in the fuel oil pressure booster top cover, see work card 4265-0601.



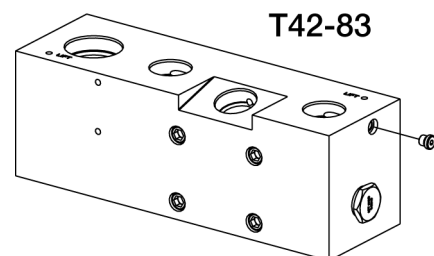
4265-0101-0029008

9. Reconditioning of the distributor block seats

Whenever the fuel oil high-pressure pipes are dismantled, it is strongly recommended to carefully inspect the seating surfaces of the distributor block.

For removal of the fuel oil high-pressure pipes, see *dismantling procedure*.

If scores or marks are found on the seating surfaces, the distributor block must be reconditioned as follows.



4265-0101-0026003

10. Refurbishing

Dismantle the distributor block from the cylinder cover. Unscrew and remove the plug screws from the block.

For major scores or marks, use the milling tool and plenty of drilling oil emulsion to mill the seating surfaces.

NOTICE

**When milling or grinding, take care not to exceed the max. grinding limits given.
See data.**

For minor scores or marks, use the grinding tool and a suitable grinding compound (e.g. Carborundum) to grind the seating surfaces.

11. Inspect the contact seats

Make sure there are no metal shavings or other debris left behind.

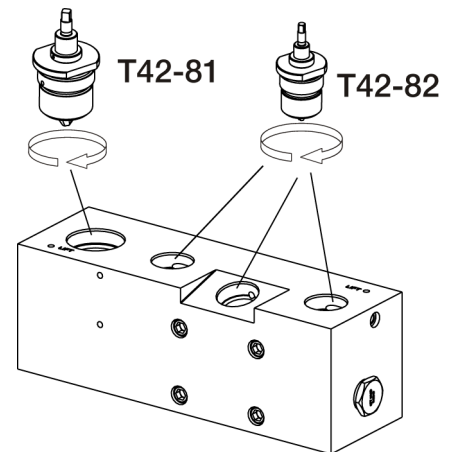
12. Possible renewal

If the max. grinding limits are exceeded, the distributor block must be renewed.

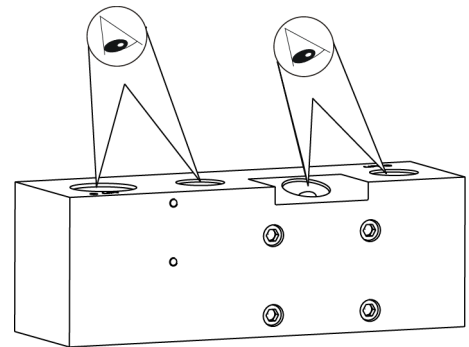
After reconditioning of the seating surfaces carefully clean the distributor block and blow through with compressed air.

Re-insert the plug screws and mount the distributor block on the cylinder cover.

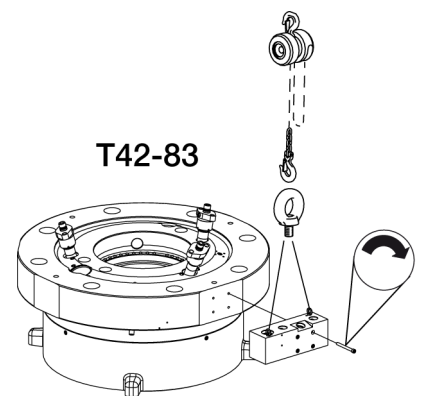
Mount the four screws securing the distributor block lightly. Do not tighten the mounting screws yet.



4265-0101-0026004



4265-0101-0006007



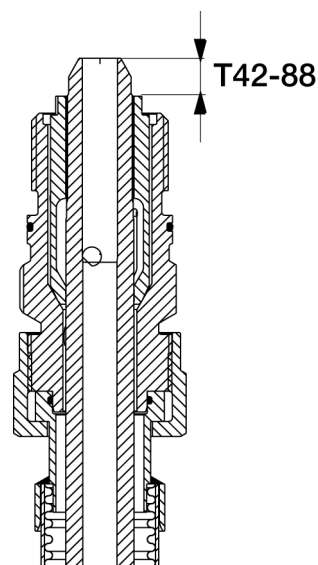
4265-0101-0026005

1. Prepare the high-pressure pipes

Check that the distance between the thrust bushing and the pipe end is correct at both ends of the large pipe.
See overhaul procedure.

Ensure that the fuel oil injection valves are fitted with new O-rings. Lubricate the thread of the valves with a heat resistant grease.

Ensure that the union nipples at the fuel oil pressure booster end, and at the distributor block end of the high-pressure pipes are fitted with new O-rings. Lubricate the thread on the union nipples with a heat resistant grease.



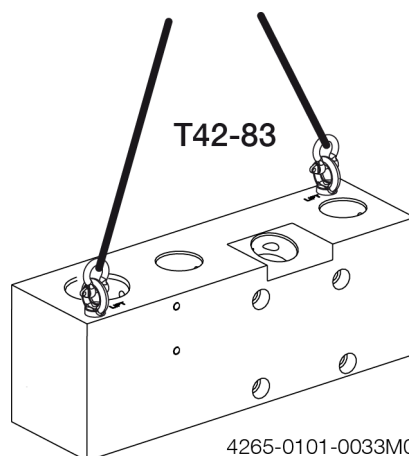
4265-0101-0026M01

2. Prepare the distributor block

If not already done, mount the eye bolts, shackles and round sling on the distributor block.

Using the engine room crane suspend the distributor block in position next to the cylinder cover.

Mount the four screws securing the distributor block lightly. Do not tighten yet.

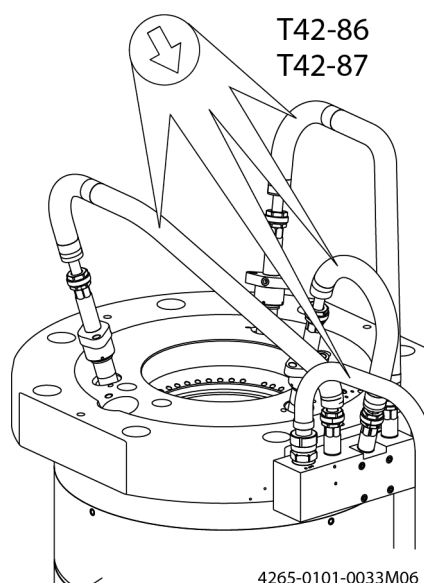


4265-0101-0033M02

3. Mount pipes

Mount the large high-pressure pipe between the fuel oil pressure booster and the distributor block.

Mount the double-walled fuel oil high-pressure pipes between the distributor block and the fuel valves.



4265-0101-0033M06

NOTICE

The nipples must be screwed by **hand**, as the threads of the parts might otherwise be damaged.

Tightening with a fork spanner should only be done after the union nipples at both ends of the pipe have been screwed into position.

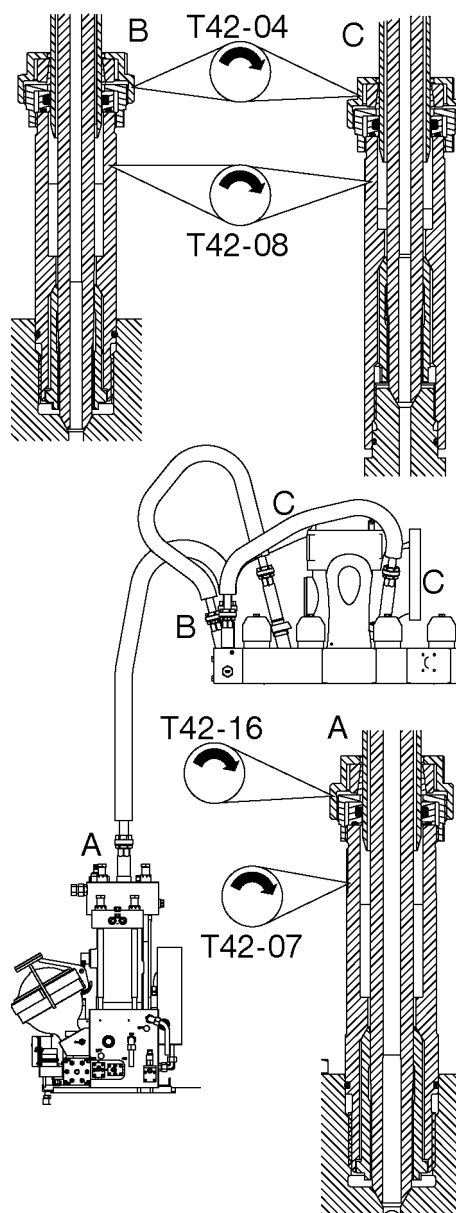
4. Tighten pipes

Tighten the union nipples to the torque stated *in data* using a crowfoot wrench and a torque spanner.

Using a crowfoot wrench, screw the innermost union nut loosely (approx. two revolutions) onto the union nipple. Screw the outermost union nut onto the innermost union nut in the same manner.

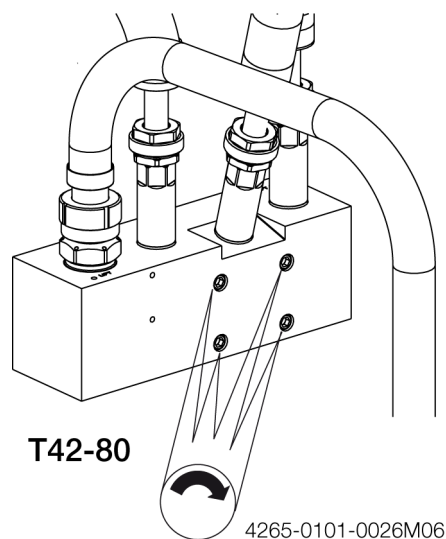
Using a torque wrench, tighten the two union nuts to the torque stated *in data*, starting with the innermost union nut and finishing with the outermost union nut. If the union nipple has to be re-tightened, the two union nuts must be loosened.

Repeat this tightening procedure on all three high pressure pipes connecting the distributor block and the fuel oil injection valves.

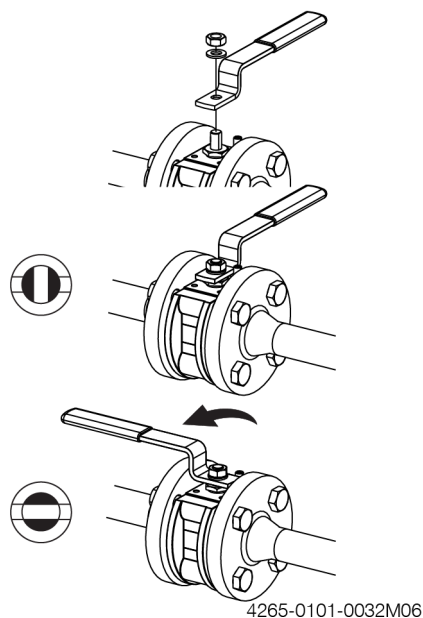


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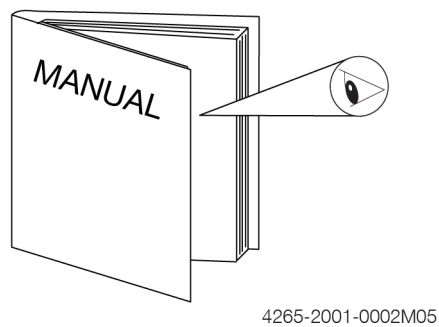
5. Secure distributor block
Tighten all four mounting screws on the distributor block.
See data T42-80



6. Open fuel inlet
Mount the handle on the fuel oil inlet valve.



7. Pressurise the hydraulic cylinder unit
Pressurise the hydraulic cylinder unit.
See work card 4565-0501.



Safety**Precautions**

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Engage turning gear
○	Shut off fuel oil
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T42-9	Fuel valve opening pressure	400--430	bar
T42-10	Fuel valve tightening torque	25	Nm
T42-11	Inlet seat, max. diameter	25	mm
T42-12	Fuel valve, weight	9	kg

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
4270-0010	095	Milling tool for fuel oil pipe seat
4270-0010	166	Grinding mandrel for valve head
4270-0010	178	Grinding mandrel for thread spindel
4270-0010	180	Grinding mandrel for holder, outside
4270-0010	191	Grinding mandrel for holder, inside
2270-0300	071	Dismantling lever for fuel valve
4270-0220	-	Fuel valve testing tools
7670-0200	-	Torque spanners
7670-0410	066	Slide caliper

1. Fuel oil injection valve

The injection valves must be given the utmost attention and care, as the greater part of irregularities that may occur during the running of the engine can be attributed to defects in these valves.

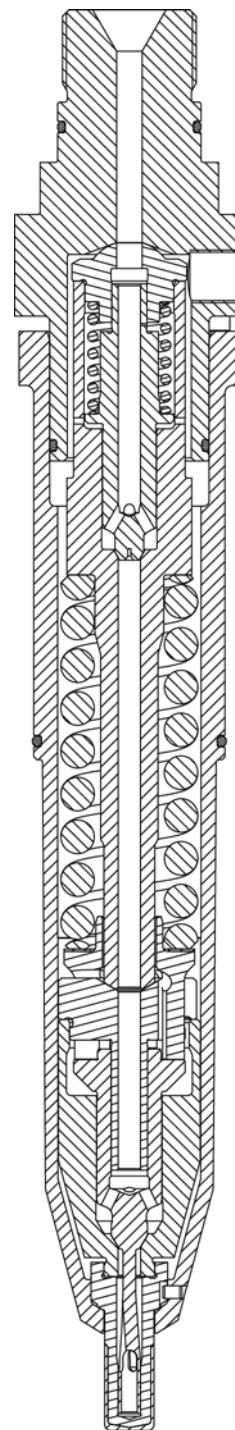
If the engine gives normal performance in accordance with diagrams and exhaust temperatures, it is only necessary to inspect the injection valves after the service period stated in the Checking and Maintenance Programme. *See maintenance schedule 0760-0301.*

In order to obtain reliable results during testing of the injection valves, all injection valves that are dismantled from the engine must be disassembled, cleaned, inspected and re-assembled before testing. *See work card 4265-0301.*

NOTICE

In the event that the slide-type injection valve is pressure tested without being cleaned between the fuel nozzle and the cut-off slide, the opening pressure value measured might be considerably lower than specified.

All injection valves must be function-tested before being mounted in the cylinder cover.



4265-0201-0018C01

2. Pressure testing pump

Use only hydraulic oil (rust-preventing) with a viscosity of between 7 and 10 cSt at 50°C.

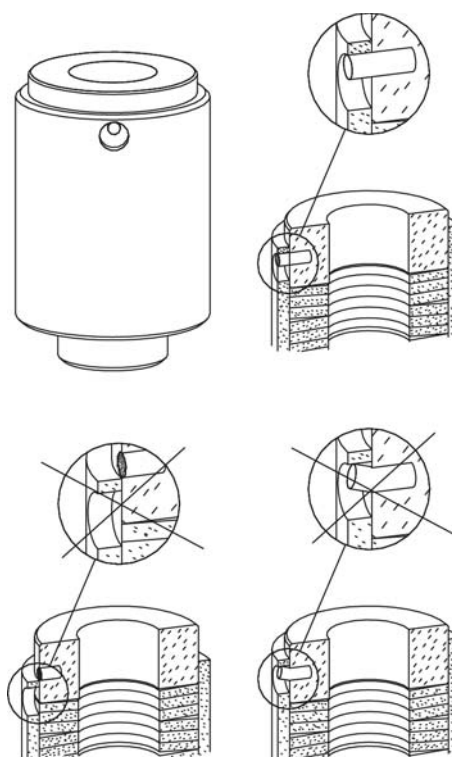
For operation of the pressure testing pump, see the supplier's instructions.

Note that the high-pressure pump should be periodically checked in accordance with the supplier's instructions.

3. Spring housing

To ensure that over tightening has not taken place, check that the locking/indicating pin has not been bent or broken off.

In the event of over tightening, replace the spring housing by a new one.

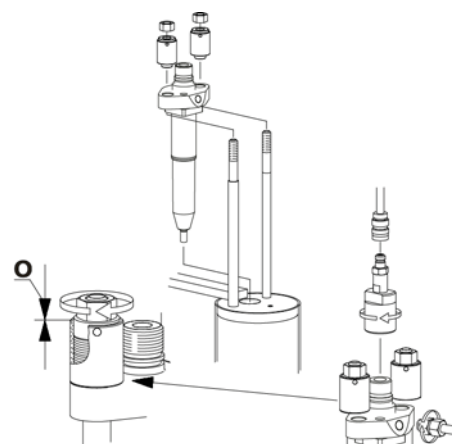


4265-0201-0002C02

4. Setting-up the injection valve

Place the injection valve in the test rig and secure it with the spring housings and nuts.

Tighten the nuts until the top face of the pressure disc is flush with the top face of the spring housings. Mount the oil pipe between the pressure testing pump and the injection valve.



4265-0201-0011C03

5. Pressure testing procedure

The following functions of the injection valve must be checked:

- Flushing and jet control
- Opening pressure
- Sealing test and sliding function
- Pressure test, O-ring sealing

WARNING



Protect yourself

Use goggles and gloves when operating the pressure testing device.

See description 0545-0100.

6. Flushing and jet control

Remove air in the system and check the fuel jet in the following way.

Slowly increase the oil pressure until straight jets of oil are ejected from the nozzle holes (no atomization).

Acceptance criteria:

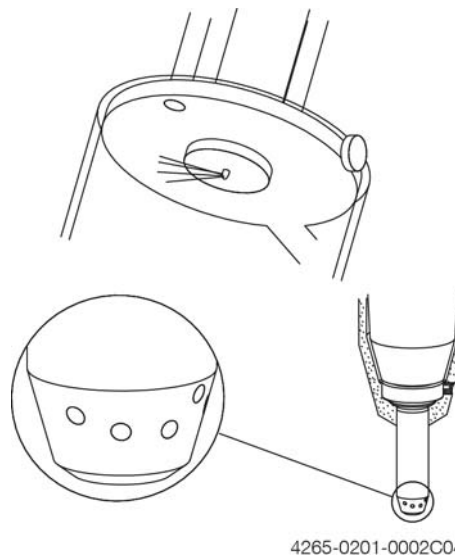
There is to be a continuous jet of oil through at least one of the nozzle holes.

Owing to the geometry of the internal part of the nozzle - and because of the height to which the spindle is lifted during pressure testing is lower than the height it is lifted during normal engine operation - the fuel oil will not necessarily flow from all of the nozzle holes.

Cause of fault:

If the jets do not fulfil the above point, the cause may be:

- Dirt in the nozzle holes
- The nozzle is not mounted correctly



7. Opening pressure

To check the opening pressure, increase the oil pressure until oil is admitted through the nozzle holes.

Acceptance criteria:

Check the opening pressure on the pressure gauge and compare with *data T42-9*.

NOTICE

Do NOT attempt to carry out an atomization test on the slide type injection valves, as this may damage the cut-off slide and nozzle.

Cause of fault:

If the opening pressure is higher than specified in *T42-9*, the cause may be that a wrong type of spring is used - replace the spring on the thrust spindle, if necessary, replace the complete thrust spindle.

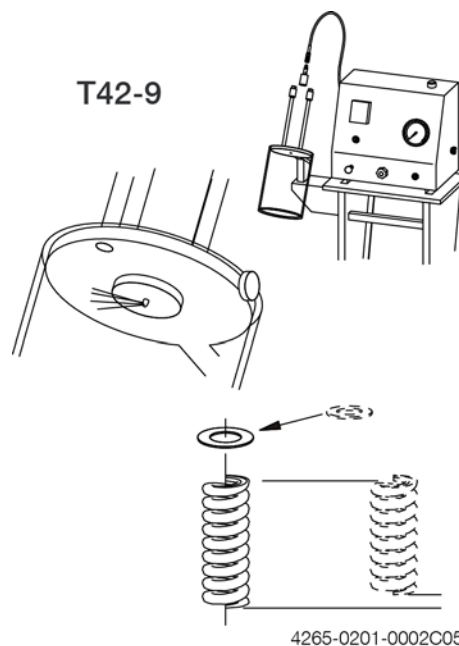
If the opening pressure is lower than specified in *T42-9*, the cause may be that the spring has sagged - replace the spring, or add a special thin disc.

NOTICE

Special thin discs are available as spares.

If a spring or a disc has been changed, the pressure testing procedure of the injection valve must be repeated.

T42-9



4265-0201-0002C05

8. Sealing test and sliding function

To check the needle valve seat for tightness and the slide for correct closing.

Slowly increase the oil pressure to about 50 bar below the opening pressure. Maintain the built-up pressure by closing for the oil supply.

Acceptance criteria:

Oil must not flow from the nozzle holes. The pressure drops relatively slowly to about 15 bar, after which it drops quickly to 0 (the slide is pressed against the conical seat and opens for circulation oil).

NOTICE

Oil flows out of the leak oil outlet when the injection valve is full of oil.

Cause of fault:

If oil flows out of the nozzle holes, the cause is either:

- Defective spindle guide at needle seat, or a sticking spindle. Examine and/or replace the spindle guide.
See work card 4265-0301.

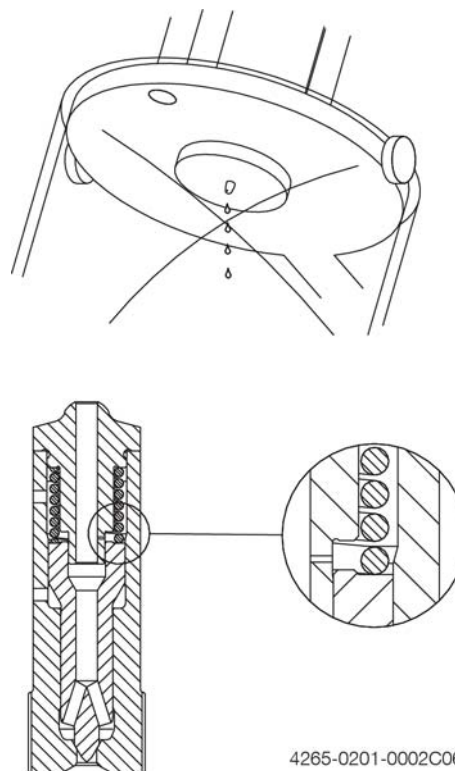
- Too quick pressure drop:
The clearances of the movable parts, both of the spindle guide and of the non-return valve, are too large, or the seats between the thrust piece/spindle in the spindle guide or thrust piece/valve slide in the non-return valve are damaged.

Examine and/or replace both the spindle guide and non-return valve.
See work card 4265-0301.

If a quick pressure drop from 15 to 0 bar cannot be registered:

- The valve slide is sticking; or
- The vent hole in the thrust piece is blocked.

If so, disassemble and examine the spindle guide, replace if necessary.
See work card 4265-0301.



9. Pressure test, O-ring sealing

To ensure that the leak oil (circulation oil) remains in the closed system, build up a working pressure of about max. 10 bar until oil flows out of the leak oil outlet.

Close the leak oil outlet with a gasket and plug screw.

Increase the working pressure to about 100 bar.

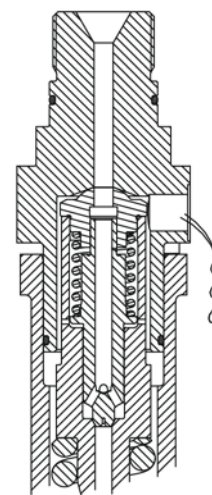
Acceptance criteria:

The built-up pressure of about 100 bar should be maintained.

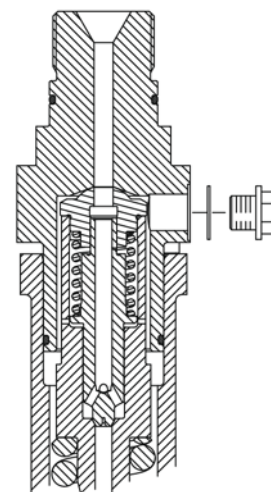
Cause of fault:

If oil leaks out between the holder and the injection valve head, the O-ring inside the injection valve head is defective, and must be replaced.

Max. 10 bar



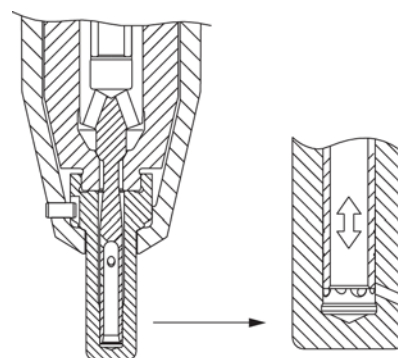
Max. 100 bar



4265-0201-0018C07

10. Atomization test

The atomization test may damage the valve because it makes the needle oscillate, with a small lift at a very high frequency. The high pressure drop across the cut-off edge and the high contact pressure between slide and fuel nozzle, in combination with the poor lubricity of the test oil, increase the risk of seizures between cut-off slide and nozzle.



4265-0201-0003C08

NOTICE

Do NOT attempt to carry out an atomization test on slide type injection valves, as this may damage the cut-off slide and nozzle.

All of these conditions involve the risk of seizure between the cut-off slide and the nozzle.

1. Removing the oil pipes

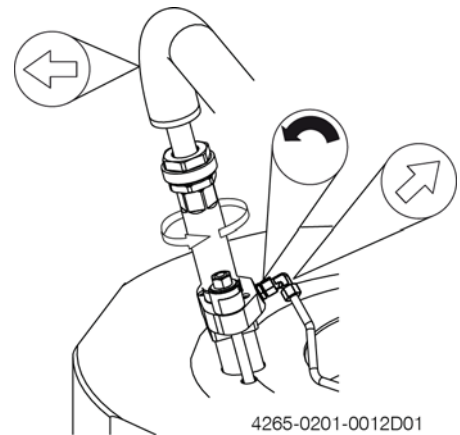
Close the fuel oil inlet and outlet valves, and drain the high-pressure pipe and the fuel oil injection valve.

Dismantle and remove the fuel oil high-pressure pipe.
See work card 4265-0101.

Disconnect the return oil pipe from the injection valve.

NOTICE

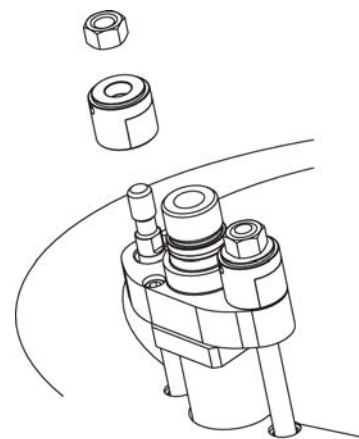
Due to variations between engine types, the actual layout of the injection valve and injection valve drain pipe may vary slightly from the injection valve shown in the sketches.



4265-0201-0012D01

2. Before removal

Remove the nuts and the spring housings.



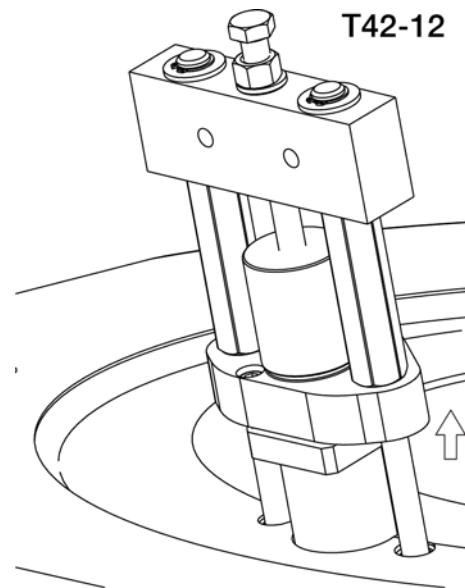
4265-0201-0012D02

3. Removing the injection valve

Mount the valve dismantling tool as shown. Pull the valve up several centimetres by turning the middle nut. The injection valve can then be removed by hand after the dismantling tool is removed.

NOTICE

If the injection valve is not to be overhauled immediately, the valve should be placed immersed in diesel oil until overhauling.



4265-0201-0013D03

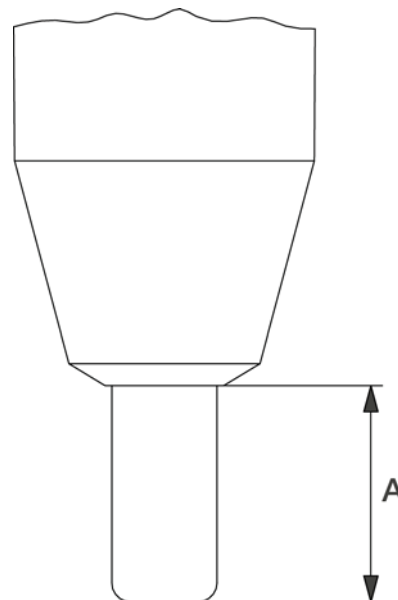
Generally when overhauling fuel oil injection valves

When injection valves are overhauled, all parts should be handled carefully and be kept clean.

Use only clean, non-fluffy rags for wiping purposes. Make sure to remove all liquid or solid impurities. Whenever injection valves are overhauled, all sealing rings should be discarded and replaced by new, faultless sealing rings before reassembly.

1. First

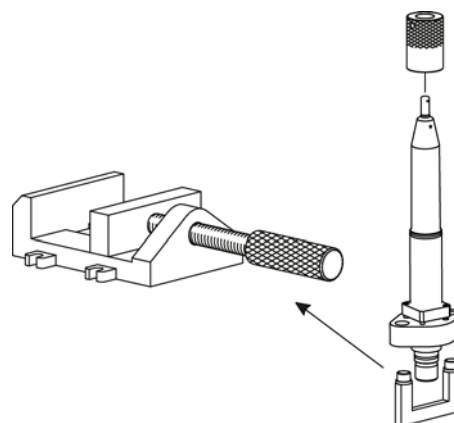
Measure the length **A** of the protruding part of the nozzle, and write down the result for correct re-assembling of the valve.



4265-0201-0001001

2. Valve holder

Place the valve holder in a machine vice, mount the injection valve in the holder and fit the valve with the guide disc from the grinding tool.

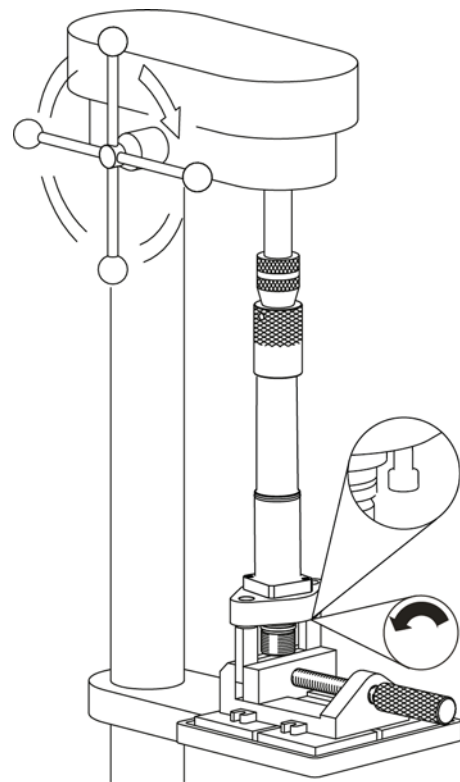


4265-0201-0011002

3. Compress the injection valve

Compress the injection valve and the spring inside, by means of a drilling machine, to avoid seizures in the injection valve head thread. Hold the injection valve compressed and unscrew and remove the screws.

Remove the valve from the valve holder.



4265-0201-0011003

4. Dismantling the injection valve

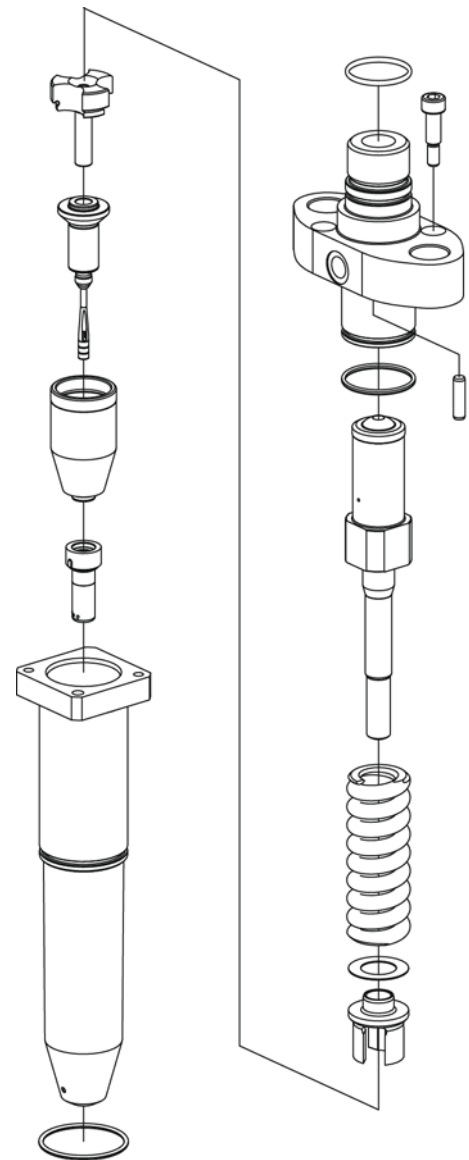
Pull the valve head clear of the valve housing.

Remove the:

- Non return valve
- Thrust spindle parts
- Thrust foot
- Spindle guide and fuel nozzle

from the valve housing.

Remove and discard all the O-rings.



4265-0201-0018O04

5. Test and examine injection valve parts

Carefully clean and examine all surfaces of the:

- Injection valve housing
- Injection valve head
- Non-return valve

If necessary, grind the seating surfaces by means of a fine-grain abrasive (such as Carborundum No. 500).

The grinding mandrels supplied are only purposed for:

- The injection valve housing.
- The injection valve head.
- The top of the non-return valve.

This grinding must only be carried out manually.

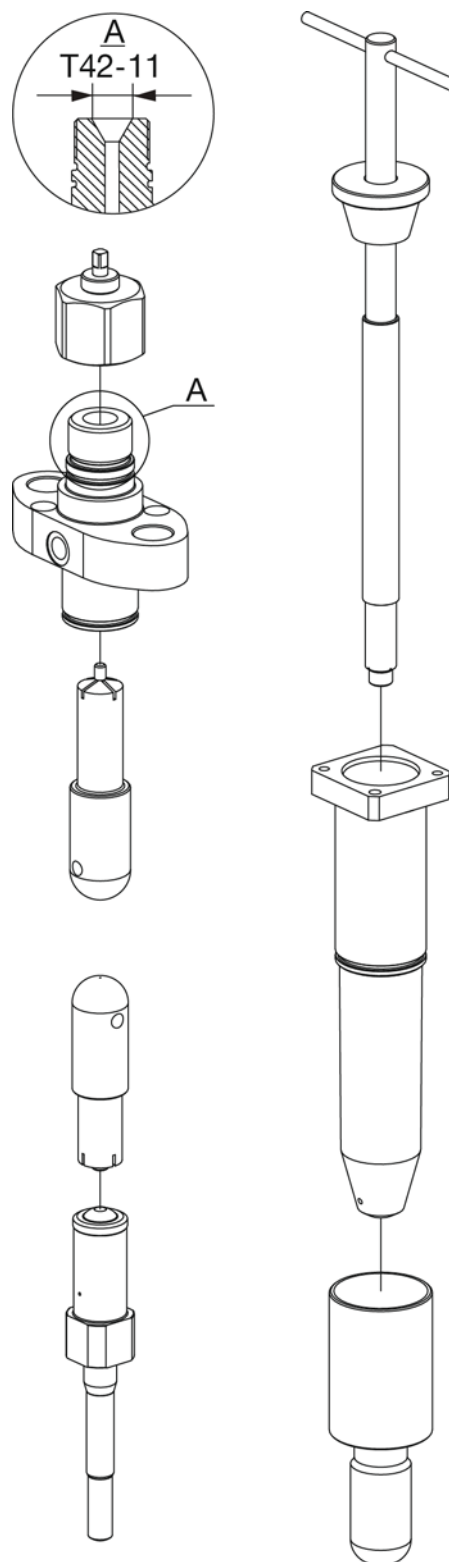
After the grinding, wash the parts in gas oil and blow clean by means of compressed air to remove any remains of the grinding compound.

In the event of more serious damage to the seating surface for the high-pressure pipe in the valve head, the milling tool can be used.

Normally, the milling tool is turned by hand, but it may be fitted in the chuck of a column-type drilling machine provided that the number of revolutions is kept at a minimum (not exceeding approx. 100 r/min). An ample supply of cutting emulsion must be used.

NOTICE

Take care not to exceed the maximum diameter of the seat, *see data*.



4265-0201-0018005

Fuel Oil Injection Valve • Overhaul

Work Card
4265-0201-0018

6. Spindle guide

The complete spindle guide, including the fuel nozzle, should be sent to an authorised MAN Diesel & Turbo repair shop for overhaul.

If this is not possible, the spindle guide may be overhauled on board.

See work card 4265-0301.

NOTICE

Do not attempt to remove the fuel nozzle from the spindle guide unless the spindle guide has been dismantled. Otherwise the cut-off slide on the spindle may be damaged.



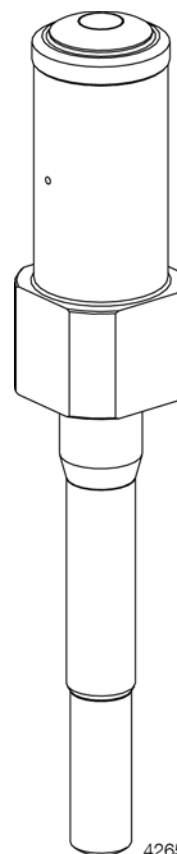
4265-0201-0003O06

7. Non-return valve

The non-return valve should be sent to an authorised MAN Diesel & Turbo repair shop for overhaul.

If this is not possible, the non-return valve may be overhauled on board.

See work card 4265-0401.



4265-0201-0009O05

8. Spindle guide into the injection valve housing

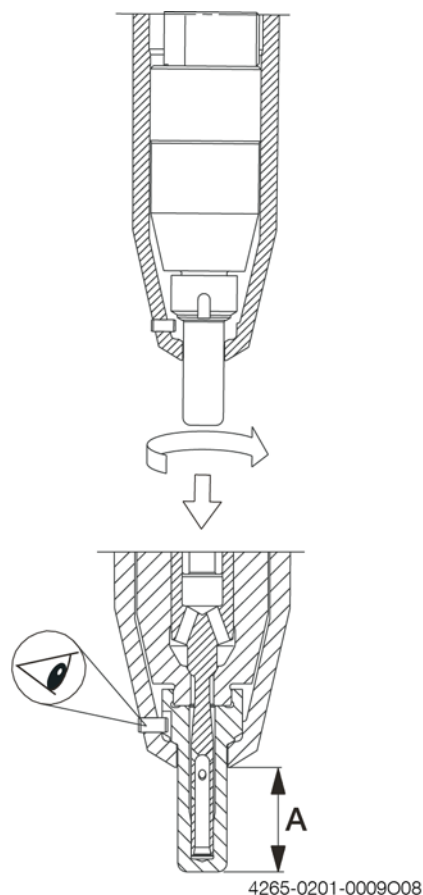
Mount the complete spindle guide, including the fuel nozzle, in the injection valve housing.

Carefully slide the spindle guide down into the valve holder, and turn the nozzle until the spindle guide engages correctly with the guide pin.

Check that distance **A** corresponds to the measurement taken before the valve was disassembled.

NOTICE

Make sure that the fuel nozzle and spindle guide engage correctly with the guide pin in the injection valve housing. This can be ascertained by attempting to turn the nozzle after mounting. It must not be possible to turn the nozzle.



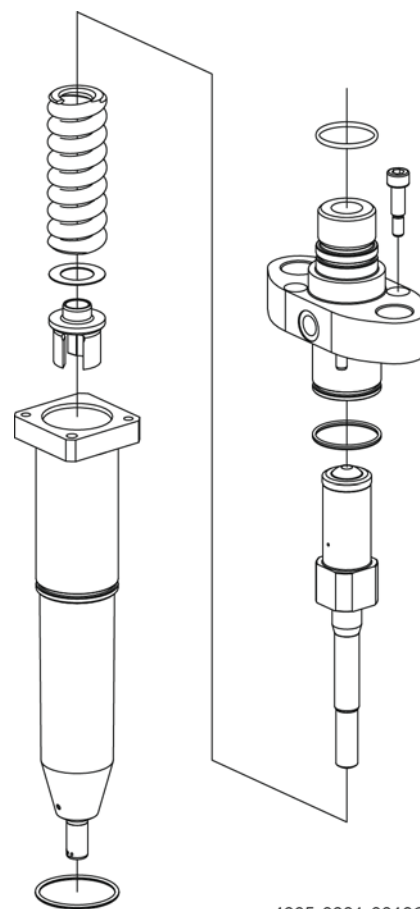
9. Assembly

Mount:

- The spring guide
- The disc and spring
- The non-return valve

in the injection valve housing. Mount a new O-ring in the groove of the injection valve housing.

Mount the valve head with new O-rings.



4265-0201-0018O09

10. Make sure

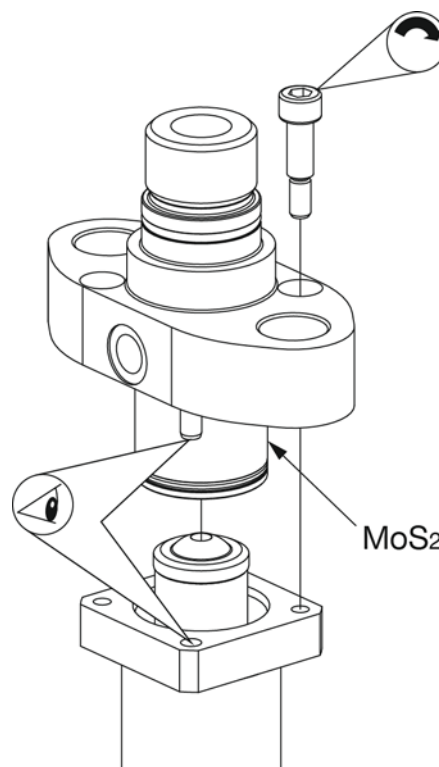
Lubricate the injection valve head with molybdenum disulphide (MoS_2).

*For the correct use of this lubricant:
See work card 7665-0901.*

Make sure that the guide pin between valve housing and valve head is intact, and press the valve head down into the valve housing.

See that the guide pin between valve housing and valve head engages correctly so as to prevent relative turning of the parts.

Mount the screws in the injection valve head.



4265-0201-0018O10

11. Tightening the injection valve head screws

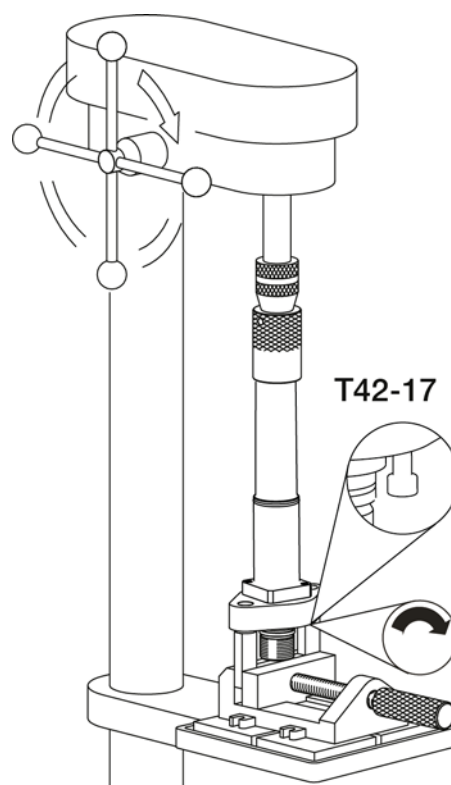
Place the valve in the valve holder in a drilling machine.

Compress the injection valve and the spring inside. Keep the valve compressed and tighten the screws to the torque stated *in data*.

After overhaul, the injection valve must be tested in the test rig.
See checking procedure.

NOTICE

If the injection valve is not to be mounted in the engine immediately after the overhaul, cover all openings of the valve with plastic to prevent dirt from entering the valve during storage.



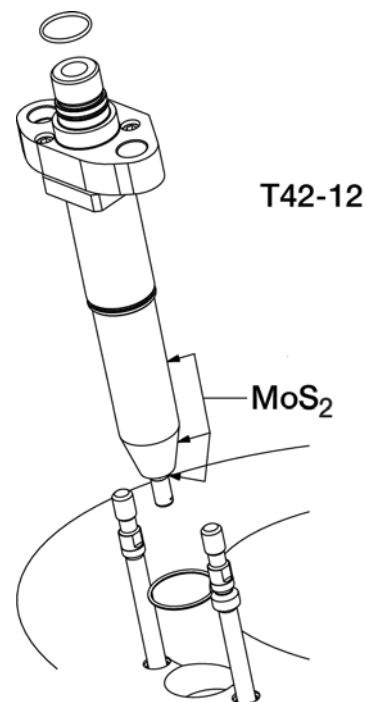
4265-0201-0011O11

1. First

Before mounting the injection valve, thoroughly clean the valve bore in the cylinder cover and check the seating in the bore for marks which, if any, must be eliminated.

For reconditioning of the valve bores in the cylinder cover, see work card 2265-0301.

If not already done, mount new O-rings on the injection valve. Lubricate the valve with Molybdenum Disulphide (MoS_2).



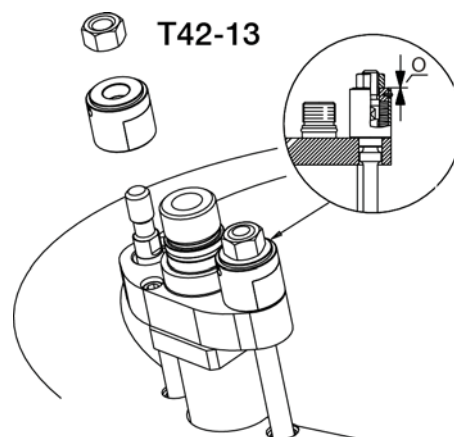
4265-0201-0012M01

2. Mount the valve

Mount the injection valve in position in the cylinder cover.

Mount the spring housings and the nuts.

Tighten the nuts until the top face of the pressure disc is flush with the top face of the spring housing. This must be done with great care, as the spring tension in the housing determines the correct tightening of the injection valve to the cylinder cover as well as the correct compression of the injection valve.



4265-0201-0012M02

3. Fuel pipe

Lubricate the thread on the union nipple of the fuel oil pipe with a heat resistant anti seize grease before mounting.

NOTICE

It is recommended to overhaul the fuel oil high-pressure pipe before mounting.

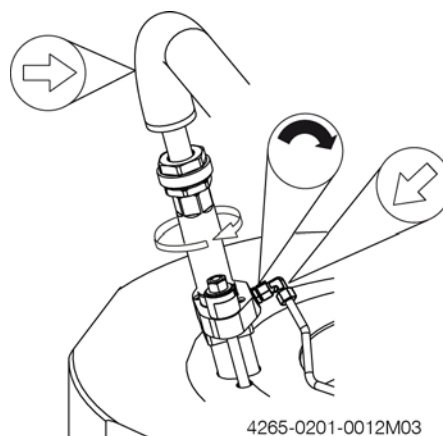
See work card 4265-0101.

As a minimum, the distance between the fuel oil pipe ends and the thrust bushings must be checked and, if necessary, adjusted.

Mount the overhauled fuel oil high-pressure pipe and the return oil pipe.
See work card 4265-0101.

NOTICE

All injection valves must be function-tested before being mounted in the cylinder cover.
See checking procedure.



Safety Precautions

Data

Ref.	Description	Value	Unit
T42-15	Nozzle spray hole cleaning tool table		
-	A: Nozzle spray hole - B: Cleaning drill - C: Test pin	-	-
-	A: 0.45 - B: 0.40 - C: 0.49	-	-
-	A: 0.50 - B: 0.45 - C: 0.54	-	-
-	A: 0.55 - B: 0.50 - C: 0.59	-	-
-	A: 0.60 - B: 0.55 - C: 0.64	-	-
-	A: 0.65 - B: 0.60 - C: 0.69	-	-
-	A: 0.70 - B: 0.65 - C: 0.74	-	-
-	A: 0.75 - B: 0.70 - C: 0.79	-	-
-	A: 0.80 - B: 0.75 - C: 0.84	-	-
-	A: 0.85 - B: 0.80 - C: 0.89	-	-
-	A: 0.90 - B: 0.85 - C: 0.94	-	-
-	A: 0.95 - B: 0.90 - C: 0.99	-	-
-	A: 1.00 - B: 0.95 - C: 1.04	-	-
-	A: 1.05 - B: 1.00 - C: 1.09	-	-
-	A: 1.10 - B: 1.05 - C: 1.14	-	-
-	A: 1.15 - B: 1.10 - C: 1.20	-	-
-	A: 1.20 - B: 1.15 - C: 1.24	-	-
-	A: 1.25 - B: 1.20 - C: 1.30	-	-
-	A: 1.30 - B: 1.25 - C: 1.34	-	-
-	A: 1.35 - B: 1.30 - C: 1.39	-	-
-	A: 1.40 - B: 1.35 - C: 1.44	-	-
-	A: 1.45 - B: 1.40 - C: 1.49	-	-
-	A: 1.50 - B: 1.45 - C: 1.54	-	-
-	A: 1.55 - B: 1.50 - C: 1.59	-	-
-	A: 1.60 - B: 1.55 - C: 1.65	-	-
-	A: 1.65 - B: 1.60 - C: 1.70	-	-
-	A: 1.70 - B: 1.65 - C: 1.74	-	-
-	A: 1.75 - B: 1.70 - C: 1.80	-	-
-	A: 1.80 - B: 1.75 - C: 1.85	-	-
-	A: 1.85 - B: 1.80 - C: 1.89	-	-
-	A: 1.90 - B: 1.85 - C: 1.94	-	-
-	A: 1.95 - B: 1.90 - C: 1.99	-	-
-	A: 2.00 - B: 1.95 - C: 2.05	-	-
-	A: 2.05 - B: 2.00 - C: 2.09	-	-
-	A: 2.10 - B: 2.05 - C: 2.14	-	-
-	A: 2.15 - B: 2.10 - C: 2.19	-	-
-	A: 2.20 - B: 2.15 - C: 2.24	-	-
-	A: 2.25 - B: 2.20 - C: 2.29	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
4270-0210	-	Fuel oil injection valve, nozzle tools

Clean the outside of the spindle guide in pure gas oil or similar.

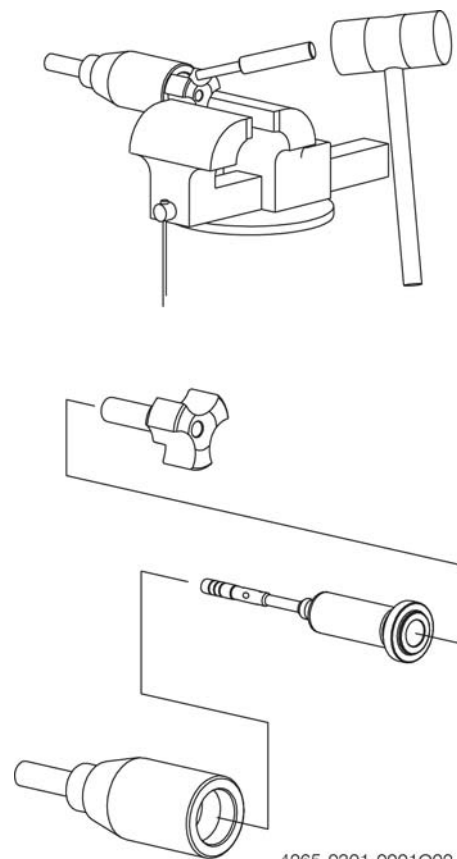
The individual parts of the spindle guide are not interchangeable, therefore only one guide is to be disassembled at a time.

NOTICE

The spindle guide, thrust piece and spindle are matched parts and may not be replaced individually.

1. Disassemble the spindle guide

Place the spindle guide in a bench vice provided with "soft" jaws, and use the brass mandrel as shown to disassemble the spindle guide.



2. Pull the fuel nozzle off the spindle guide

Mount the pulling tool around the fuel nozzle on the spindle guide. Turn the nut to pull the fuel nozzle off the spindle guide.

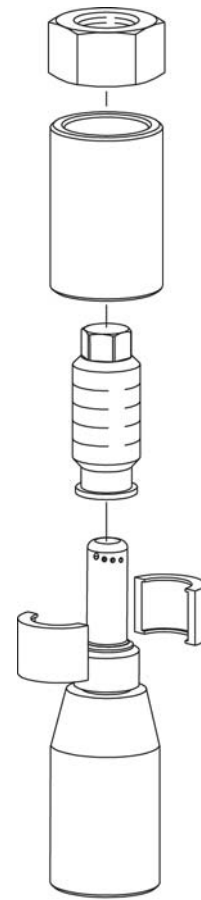
NOTICE

The pulling tool is not standard for all engines, but may be delivered as an optional extra.

3. Alternative

If no pulling tool is available, the fuel nozzle can be dismantled from the spindle guide using two screwdrivers.

Place the screwdrivers opposite each other in the small gap between the fuel nozzle and the spindle guide and very carefully force the fuel nozzle off the spindle guide.



4265-0301-0001004

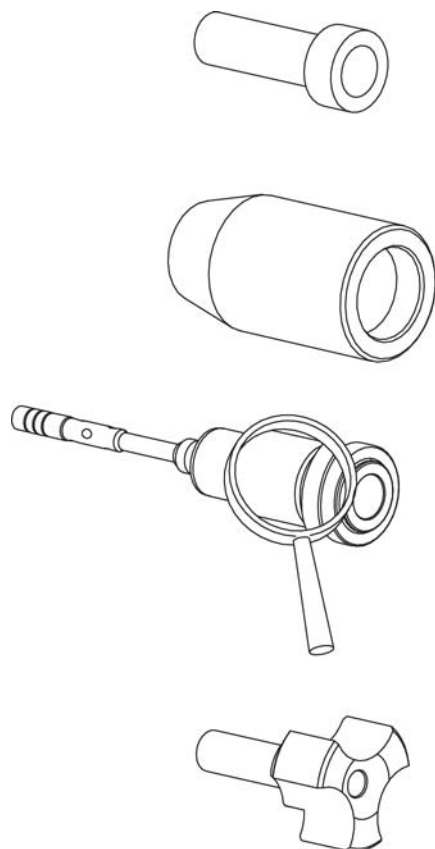
4. Check and examine all parts

Clean all the parts of the spindle guide in gas oil and wipe dry with a clean piece of cloth.

Clean all parts again in gas oil or 'Electrocleaner' and wipe dry with a clean piece of cloth.

Place all the parts on a clean, soft, lint-free cloth and examine them through an 8-10 times magnification magnifying glass and an inspection lamp.

During the examination, pay special attention to the seating surfaces and sliding surfaces of the parts.

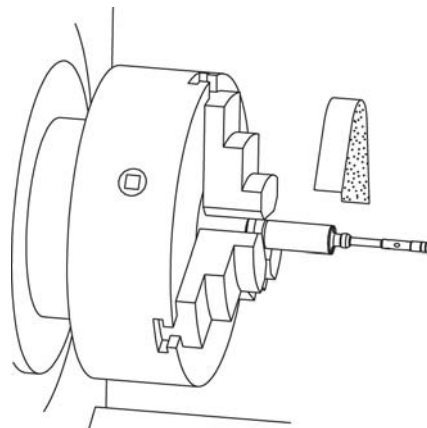


4265-0301-0001O05

5. Preparation for polishing

Remove any deposits or very fine scratches by placing the spindle, thrust piece or spindle guide respectively in a lathe, as shown, and polishing with a very fine conventional polishing linen 'grade 360'.

Use also a little oil for the polishing (a coarser polishing linen must absolutely not be used).



4265-0301-0001O06

NOTICE

The sliding surface of the cut-off slide may only be polished very carefully. The sliding surface must not be damaged.

After polishing, clean the parts again and re-check the seat on thrust piece/spindle, the seat on slide valve/spindle, and the seat on spindle/guide. Use an inspection lamp and an 8-10 times enlargement magnifying glass.

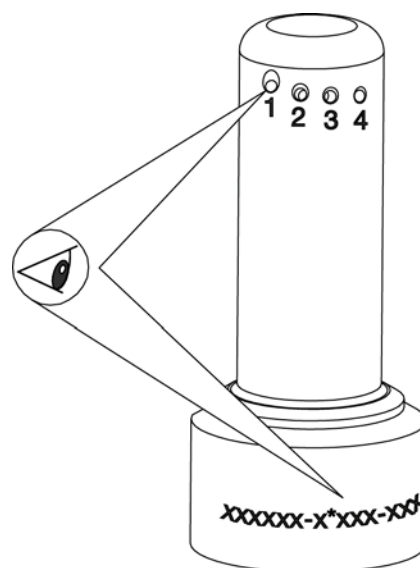
If the seats are not in order, i.e. if there are pressing-in marks or similar on the seats, the complete spindle guide must be discarded.

6. Fuel nozzle cleaning Clean any carbon deposits from the central bore of the fuel nozzle by means of the special brass brush. Clean the fuel nozzle with gas oil and wipe dry with a clean cloth.



4265-0301-0001007

7. Find the correct matching test pin in the data sheet table Read the nominal hole size on the cylindrical part of the nozzle, as shown in the figure. The hole size is given in 1/100 mm. Depending on the engine model, there can be one or more different sizes of the holes. Find the correct drill size and matching test pin in the table, *T42-15, in data*, via the nominal hole size.



4265-0301-0001008

8. Spray holes

Clean the spray holes, using gas oil and the special drills supplied.

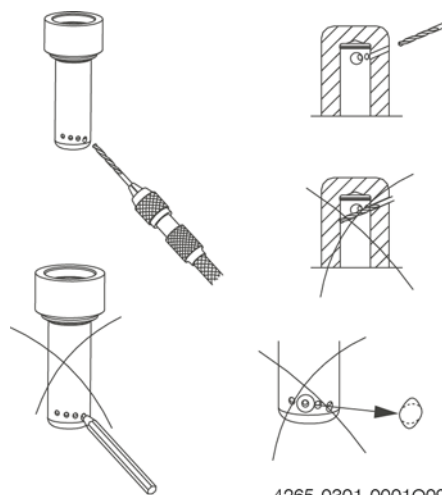
NOTICE

During this operation be very careful not to push the drill too far to avoid scratching the snug-fit surface on the inside of the fuel nozzle.

Then test the spray holes with the test pin. If the test pin is able to enter just one of the holes, the fuel nozzle must be discarded.

This also applies to nozzles with oval holes (can be ascertained with a magnifying glass).

Check the fuel nozzle before mounting on the spindle guide, the cut-off slide must be able to move freely inside the nozzle.



4265-0301-0001009

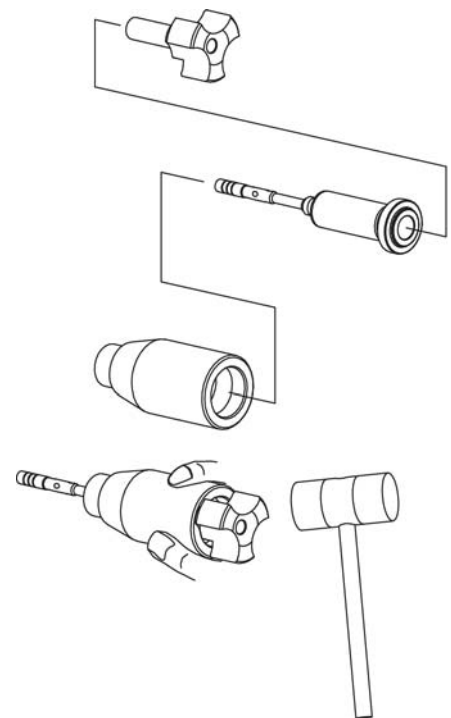
NOTICE

It is recommended that the fuel nozzle is changed whenever the spindle guide is being overhauled or at the maximum running hours
See checking and maintenance schedule 0760-0301.

9. Spindle and the thrust piece

Lubricate the spindle and the thrust piece with the cut-off slide with a little Molybdenum Disulphide (MoS_2).

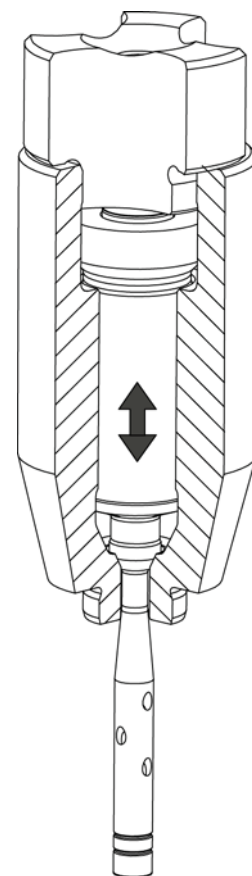
10. Thrust piece, spindle and the spindle guide Assemble the thrust piece, the spindle and the spindle guide and carefully knock the parts together using a soft hammer.



4265-0301-0001O11

11. Free spindle movement

Shake the spindle guide back and forth. The spindle with the cut-off slide must be able to slide freely back and forth inside the spindle guide, with a "clicking" sound.



4265-0301-0001O12

12. Mounting of nozzle

Lubricate the sliding surfaces of the nozzle and the spindle with a little Molybdenum Disulphide (MoS_2).

Mount the nozzle on the spindle guide.

Place the parts on the plane of a drilling machine or hydraulic press and position the mounting tool over the parts. Make sure that all the parts are perfectly aligned. Press the nozzle on to the spindle guide.

NOTICE

The mounting tools are not standard for all engines but may be delivered as optional extras.

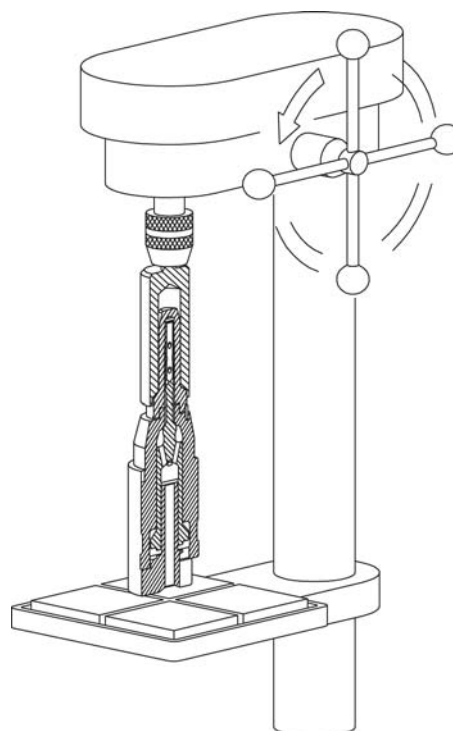
If no mounting tools are available, the nozzle can be mounted on the spindle guide using a short piece of pipe.

Place the pipe around the nozzle, so that the lower end of the pipe rests on the "foot" of the fuel nozzle. Then press the parts together the same way as when using the mounting tools.

Check that the spindle inside the spindle guide is able to move freely.
See overhaul procedure, step 11.

13. Remember!

If the spindle guide is not to be mounted in a injection valve immediately after the overhaul, cover all openings of the spindle guide with plastic to prevent dirt from entering the spindle guide during storage.



4265-0301-0001O13

Safety**Precautions**

for detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Shut off air supply to exhaust valve - Only with stopped lub. oil pumps
☐	Engage turning gear
☐	Shut off cooling water
☐	Shut off fuel oil
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

Data

Ref.	Description	Value	Unit
-	Table is empty on purpose. No Data needed.	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

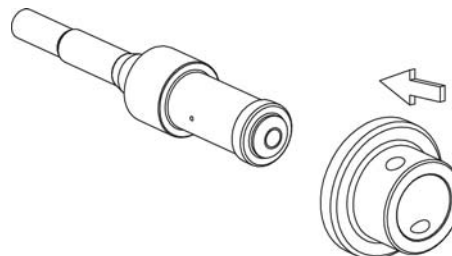
Plate	Item No.	Description
4270-0010	154	Flange for dismantling non-return valve
4270-0230	-	Fuel oil injection valve, inspection tool

NOTICE

Extreme care and accuracy should be exercised when carrying out this operation.

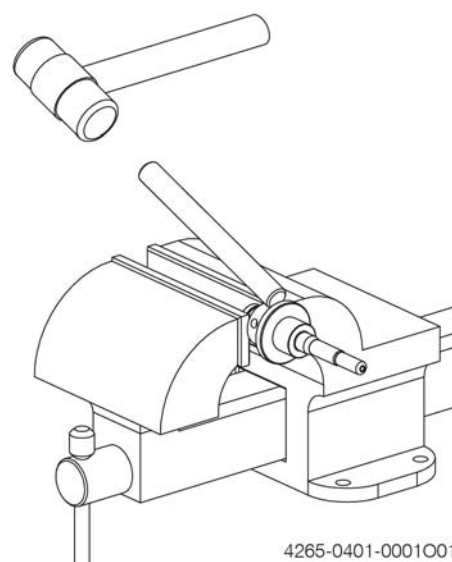
1. Cleaning "outside"

Clean the outside of the non-return valve with pure gas oil. The individual parts are not interchangeable, therefore only one guide is to be disassembled at a time.

**NOTICE**

Except for the slide valve spring, defective parts cannot be replaced individually by new ones.

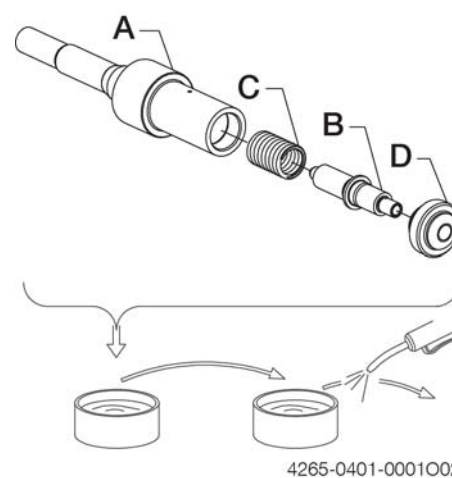
Place the non-return valve as shown in a bench vice provided with "soft" jaws, and disassemble the non-return valve, using the disassembling tool and a hammer.



2. Cleaning "inside"

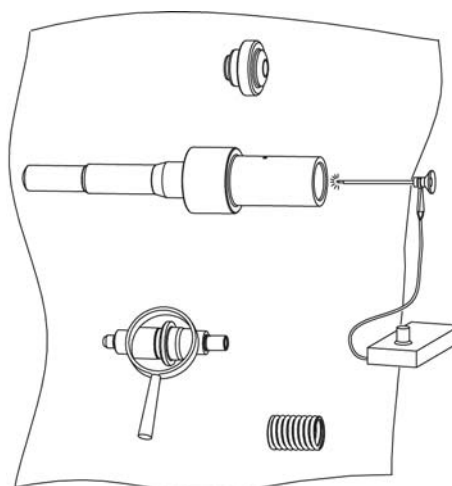
Clean all the parts for the spindle guide in gas oil and wipe them dry with a clean piece of cloth.

Finally, clean in either gas oil, kerosene or 'Electrocleaner', and wipe the parts dry with a clean piece of cloth.



3. Inspection after cleaning

Now place the parts on clean, lint-free rags and examine with an 8-10 times enlargement magnifying glass, and an inspection lamp with magnifying glass as shown on the sketch.



4265-0401-0001003

4. Examine movable parts for coating

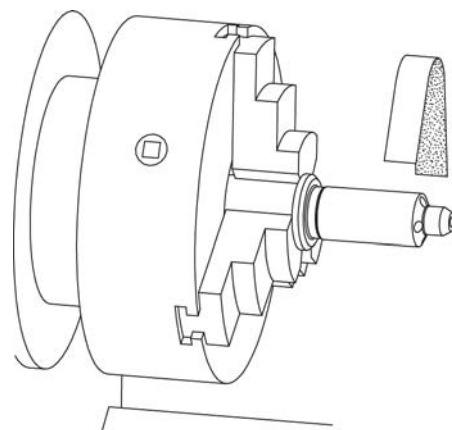
Examine the slide faces of movable parts for coating.

Vent slide **B**/housing **A** will be too tight if there is a coating.

The letters A-D refer to the letters/parts in step 2.

Fix vent slide **B** and, subsequently, housing **A** in a lathe as shown and remove the coating by means of very fine conventional polishing linen 'grade 360'.

Also a little oil should be used (a coarser polishing linen must absolutely not be used).



4265-0401-0001004

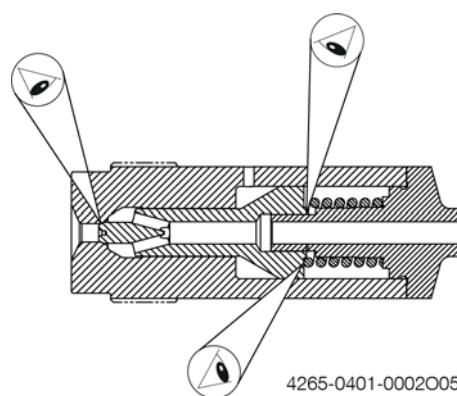
5. Back to cleaning "inside"

Check spring **C** for the thrust piece for outside wear marks. If defective, it should be exchanged.

Check the seat on thrust piece **D**/vent slide, and the seat on vent slide/housing. Use an inspection lamp and an 8-10 times enlargement magnifying glass.

Check that the circulation oil hole is clean.

If the seats are not in order, i.e. if there are pressing-in marks or similar on the seats, the complete spindle guide must be discarded.



4265-0401-0002005

6. Mount the non-return valve as follow

Lubricate all movable parts with molybdenum disulphide (MoS_2).

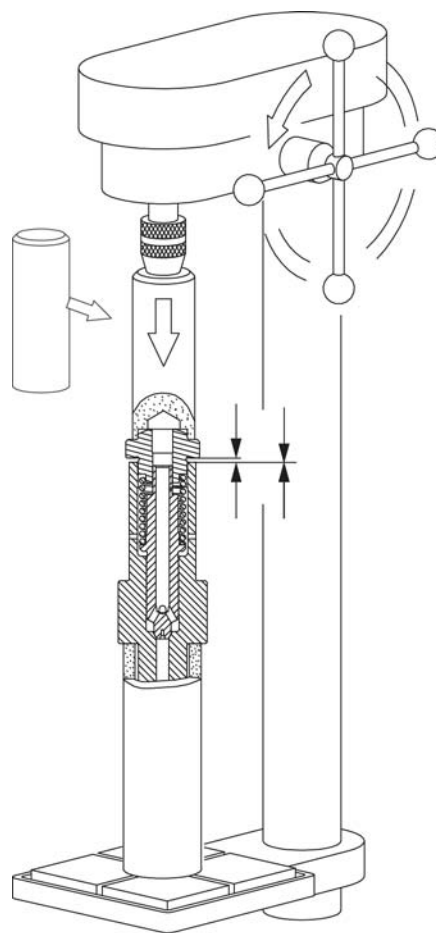
Place the loosely-assembled non-return valve on the plane of a drilling machine, with the tool positioned as shown. Use a short piece of pipe to place the valve in.

Make sure that the thrust piece and the other parts are perfectly aligned and that the thrust piece is guided in the vent slide.

Press the handle until the housing and thrust piece meet.

NOTICE

If the non-return valve is not to be mounted in a injection valve immediately after the overhaul, cover all openings of the non-return valve with plastic to prevent dirt from entering the valve during storage.



4265-0401-0001006

Safety Precautions

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Engage turning gear
○	Shut off fuel oil
○	Stop lubricating oil supply
○	Shut down hydraulic power supply



Data

Ref.	Description	Value	Unit
T42-21	Booster complete	250	kg
T42-22	Booster housing	100	kg
T42-23	Hydraulic plunger	20	kg
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
4270-0010	071	Lifting tool for fuel pump housing
4270-0010	369	Lifting tool for hydraulic plunger
7670-0200	-	Torque spanners

NOTICE

Ensure that the area around the workplace is clean before and during any dismantling of the fuel oil pressure booster.

! WARNING**Pressurised system**

Ensure that the hydraulic cylinder unit is depressurised, that the fuel oil inlet valve is closed and that the fuel oil drain valve is open before dismantling any pipes.

1. Preparations

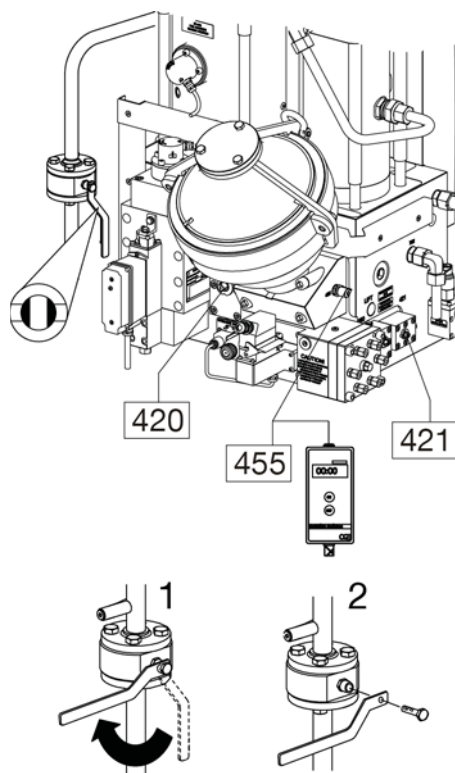
Depressurise the hydraulic cylinder unit.
See work card 4565-0501.

Close the fuel oil inlet valve.

NOTICE**For safety reasons**

Remove the fuel oil inlet valve handle

Open the fuel oil drain.



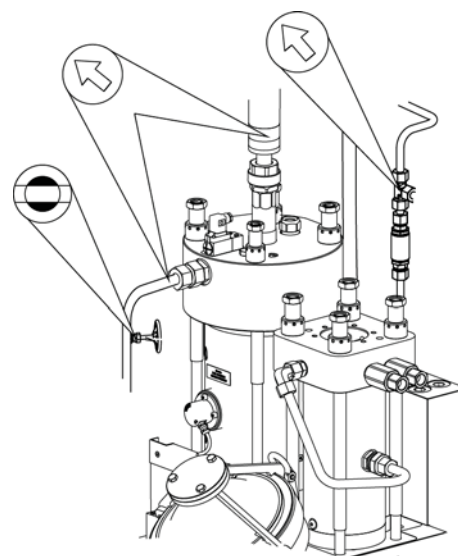
4265-0701-0009D01

2. Remove pipes

Remove the fuel oil high pressure pipes.
See work card 4265-0101.

Remove the fuel oil inlet pipe.

Remove all drain pipes connected to the fuel oil pressure booster.

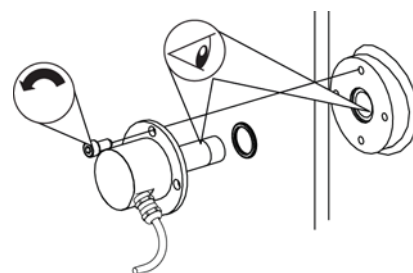


4265-0601-0012D02

3. Remove the inductive sensor

Loosen the screws and remove the inductive sensor.

Clean the inductive sensor and inspect it for damages.



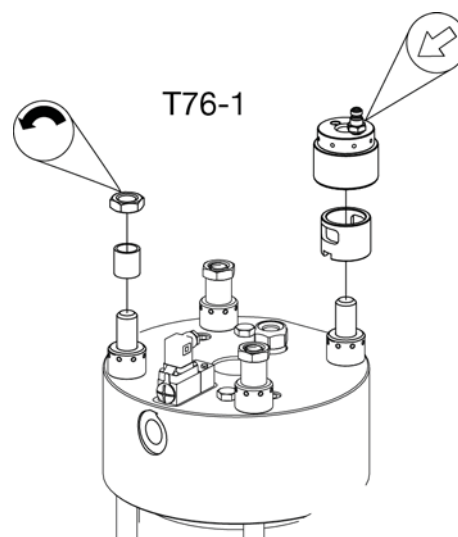
4265-0501-0003D06

4. Loosen the nuts hydraulically

Remove the nuts and pipes protecting the threads.

Loosen and remove the nuts, using the hydraulic jacks.

For use of hydraulic tools, see work card 7665-0101.



4265-0601-0012D03

5. Remove the fuel oil pressure booster

Mount the lifting tool on top of the fuel oil pressure booster.

See work card 4265-0601.

Carefully lift the fuel oil pressure booster clear of the hydraulic block and the fuel oil pressure booster studs.

Cover the hole in the hydraulic block, to keep the hydraulic high pressure system clean.

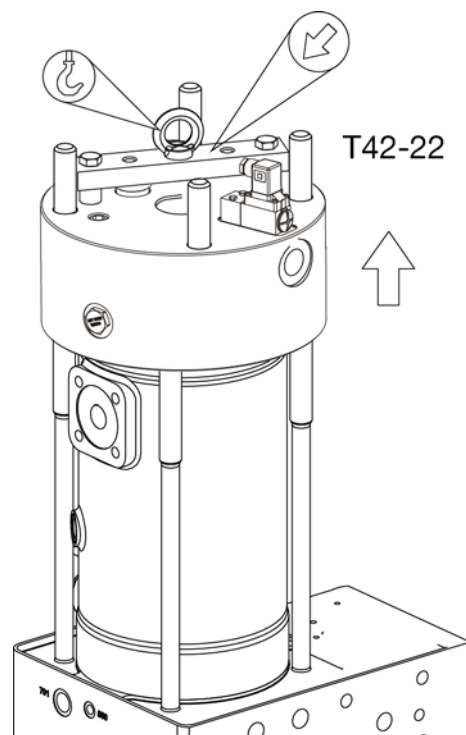


WARNING

Safe working load (SWL)

Always use lifting gear with sufficient SWL.

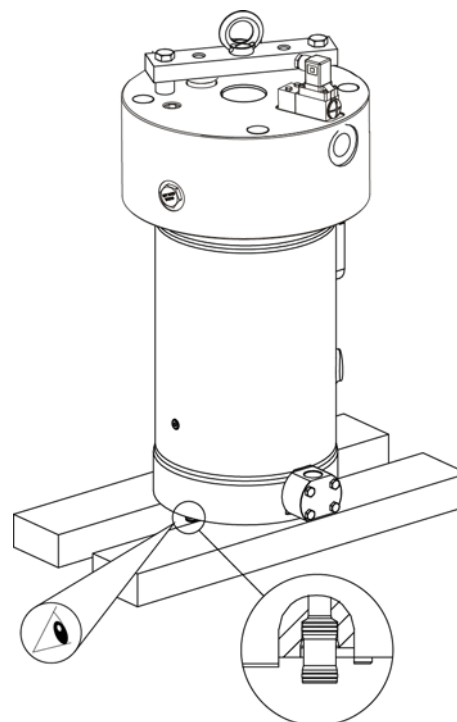
See data.



4265-0501-0013D04

6. Remember!

Land the fuel oil pressure booster on a wooden support and take care not to damage the drain oil bushing.

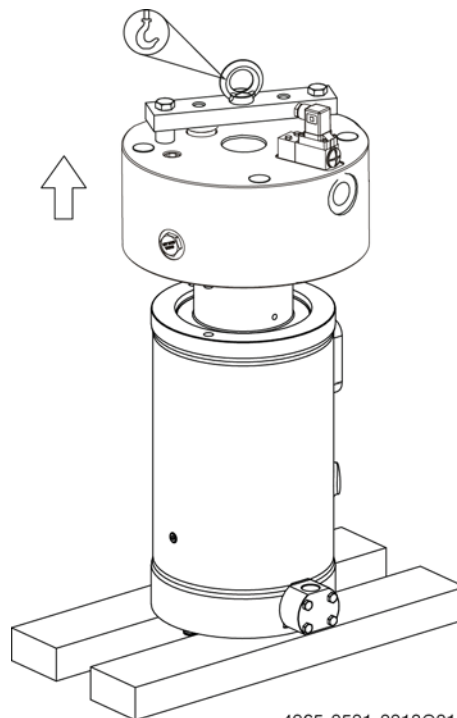


4265-0501-0013D05

1. Booster top cover

Place the fuel oil pressure booster on a wooden support.

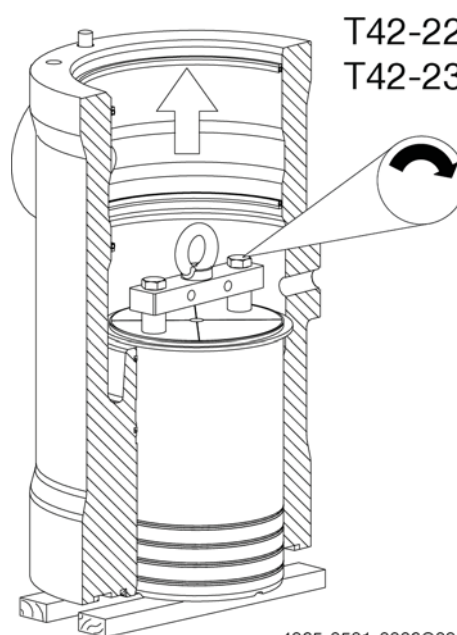
Remove the booster top cover.
See work card 4265-0601.



4265-0501-0013O01

2. Lift up the plunger

Mount the lifting tool on top of the hydraulic plunger.

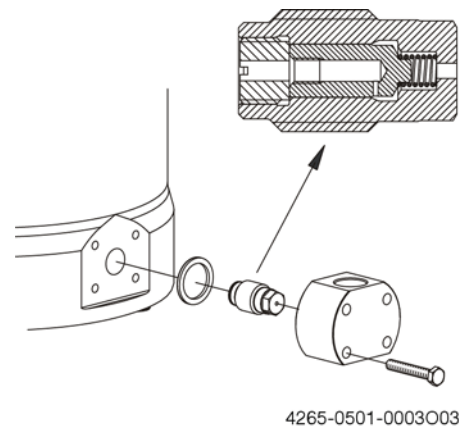


4265-0501-0006O02

3. Throttle valve

Unscrew the flange for the throttle valve.

Unscrew and remove the throttle valve, clean the valve in gas oil and blow through with compressed air.



4265-0501-0003O03

4. Booster housing

Clean the booster housing and the hydraulic plunger with kerosene or gas oil.

Place the booster housing on one side.

Remove the two sealing rings from the cylindrical part of the booster housing and the sealing ring from the bottom.

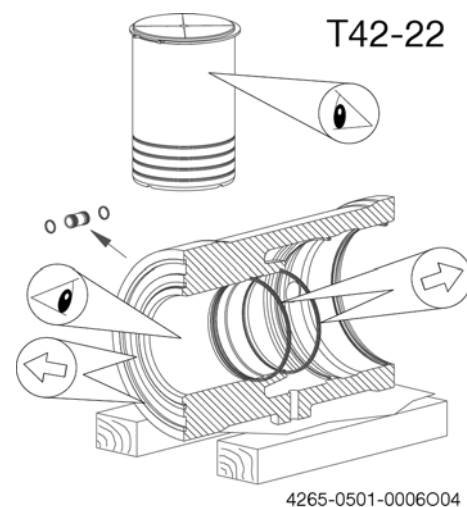
Discard the sealing rings.

Carefully clean the bottom of the booster housing.

Inspect the hydraulic cylinder surface and the hydraulic plunger for wear and seizures.

Pull out the drain oil bushing and discard the two sealing rings. Clean the hole and the bushing.

Mount the bushing with new sealing rings.

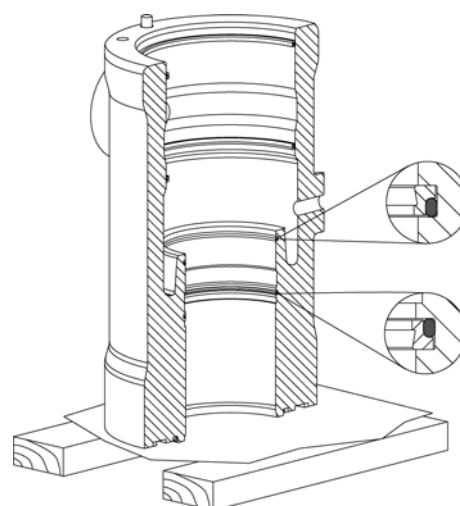


4265-0501-0006O04

5. Sealing rings

Mount new sealing rings in the hydraulic cylinder.

Turn the booster housing to an upright position and place it on a clean piece of oil paper.



4265-0501-0006005

6. Mount the hydraulic plunger

Lubricate the cylinder (lower part) and the hydraulic plunger with molybdenum disulfide grease.

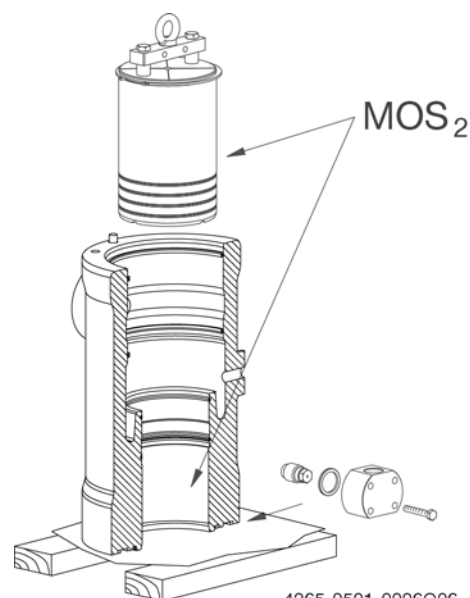
Mount the hydraulic plunger.

Apply preservation oil to the remaining internal surfaces to prevent corrosion.

NOTICE

All parts of the hydraulic system must be kept absolutely clean and free of impurities.

In this case, pay particular attention to the hydraulic plunger and the lower part of the booster housing.



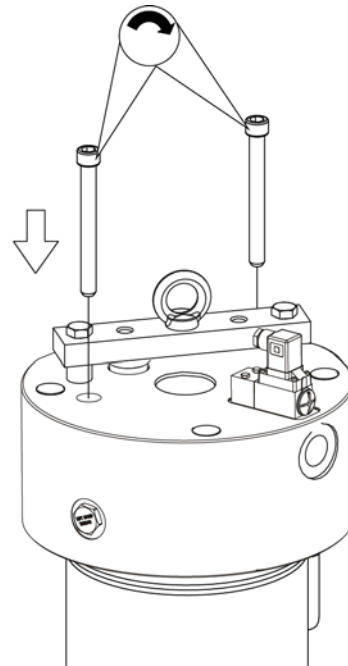
4265-0501-0006006

Mount the throttle valve with a new disc.

Mount the throttle valve cover with a new seal.

7. Booster cover

Mount the booster top cover and tighten the top cover screws.
See work card 4265-0601.



4265-0501-0013O07

8. Storage

If the booster is stored before use, apply preservation oil to all machined surfaces to prevent corrosion and cover all openings with plastic plugs.

NOTICE

Ensure that the area around the workplace is clean before and during assembly of the hydraulic system.

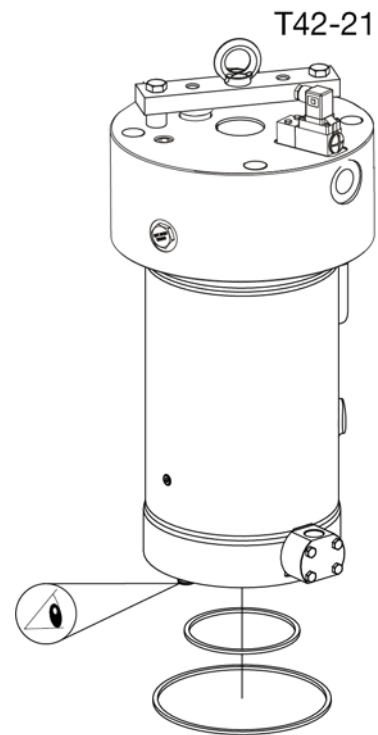
1. Preparing for mounting

If the fuel oil pressure booster has been preserved for storage, remove all preservation and plastic covers.

Mount the lifting tool on top of the fuel oil pressure booster.

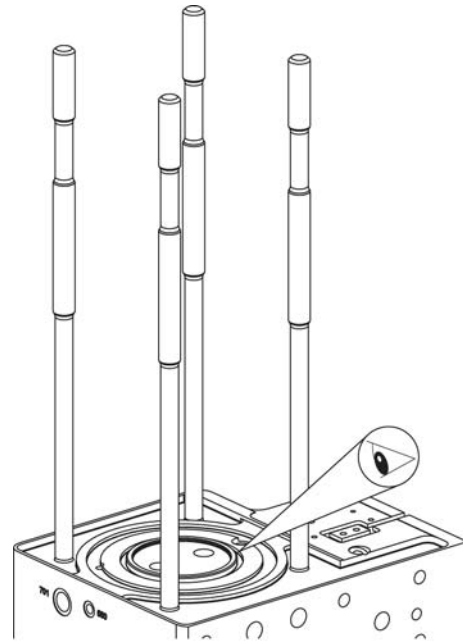
Lift up the fuel oil pressure booster, and check if the bottom surface is clean and free of impurities.

Mount new sealing rings if not already done.



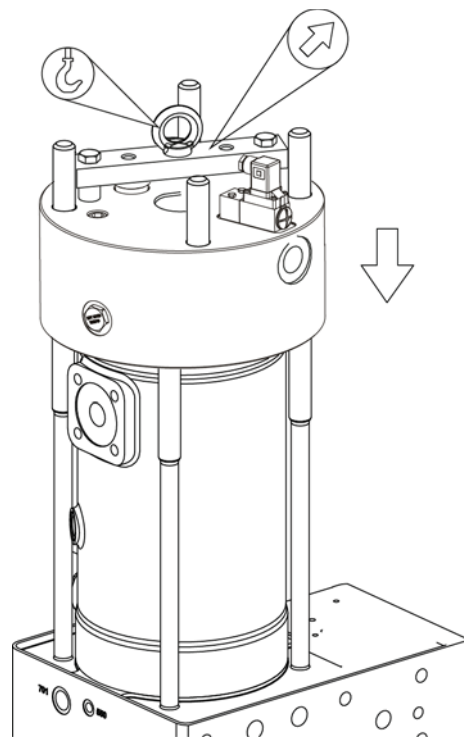
4265-0501-0013M01

2. Check the hydraulic block face Check that the face on the hydraulic block is completely clean.



4265-0501-0012M02

3. Carefully Land the fuel oil pressure booster on the hydraulic block.
Remove the lifting tool.



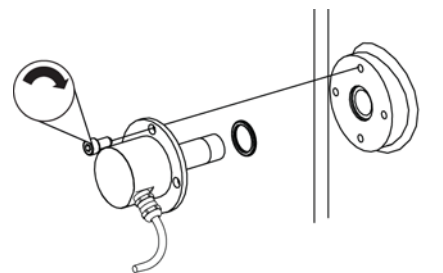
4265-0501-0013M03

4. Mount the inductive sensor

Clean the inductive sensor and mount a new O-ring.

Apply protective oil to the part of the sensor that goes into the pressure booster.

Mount the inductive sensor and tighten the screws.

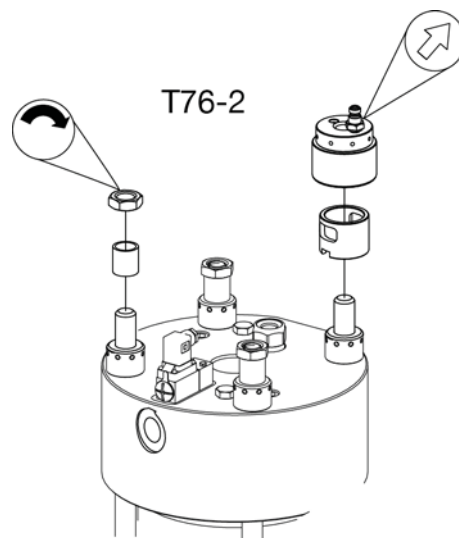


4265-0501-0003M07

5. Tighten the nuts

Tighten the nuts hydraulically.

For use of hydraulic tools, see work card 7665-0101.



4265-0501-0013M04

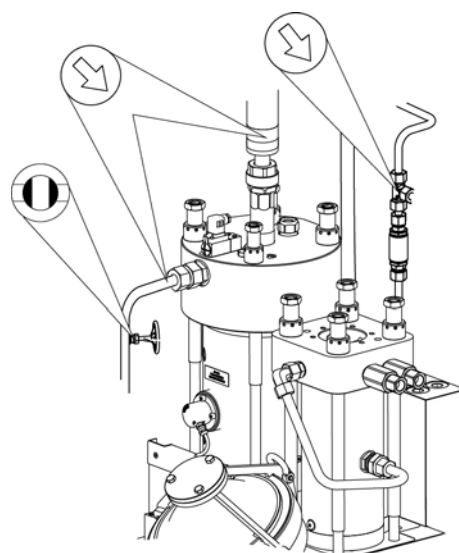
6. Connect drain pipes

Connect and tighten all drain pipes to the fuel oil pressure booster.

Connect the fuel oil inlet pipe.

Connect the fuel oil high pressure pipes.
See work card 4265-0101.

Close the fuel oil drain valve.



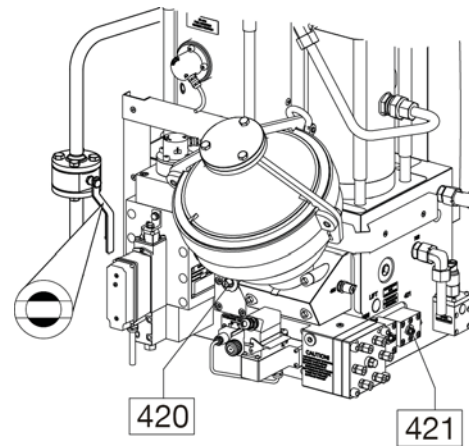
4265-0601-0012M05

7. Pressurise

Pressurise the hydraulic cylinder unit.
See work card 4565-0501.

Close the fuel oil drain.

Mount the handle on the fuel inlet valve
and open the valve.



4265-0701-0009M03

Safety**Precautions**

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Engage turning gear
○	Shut off fuel oil
○	Stop lubricating oil supply
○	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T42-28	Fuel outlet seat, max.grinding diameter	30	mm
T42-29	Booster top cover	130	kg
T42-30	Fuel plunger	10	kg
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
4270-0010	071	Lifting tool for fuel pump housing
4270-0010	095	Milling tool for fuel oil pipe seat
4270-0010	321	Locking device
4270-0900	-	Mounting tools - top cover seals
7670-0200	-	Torque spanners
7670-0410	066	Slide caliper

NOTICE

Ensure that the area around the workplace is clean before and during any dismantling of the fuel oil pressure booster.

**WARNING****Pressurised system**

Ensure that the hydraulic cylinder unit is depressurised, that the fuel oil inlet valve is closed and that the fuel oil drain valve is open before dismantling any pipes.

1. Preparations

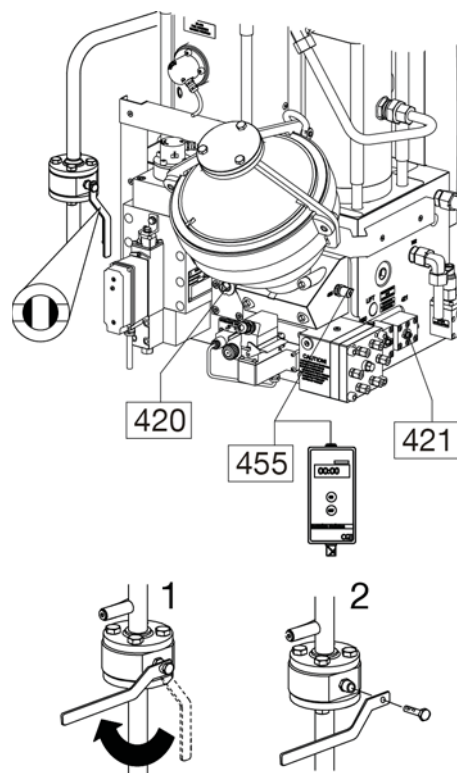
Depressurise the hydraulic cylinder unit.
See work card 4565-0501.

Close the fuel oil inlet valve.

NOTICE**For safety reasons**

Remove the fuel oil inlet valve handle

Open the fuel oil drain.



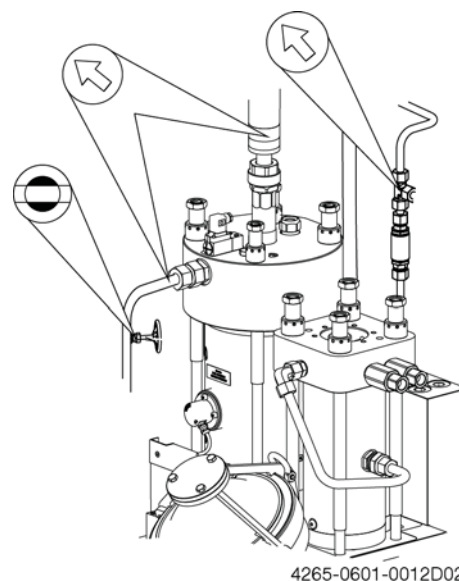
4265-0701-0009D01

2. Remove pipes

Remove the fuel oil high pressure pipes.
See work card 4265-0101.

Drain the fuel oil pressure booster for oil.

Remove the pipe connected to the fuel oil pressure booster.



4265-0601-0012D02

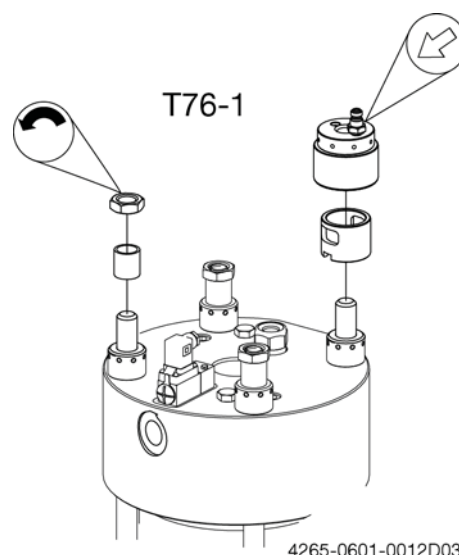
3. Loosen the nuts hydraulically

Mount the spacer rings and the hydraulic jacks over the nuts.

Pump up the hydraulic jacks to the dismantling pressure, as specified *in data*.

Loosen and remove the nuts.

For operation of the hydraulic tools, see work card 7665-0101.

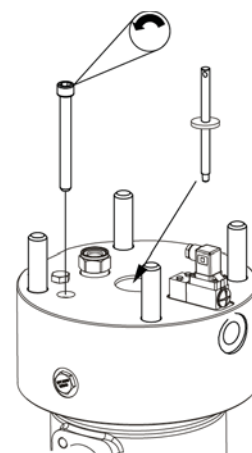


4265-0601-0012D03

4. Centre plug screw

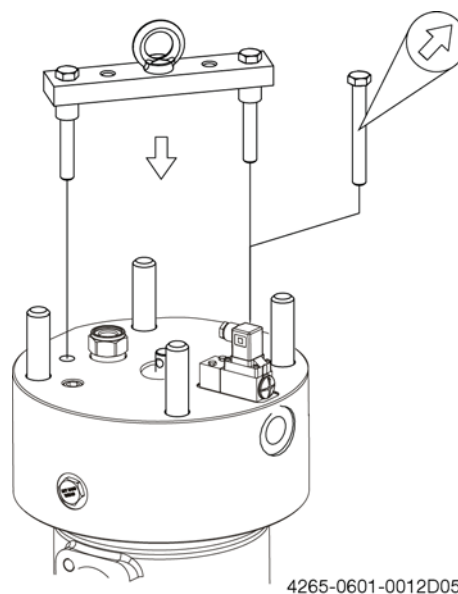
Mount the retaining tool for the fuel plunger.

Remove the two Allen screws.



4265-0601-0012D04

5. Mount the lifting tool Remove the two hexagon head screws and mount the lifting tool in the holes.



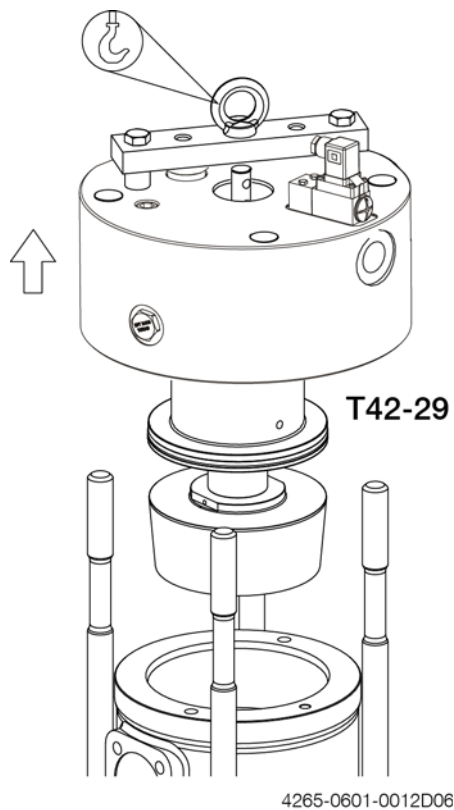
6. Lift the top cover Carefully lift up the top cover assembly, and land it on a wooden support.



WARNING

Safe working load (SWL)

Always use lifting gear with sufficient SWL.
See data.



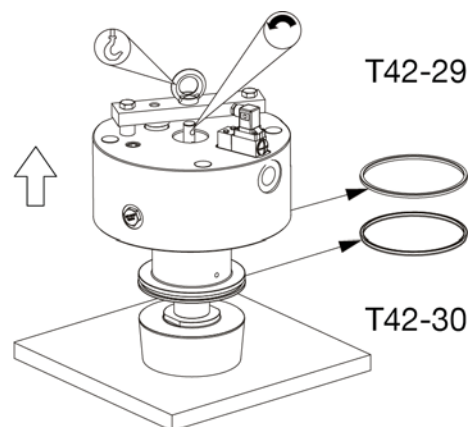
1. Discard the sealing rings

Land the top cover assembly on a wooden support.

Unscrew the retaining tool for the fuel plunger.

Carefully lift the booster top cover clear of the plunger.

Remove and discard the sealing rings.



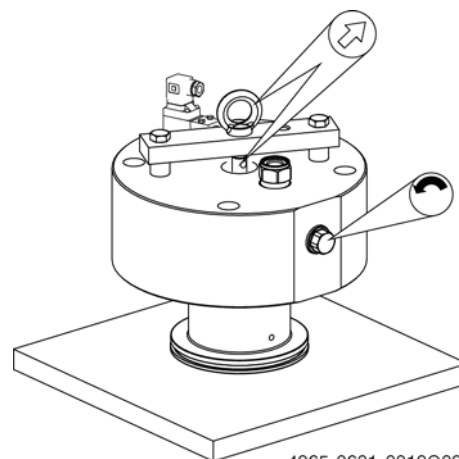
4265-0601-0012O01

2. Remove the suction valve

Remove the lifting tool and the retaining tool from the top cover.

Unscrew and remove the suction valve from the top cover.

See work card 4265-0701.



4265-0601-0012O02

3. Milling / grinding

Carefully clean and examine the top cover.

Reconditioning of the seatings for the high-pressure pipes is carried out by milling according to the following procedure:

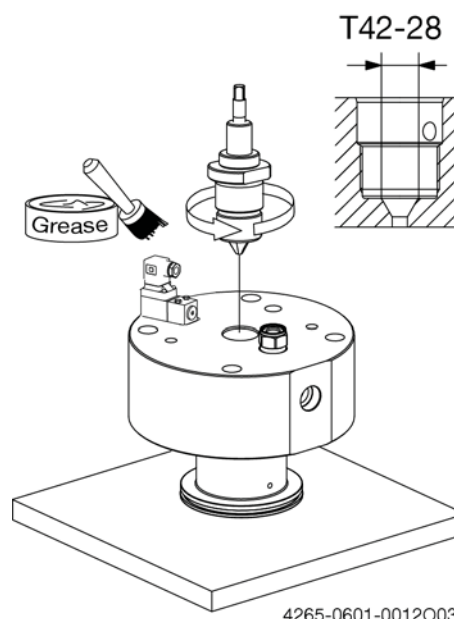
Fill the oil ducts in the top cover with Vaseline or heavy grease.

During the work the milling tool is guided by the guide screwed into the thread for the high-pressure pipe.

Turn the milling tool by means of, e.g. a tap wrench, while tightening the guide screw lightly to provide a suitable pressure between milling tool and seat.

During the milling, add drilling oil emulsion liberally.

For the max. milling/grinding diameter of the seat,
see data T42-28.



4. After completing the milling

Blow out the Vaseline/grease from the oil ducts by means of compressed air.

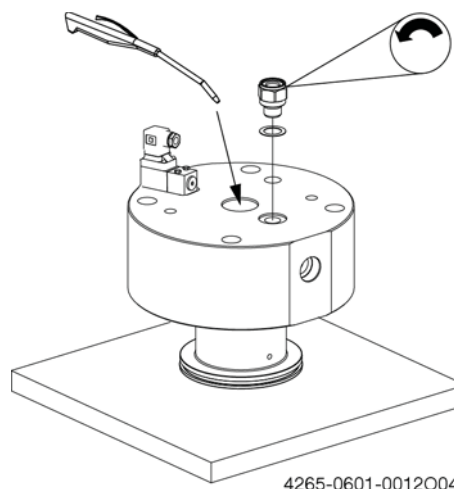


Always use eye protection when working with compressed air.

Clean the top cover with gas oil, and blow dry with compressed air.

Unscrew the orifice plug for return oil.

Clean the plug and remount it.

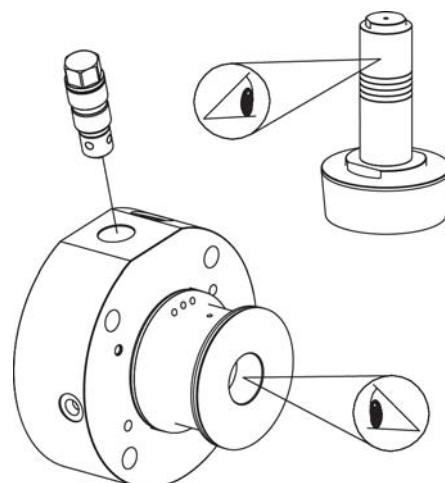


5. Top cover and fuel plunger

Place the top cover on one side and clean the bore for the fuel plunger in clean kerosene. Inspect the bore and plunger.

Mount the suction valve.
See work card 4265-0701.

The top cover and fuel plunger are matched parts and must only be renewed as a set.



4265-0601-0002005

6. Before mounting new sealing rings

Before mounting new sealing rings on the top cover, **heat them to 100°C** for at least five minutes.

**NOTICE**

Ensure not to exceed the maximum allowable temperature.



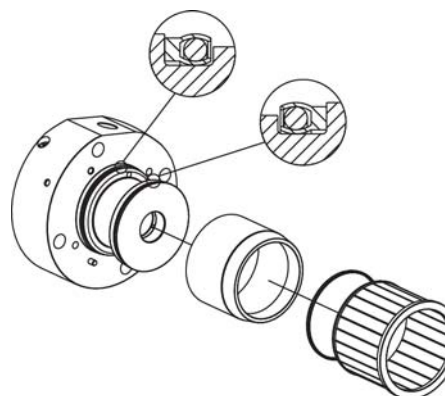
4265-0601-0002006

7. Sealing rings

Mount the sealing rings as shown.

Place the cone on the top cover and mount the uppermost ring first.

Push the sealing ring in place with the pushing tool.



4265-0601-0002007

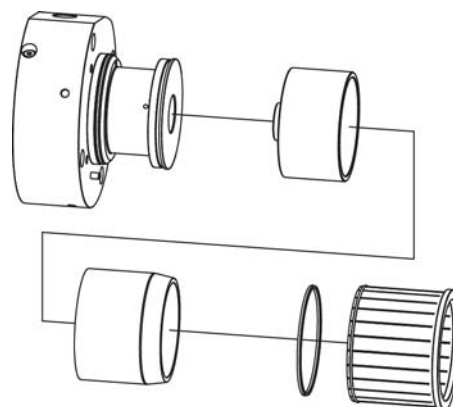
8. How to mount the sealing ring

Remove the cone from the top cover and place the spacer ring tap in the hole for the plunger.

Place the cone on the top cover and on the spacer ring.

Mount the sealing ring in the lowermost groove by use of the pushing tool.

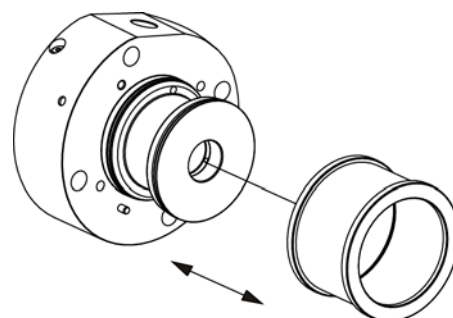
Remove the cone and the spacer ring.



4265-0601-0002008

9. Compress the sealing rings

Compress the sealing rings with the compression tool.



4265-0601-0002009

10. Plunger

Turn the top cover to an upright position.

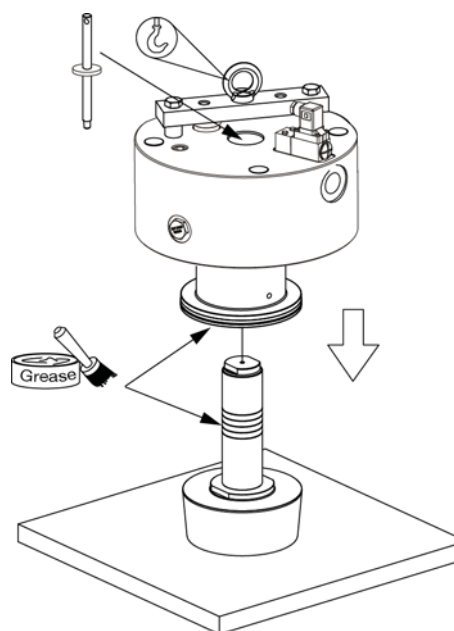
Place the retaining tool for the fuel plunger in the centre hole and mount the lifting tool.

Place the plunger on a plane surface.

Apply a little clean grease to the inner hole in the top cover and a thin layer to the plunger.

Carefully lower the top cover onto the fuel plunger, until the top cover rests on the plunger.

Screw the retaining tool into the fuel plunger, to lock the plunger in position.



4265-0601-0012010

NOTICE

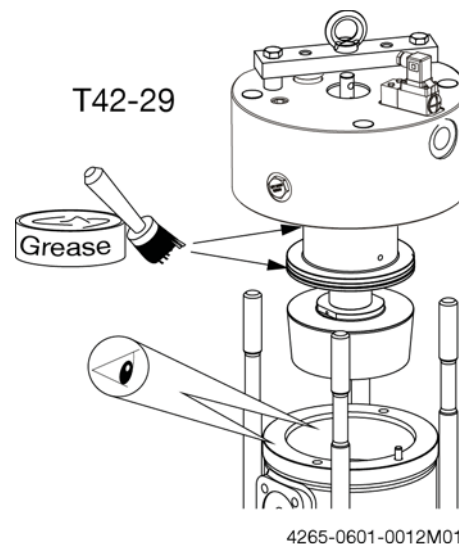
Ensure that the area around the workplace is clean before and during assembly of the hydraulic system.

1. Mounting the top cover

Mount the lifting tool on the new or overhauled top cover assembly.

Lift the top cover assembly and apply grease to the new sealing rings.

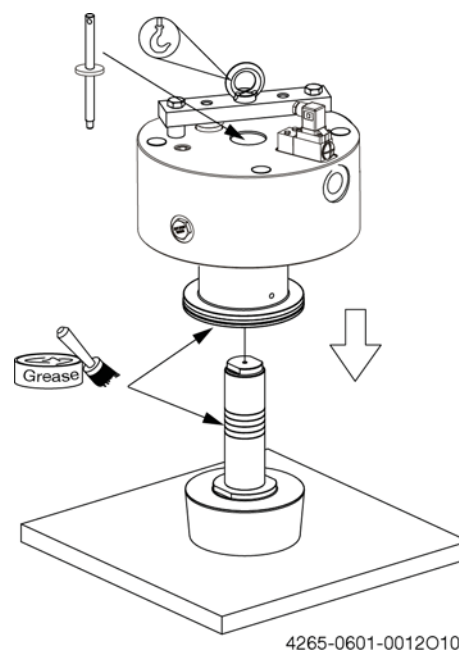
Check that the face on the fuel oil pressure booster housing and the inside cylindrical part are clean and free of fuel oil.



2. Check for a correct positioning

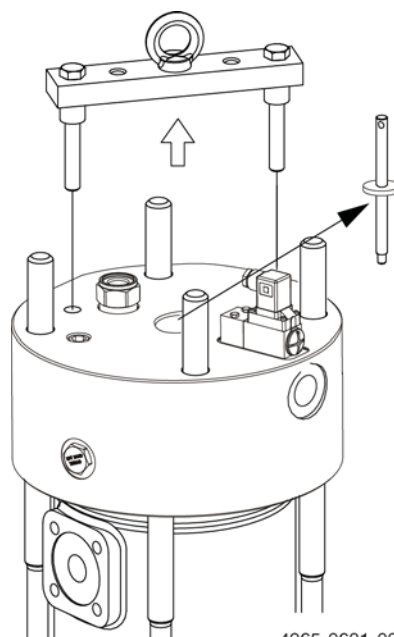
Carefully land the top cover on the fuel oil pressure booster.

Check that the guide pin in the top cover is entering the hole in the fuel oil pressure booster housing for correct positioning.



3. Lifting- and retaining tool Remove the lifting tool from the top cover.

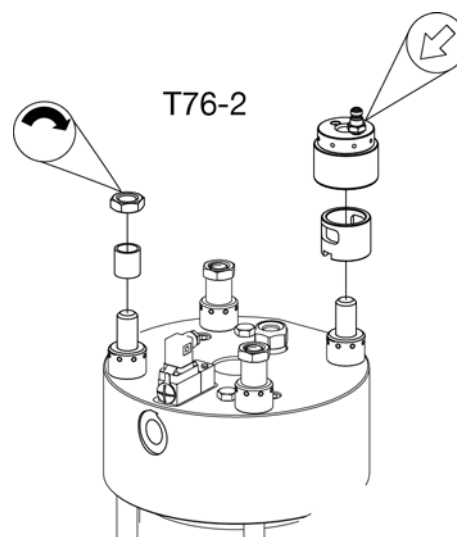
Unscrew and remove the retaining tool for the fuel plunger.



4265-0601-0012M03

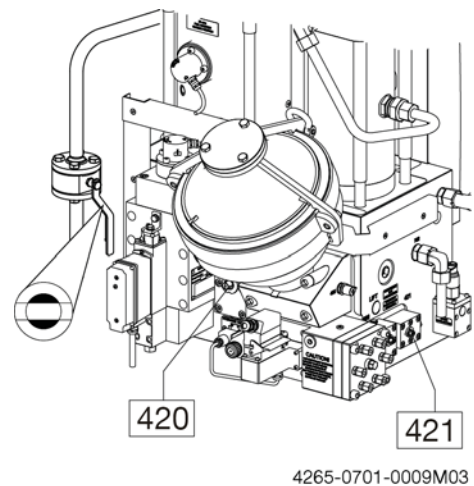
4. Tighten the nuts
- Screw the nuts on to the studs.
- Mount the spacer rings and the hydraulic jacks over the nuts.
- Pump up the jacks to the tightening pressure, as specified *in data*.
- Tighten the nuts, and remove the hydraulic jacks and the spacer rings.

For use of hydraulic tools, see work card 7665-0101.



4265-0601-0012M04

- Mount the handle on the fuel inlet valve and open the valve.



Safety**Precautions**

for detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off safety air supply - Not ME Engines
☐	Shut off control air supply
☐	Engage turning gear
☐	Shut off fuel oil
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T42-33	Fuel suction valve, tightening torque	250	Nm

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
7670-0200	-	Torque spanners

NOTICE

Ensure that the area around the workplace is clean before and during any dismantling of the fuel oil pressure booster.

! WARNING**Pressurised system**

Ensure that the hydraulic cylinder unit is depressurised, that the fuel oil inlet valve is closed and that the fuel oil drain valve is open before dismantling any pipes.

1. Preparations

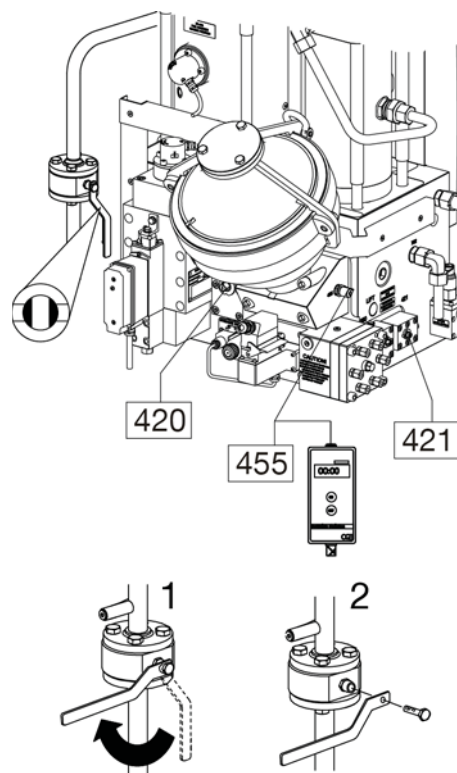
Depressurise the hydraulic cylinder unit.
See work card 4565-0501.

Close the fuel oil inlet valve.

NOTICE**For safety reasons**

Remove the fuel oil inlet valve handle

Open the fuel oil drain.

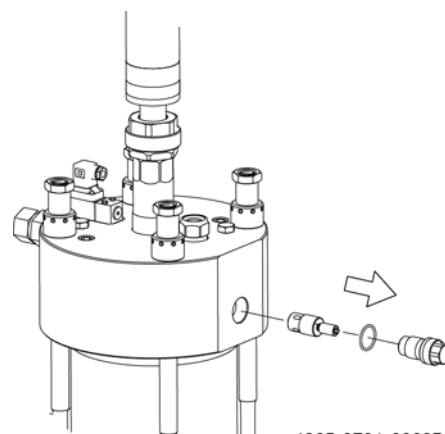


4265-0701-0009D01

2. Unscrew the union nut

Unscrew the union nut for the suction valve, remove and discard the O-ring.

Pull out the suction valve.

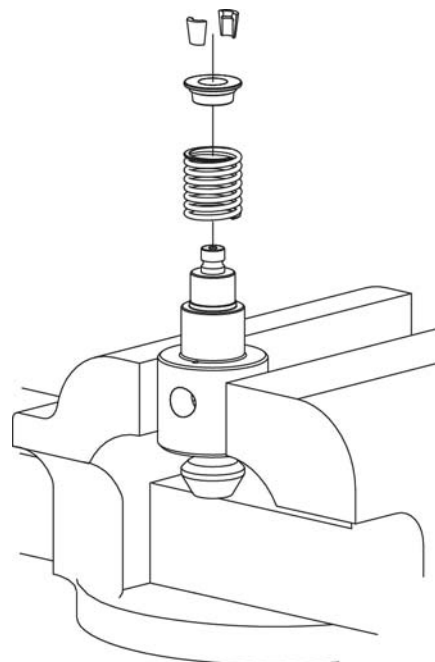


4265-0701-0009D02

1. Clean the fuel suction valve

Set up the fuel suction valve in a bench vice with "soft" jaws and press down the spring by means of the cone to release the valve spindle from the two-part conical ring.

Clean the parts thoroughly in clean diesel oil and carefully dry.



4265-0701-0002O01

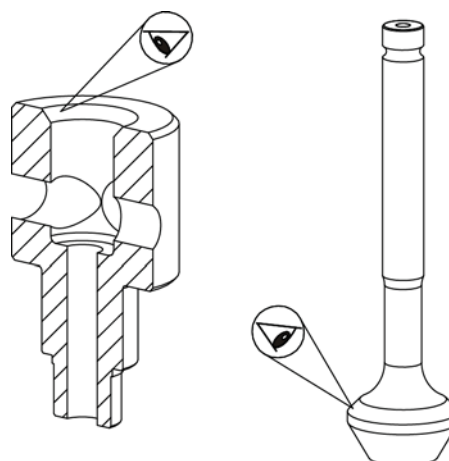
2. The valve spindle

Inspect the seat on the valve spindle and the seat on the valve housing for damage.

If the seats are worn or damaged, a new suction valve must be mounted.

It is not recommended to recondition the valve by lapping.

Lapping will damage the seat geometry and lead to very limited running time for the valve.



4265-0701-0002O02

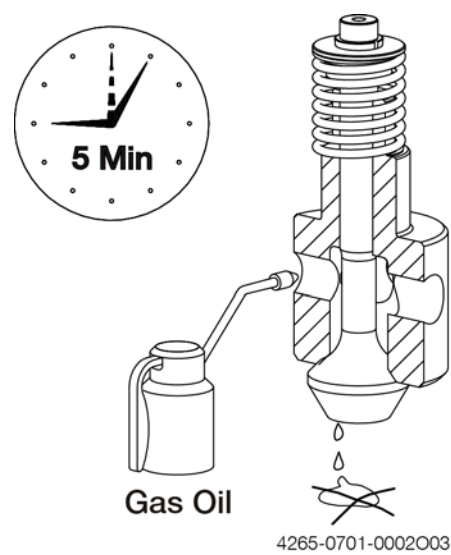
3. After cleaning the valve spindle

After cleaning and inspecting all the parts, lubricate these with molybdenum disulphide (MoS_2) and assemble the suction valve.

Check the seats for tightness by filling the inlet hole with diesel oil and waiting 5 minutes. No oil may pass through the seats.

NOTICE

If the suction valve is not to be mounted on the engine immediately after the overhaul, cover all openings of the valve with plastic to prevent dirt from entering the valve during storage.



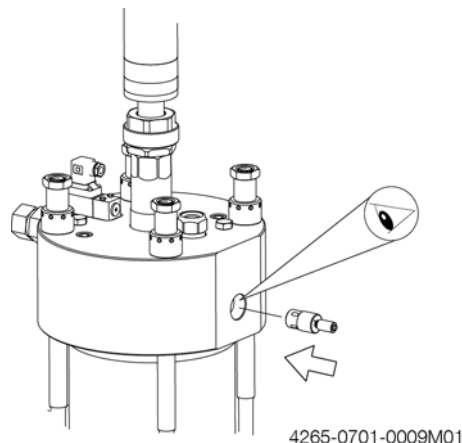
NOTICE

Ensure that the area around the workplace is clean before and during assembly of the hydraulic system.

1. Mount new suction valve

Check that the face for the suction valve is clean.

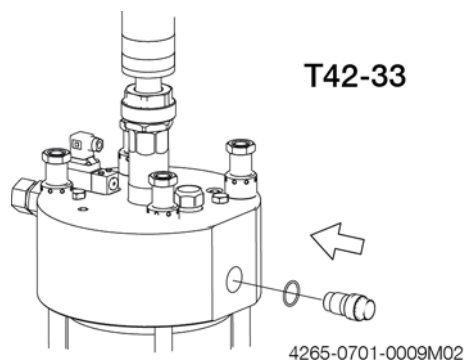
Mount the overhauled or new suction valve.



2. Mount a new O-ring on the union nut

Lubricate the O-ring and the thread on the union nut with molybdenum disulphide (MoS_2) grease.

Mount and tighten the nut to the specified torque.
See data.

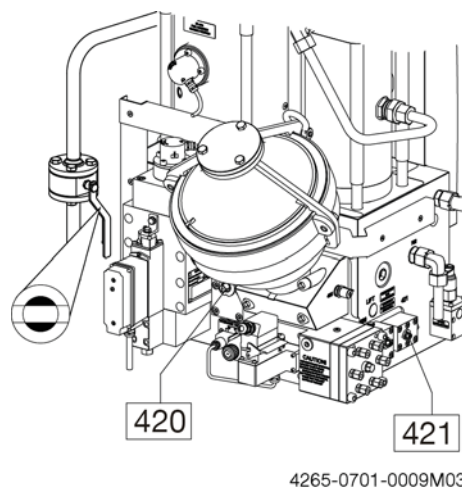


3. Pressurise

Pressurise the hydraulic cylinder unit.
See work card 4565-0501.

Close the fuel oil drain.

Mount the handle on the fuel inlet valve and open the valve.



Safety Precautions

Data

Ref.	Description	Value	Unit
T42-78	Maximum water content fuel oil	1.0	%

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

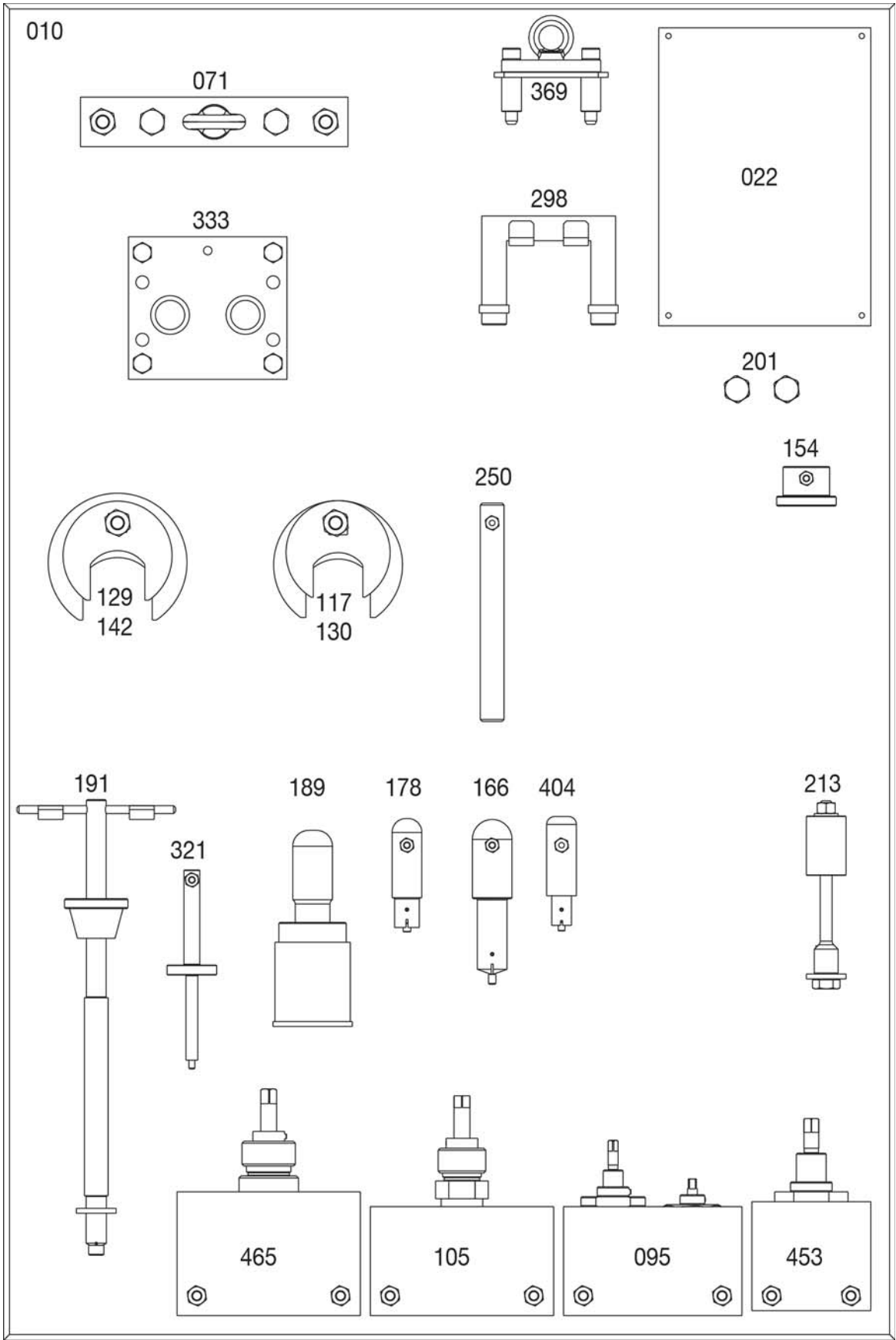
Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.

1. Fuel oil checking

The fuel oil is to be checked for water content weekly.

In addition to this we recommend that samples of each bunker lot and the documents received together with the bunker oil is kept onboard.

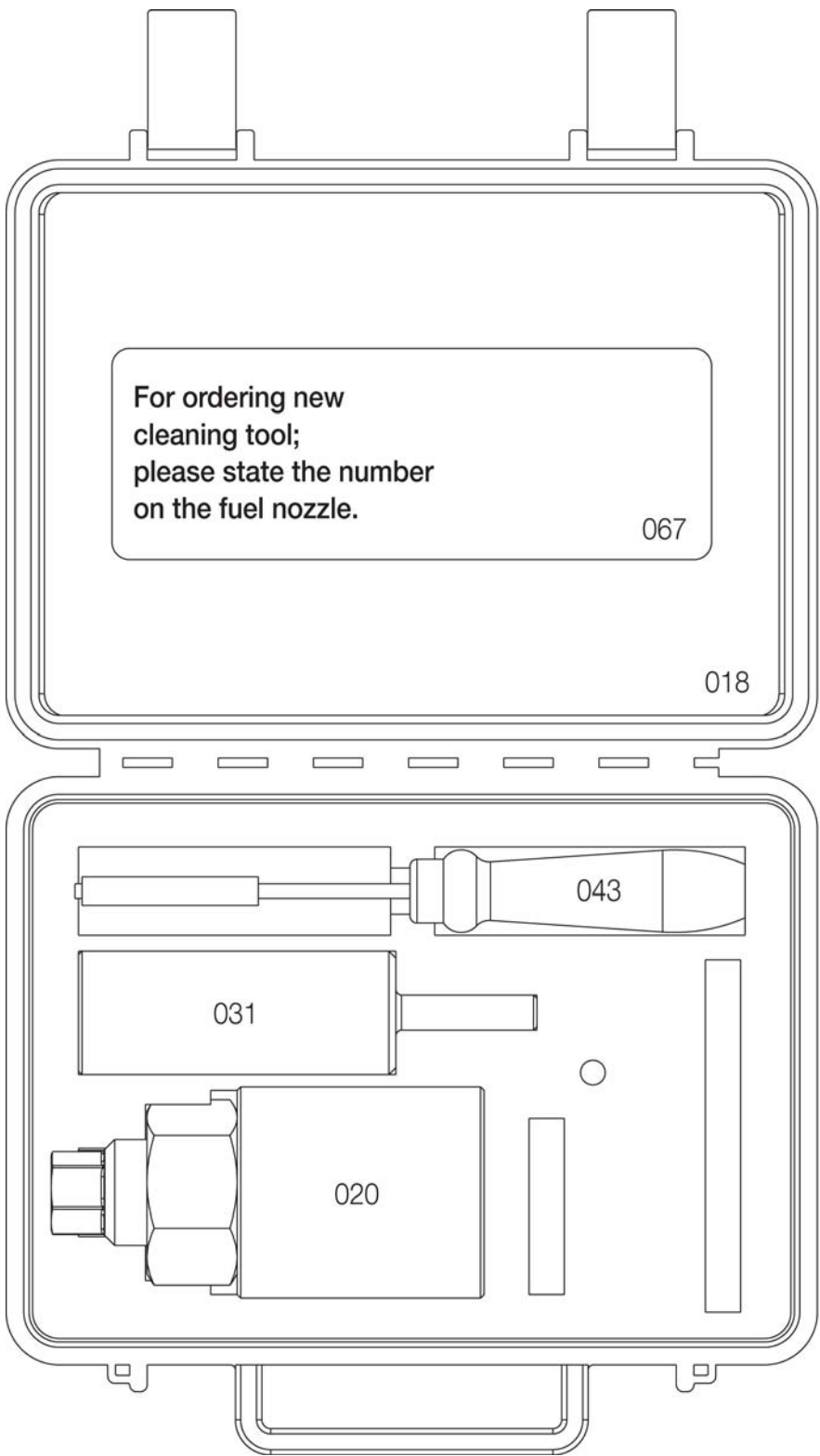
Detailed description of fuel specifications, samples and fuel oil treatment can be seen in *description 4245-0100, Fuel Specification*.



Fuel Oil System Panel Tools

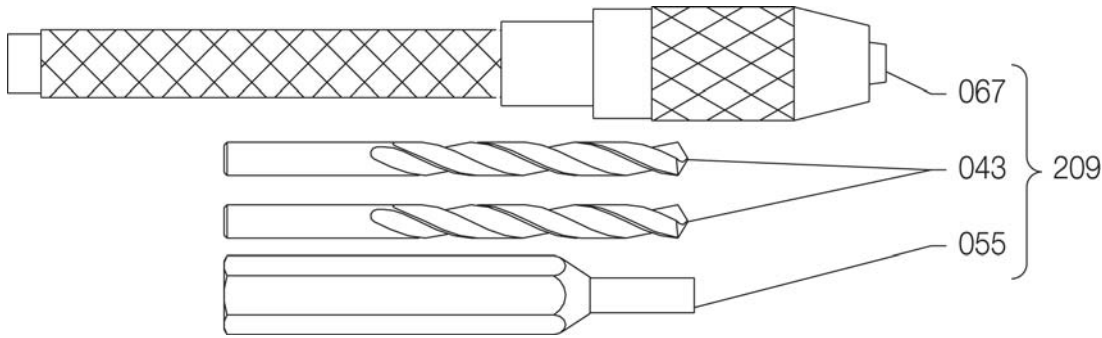
Plate
4270-0010-0045

Item No.	Qty	Item Designation
010	-	Panel for tools
022	-	Name plate
071	-	Lifting tool for fuel pump housing
095	-	Milling tool for fuel oil pipe seat
105	-	Milling tool for fuel oil pipe
117	-	Crowfoot wrench head
129	-	Crowfoot wrench head
130	-	Crowfoot wrench head
142	-	Crowfoot wrench head
154	-	Flange for dismantling non return valve
166	-	Grinding mandrel for valve head
178	-	Grinding mandrel for thrust spindle
189	-	Grinding mandrel for holder, outside
191	-	Grinding mandrel for holder, inside
201	-	Screw
213	-	Extracting tool for suction valve
250	-	Drift for spindle guide
298	-	Assembling tools
321	-	Locking device
333	-	Flushing valve
369	-	Lifting tool for hydraulic plunger
404	-	Grinding mandrel for thrust spindle
453	-	Cutting tool for seat of distributor piece
465	-	Milling tool for fuel oil pipe



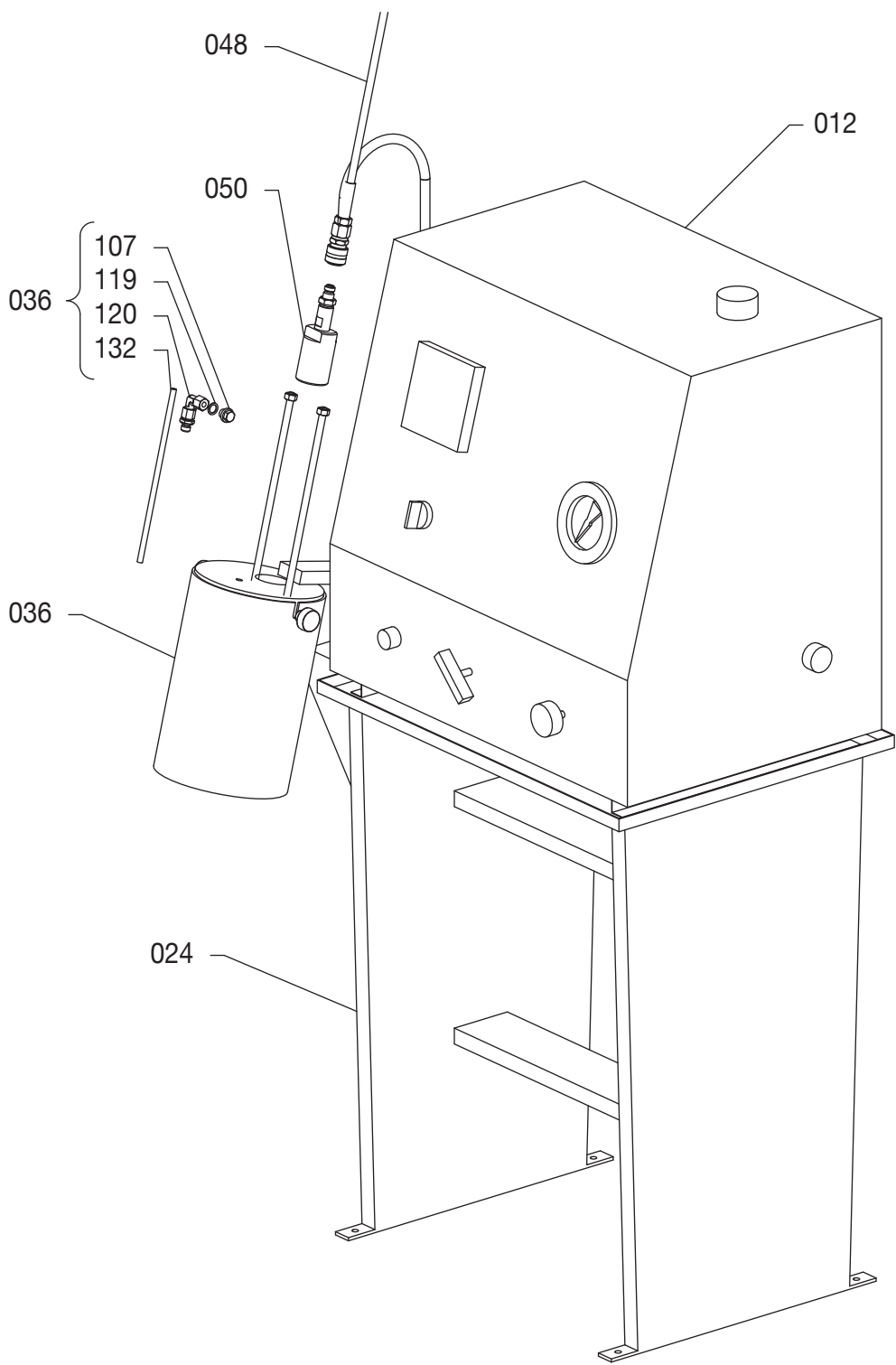
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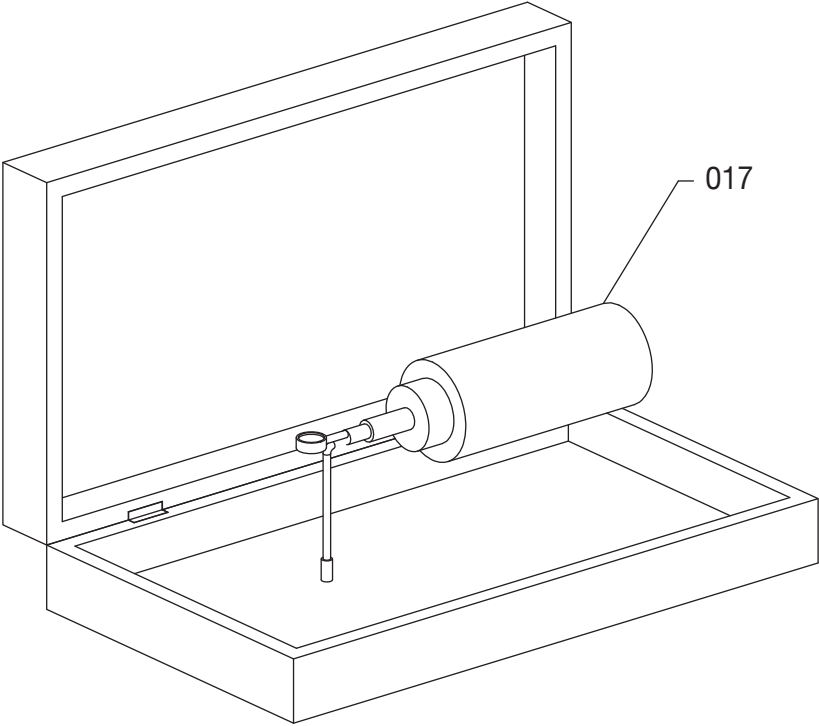


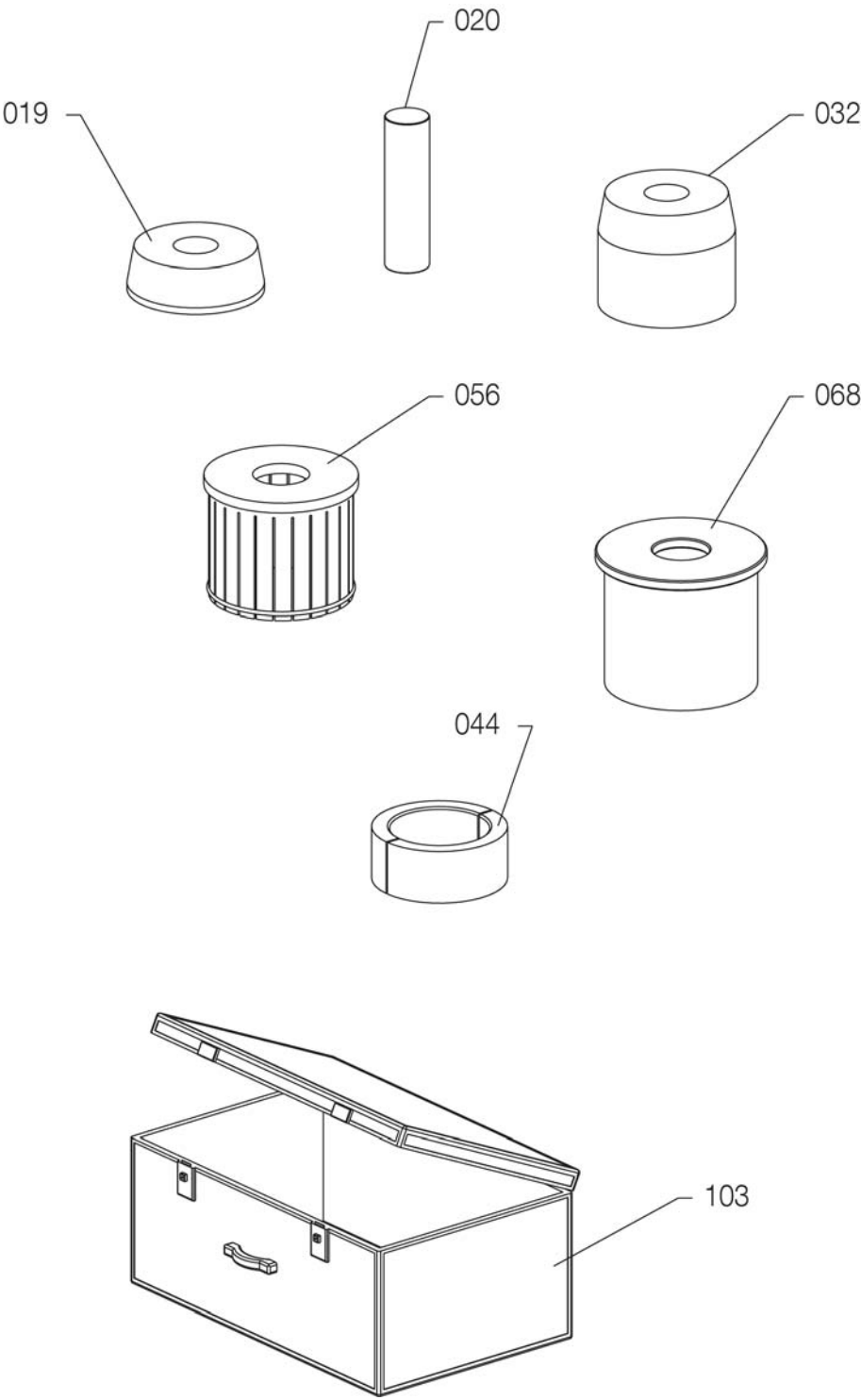
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Preface Chapter	Hydraulics	4540-0100-0002
Description	Hydraulic System for ME Engines	4545-0150-0003
Drawing	EL Driven HPS, FIVA	4555-0125-0001
	EL Driven HPS, FIVA	4555-0125-0002
	Combined HPS, Common LPS, FIVA	4555-0135-0001
	Combined HPS, Separate LPS, FIVA	4555-0140-0001
	Gear Driven HPS, Common LPS ME Engine Version 5, Rexroth Pumps	4555-0146-0003
	Gear Driven HPS, Common LPS ME Engine Version 5, Eaton Pumps	4555-0147-0002
	Detection of Malfunction and Leaks in Hydraulic System	4555-0150-0001
	Throttle Valve on Fuel Oil Pressure Booster	4555-0155-0002
	Level Switch on ME Cylinder Lubricator	4555-0165-0001
	Hydraulic Control Oil System, Separate LPS	4555-0170-0001
	Piping	4555-0171-0002
Work Card	Exhaust Valve Actuator, Data	4565-0100-0011
	Exhaust Valve Actuator	4565-0101-0007
	Hydraulic Oil Pump	4565-0201-0003
	Hydraulic Oil Pump	4565-0201-0005
	Hydraulic System, Data	4565-0300-0005
	Hydraulic System	4565-0301-0016
	Hydraulic Cylinder Unit, Data	4565-0500-0001
	Hydraulic Cylinder Unit	4565-0501-0010
	Accumulators, Data	4565-0550-0004
	Accumulators	4565-0551-0013
	Control Valves, Data	4565-0600-0005
	Control Valves	4565-0601-0010
	Hydraulic Power Supply, Data	4565-1000-0001
	Hydraulic Power Supply	4565-1001-0005
	Hydraulic Power Supply Gearbox, Data	4565-1200-0001
	Hydraulic Power Supply Gearbox	4565-1201-0008
Tool Plate	Equipment for Testing Accumulators	4570-0540-0003
	Accumulator Tools	4570-0550-0004
	Accumulator Tools	4570-0550-0005

Hydraulic Cylinder Unit

HCU

The Hydraulic Cylinder Unit (one per cylinder) consists of a distributor block, the electronically controlled fuel injection system and electronically controlled exhaust valve actuation.

FIVA

The design of the hydraulically-activated valve is similar to that on the MC engines, i.e. the exhaust valve is opened hydraulically and is closed by an 'air spring'. The Fuel Injection and Exhaust Valve Actuation fitted to each HCU consists of the FIVA 'on/off valve' and the two-stage hydraulic exhaust valve activator. The electronic FIVA 'on/off valve' (controlled by the ECS) opens the oil flow to the two-stage hydraulic actuator.

Exhaust Valve Actuator

The exhaust valve is closed by connecting the hydraulic piston to a drain via the FIVA valve and letting the air spring of the exhaust valve drive it to closed position. This movement also drives the pushrod oil back into the exhaust actuator preparing it for the next actuation.

Fuel Oil Pressure Booster

Each engine cylinder is equipped with its own fuel oil pressure booster, which is mounted corresponding to the cylinder concerned on the HCU. The booster housing is attached to the housing by studs and nuts.

Distributor Block

The distributor block serves as a mechanical support for the hydraulically-activated Fuel Oil Pressure Booster and exhaust valve actuator, each with an electronically controlled control valve, the FIVA valve.

The function of the distributor block is, as its name indicates, to distribute the hydraulic oil to the FIVA control valve mounted on the distributor block.

Accumulators

Fitted on the distributor block are hydraulic accumulators precharged with nitrogen. Their function is to ensure that the necessary hydraulic oil peak flow is available for the injection of fuel oil and actuation of the exhaust valve.

Manuel valves

Close to the FIVA valve are two manually operated valves. One valve connects the high-pressure inlet side while the other connects the accumulators to the bedplate (drain).

These manually operated valves are used to isolate individual HCUs during their overhaul. A manually activated valve connects the oil pushrod to its supply. This valve must be closed during overhaul of the exhaust valve.

Oil Filter

The main filter in the hydraulic power system is of the multi-cartridge, self-cleaning type, with automatic backflushing of the cartridges.

The backflushing of each cartridge is carried out with compressed air on a time basis, but is also activated if the pressure drop across the filter exceeds a certain level.

A redundant filter is mounted in parallel with the main filter and is used during overhaul of the main filter. Switching to the redundant filter and back again is done manually without interrupting the oil flow to the pumps.

General

This chapter describes the system layout, components and operating principle of the hydraulic systems shown in Drawing 4555-0125, etc.

All position numbers are described and their intended use is explained.

Also shown is Drawing 4555-0150 used when detection of malfunctions and leaks in the hydraulic system can be useful (this document is general, and position numbers named in this document may not be used on your system).

1 ME Engine Concept and Mechanical Hydraulic System Layout

The ME engine concept primarily concerns the use of a mechanical hydraulic system for actuation of the fuel injection pumps and the exhaust valves, which are electronically controlled by a computer based control system. The starting air system is also controlled electronically by the ME control system.

Introduction of the hydraulic injection and exhaust actuation requires a hydraulic power supply, designed with all the necessary functionality needed. The hydraulic system used on the ME engine is outlined in the related diagrams on Drawing 4555-0125, etc.

With reference to these diagrams, the layout is explained in the following.

Main system lubricating oil is used as the hydraulic medium. The oil is filtered by the filter unit to the appropriate purity for use in an oil hydraulic system. The oil is then pressurised either by the Engine Driven Pumps or the Electrical Driven Pumps, when the engine is rotating, or by the Electrically Driven Pumps, when the engine is at standstill. In the Safety and Accumulator Block, pressurised oil is accumulated to ensure a stable oil supply to the Hydraulic Cylinder Units (HCU).

A HCU is fitted to each cylinder. The HCU comprises a distribution block, carrying the hydraulically activated Fuel Oil Pressure Booster and the exhaust valve actuator. The control valve the FIVA valve, and the necessary accumulators are mounted on the distributing block. The block connects the high-pressure oil supply to both the fuel oil injection system and the exhaust valve actuation system.

The fuel oil injection system consists of the hydraulically activated fuel oil pressure booster with associated control valve, high-pressure pipes and fuel valves.

The exhaust valve actuation system consists of an exhaust valve actuator with associated control valve, the oil push rod (high-pressure pipe), and finally the exhaust valve.

The fuel valves and the hydraulically activated exhaust valve itself are similar to those of the MC engines.

The starting valves are pneumatically opened by activating the solenoid valves (ZV 1120 C, pos. 51) controlled by the Engine Control System, *see the related diagram "Pneumatic Manoeuvring System Diagram" Drawing 7055-0155.*

For cylinder lubrication, the ME Lube System is used, with lubricators located on the HCU.

2 Functional Description

2.1 Hydraulic Power Supply Unit

The function of the Hydraulic Power Supply (HPS) unit is to deliver the necessary high-pressure hydraulic oil flow to the fuel injection system and exhaust valve actuation when the engine is either at stand-by or running.

The HPS unit consists of:

- 2.1.1 Filter unit
- 2.1.2 Electrically driven start-up or start-up/back-up pumps
- 2.1.3 Engine driven pumps
- 2.1.4 Safety and accumulator block
- 2.1.5 High pressure piping
- 2.1.6 Drip pan with leak sensors

2.1.1 Filter Unit

The main filter (pos. 106) of the HPS unit is of the multi-cartridge, self-cleaning type with automatic back-flushing of the cartridges.

The back-flushing is performed with compressed air. It is effected regularly on a time basis, or if the pressure drop across the filter exceeds a pre-defined level.

A redundant filter (pos. 105) is installed in parallel with the main filter, and is used during overhaul of the main filter. Switching to the redundant filter and back is done manually without interrupting the oil flow to the pumps.

The butterfly valve (pos. 115) is closed during all normal service conditions. It is used in situations where cleaning of the entire supply of lubricating oil is required.

The ME filter unit has a 6 microns nominal mesh size. The redundant filter has 25 microns nominal mesh size. The conventional lubricating oil filter used for the engine has a nominal mesh size of 34 - 48 microns.

The ME filter is fitted with a differential pressure indicator and produces an output signal to activate an alarm if the pressure drop exceeds a certain limit.

2.1.2 Electrically Driven Start-up or Start-up/Back-up Pumps

The Hydraulic power supply is available in three versions.

One version is the classic ME power supply where the hydraulic power is generated by engine driven pumps, and the start-up pressure is created by electrically driven pumps. The capacity of the start-up pumps is only sufficient to generate the start-up pressure. The engine cannot run with the engine driven pumps out of operation.

The second version is similar to version one, aside from the fact that the electrically driven start-up/back-up pumps have a capacity sufficient to give at least 15% engine power (Named "Combined"). The electric power consumption should be taken into consideration in the specification of the auxiliary machinery capacity.

The third version is the version with main Electrical Driven pumps all of the variable displacement type. In case when using 4-5 pumps one or two pumps is adjusted to 75% displacement all the time. During start-up one of the variable pumps is to be started one by one and when the engine has reached a predefined load the pump with full displacement will start. The number of pumps depending on the size of the cylinderbore.

The purpose of the electrically driven pumps is to ensure adequate hydraulic system pressure in situations where the main engine is not rotating, and thus not driving the engine driven pumps. The electrically driven pumps operate when there is no hydraulic oil consumption. Therefore, only a small capacity is needed, and the pumps are thus relatively small compared to the engine driven pumps.

The electrically driven pumps are either of the fixed or variable displacement type.

Following a situation where the system has been depressurised, for instance after an engine shutdown or a black-out, the electrically driven pumps must run for a certain period to build up an adequate system pressure for starting the engine. The length of this period is determined by the accumulator capacity in the system and the flow produced by the electrically driven highpressure pump.

When running with gear driven pumps, the pressure relief valves installed in the circuit limits the maximum pressure in the circuit and leads excessive oil back to the suction side of the pumps.

The operation of the high-pressure pumps is supervised by means of the pressure transducers (pos. 320).

2.1.3 Engine Driven Pumps

All engine driven, hydraulic oil pumps are of the variable displacement type and of the same size. The displacement is electronically controlled by the ECS via a built in control valve on the pumps.

The pumps function when the engine is rotating, as they are mechanically driven by the gear assembly, which is permanently connected to the crankshaft. Their flow is determined by the actual displacement and rotational speed.

The pumps are designed to have two directions of rotation. This is necessary as most engines are reversible. Upon reversing of the engine, the displacement control of the ECS must activate the swash plate to keep the direction of the flow.

The engine driven pumps supply the hydraulic pressure for the engine when it is running.

In the event of failure of one pump, the remaining pumps are dimensioned to be capable of supplying sufficient hydraulic oil corresponding to 66% engine load.

In the event that the electric power to the pump displacement control valve is lost, the pump will mechanically go to maximum displacement in the AH direction. The non-return valves (pos. 215) are installed to protect the pump in case of the control system failing. The valve open and allow the pump to draw oil from the high pressure side and deliver the oil back to the suction side again.

2.1.4 Safety and Accumulator Block

The pre-charged accumulators of the Safety and Accumulator Block (on some newer engines the accumulators are mounted directly on the engine-driven pumps) are partly filled with a high pressure oil, ensuring a stable supply, without fluctuation, to the cylinder units.

The block contains pressure relief valves, which protects the high pressure system against excessive pressure.

The relief valves protect the electrically driven pumps and controls the maximum pressure in the system during pressure build-up before starting. This is done when operating on plants which require continuous boosting of the exhaust oil push rod (exhaust valve activation).

The valve (pos. 310) protects the engine driven pumps against a too high pressure. It is electrically controlled by the ECS and can be opened in different situations to feed the hydraulic oil back to the suction side of the engine driven pumps.

The valve (pos. 311) is the main system pressure relief valve protecting the entire system. This valve has the highest pressure setting of the relief valves (pos. 310, 311 and 312).

Non-return valves (pos. 304 and 305) are installed at the hydraulic oil outlet from the engine driven and electrically driven pumps, in order to prevent back-flow through any inactive pump.

The pressure transducers (pos. 320) are used by the ECS for controlling the engine driven and electrically driven pumps.

The non-return valves (pos. 215) are related to the operation of a failing engine driven pump described above.

Pressure relief valves (pos. 310, 311 and 312) have safety functions as described above. The electrical actuation of the valves pos. 310 is duplicated (not shown on the diagram) to allow redundant control as implemented in the ECS.

2.1.5 High Pressure Piping

The hydraulic oil pipes between the Hydraulic Power Supply unit and the Hydraulic Cylinder Units employ piping or hoses. Single wall piping is also used for high pressure pipes between the individual HCU units.

On Drawing 4555-0171 the single wall pipe design is shown.

2.1.6 Drip pan with leak sensors

A drip pan is located just below the hydraulic power supply unit to collect leaking oil and lead it to a drain. In the drip pan, two leak detecting level switches (pos. 360 and 361) are installed. A small, yet significant leak from the HPS will, due to the restriction in the outlet, cause the level in the drip pan to rise and be detected by the lower level switch (pos. 360). This situation will activate an alarm. A severe leak will also be detected by the higher switch (pos. 361) and cause the ECS to shut down the engine.

3 Hydraulic Cylinder Unit

The Hydraulic Cylinder Unit (one per cylinder) consists of a distribution block, an electronically controlled fuel injection system and an electronically controlled exhaust valve actuation system. The distribution block serves as a mechanical support for the hydraulically activated fuel oil pressure booster (pos. 500) and exhaust valve actuator (pos. 515), each with their electronically controlled control valve ELFI/ELVA or common FIVA, respectively.

4 Distribution Block

The function of the distribution block, as its name implies, is to distribute the hydraulic oil to the ELFI/ELVA or FIVA control valves mounted on the distribution block.

Nitrogen pre-charged hydraulic accumulators (pos.450) are fitted on the distribution block. Their function is to ensure that the necessary hydraulic oil peak flow is available for injection of fuel oil and actuation of the exhaust valve.

Close to the ELFI/ELVA or FIVA valves, are two manually operated valves. One valve connects the high pressure inlet side (pos. 420) and the other (pos. 421) connects the accumulators to the bedplate (drain).

These manually operated valves are used for separating and blocking off the HCUs during overhaul.



To protect the accumulators from unnecessary stresses (fast acceleration of the membrane) and oil jets, the valve Pos. 420 must not be opened when the oil system is pressurized.

After check/overhaul or whatever situation where the valve Pos. 420 has been closed the opening procedure is:

- 1) The engine must be stopped (no oil pressure).
- 2) Open/Close all valves into normal running position.
- 3) Pressurise the system by starting the Start-up pumps.

The manually activated valve (pos. 531) connects pressure supply to the oil push rod. The valve must be closed during overhaul of the exhaust valve.

5 Electronically Controlled Fuel Injection

The electronically controlled fuel injection system consists of the hydraulically activated fuel oil pressure booster, its controlling valve (ELFI or FIVA) and the fuel valves.

The ELFI or FIVA valve (controlled by the ECS) is capable of fast and precise control of the oil flow to the fuel oil pressure booster. This oil flow pushes the hydraulic piston (pos. 502) and the fuel injection plunger (pos. 504), generating the injection pressure and hence, the injection.

When the injection is finished, the plunger and piston are returned to their starting positions by connecting the piston to a drain and driving the plunger back by means of the pressure in the fuel supply. The fuel oil pressure booster is then filled and ready for the next injection.

The design principle of the high pressure pipes and fuel valves is similar to that of the MC engines. The fuel system permits continuous circulation of the heated heavy fuel oil through the fuel oil pressure boosters and fuel valves. This keeps the system heated during engine standstill.

6 Functional description of the Throttle Valve on the Fuel Oil Pressure Booster

As seen in *Drawing 4555-0155*, a throttle valve is situated at the bottom of the Fuel Oil Pressure Booster Housing.

Via a bore from the housing bottom, the oil space underneath the Fuel Oil Pressure Booster Piston is vented through the throttle valve.

A small bore in the throttle valve piston ensures ventilation of the oil space at engine standstill (no oil pressure and low oil pressure at start-up), thereby keeping the engine ready for start without having to ventilate the system.

When the Fuel Oil Pressure Booster is activated by the FIVA valve, the oil pressure in the space underneath the Fuel Oil Pressure Booster will rise significantly to lift the piston. At the same time, the high pressure oil will overcome the resistance of the spring in the throttle valve and the piston in the throttle valve will close.

In this way the oil amount vented from the space underneath the main piston is kept very low.

7 Electronic Exhaust Valve Actuation System

The design of the hydraulically activated exhaust valve is similar to that on the MC type engines, i.e. the exhaust valve is opened hydraulically and it is closed by an "air spring".

The actuator system fitted to each HCU consists of the ELVA or FIVA and the two-stage hydraulic exhaust valve activator.

The electronic ELVA or FIVA (controlled by the ECS) opens for the oil flow to the two-stage hydraulic actuator.

In the first stage the activation piston (pos. 517) is driven by the hydraulic pressure acting on both the activation piston itself and the hydraulic piston (pos. 516). The first stage performs the initial valve opening against the cylinder pressure. In the second stage the movement of the hydraulic piston is stopped, and the activation piston performs the second stage, lower force, main stroke of the exhaust valve alone.

The exhaust valve is closed by connecting the activation piston to a drain via the ELVA or FIVA valve and letting the air spring of the exhaust valve drive it to closed position. This movement also drives the push rod oil back into the exhaust actuator, preparing it for the next actuation.

The HCU design ensures that a failing HCU can be disconnected from the high pressure system by manually operated valves, thereby enabling repair work while the engine is running on the remaining cylinders.

In the case that the control signal for the ELFI or FIVA valve is missing (pressurised or non-pressurised system), the control spring will position the valve so that the hydraulic piston oil from the space below is connected to tank. This is the fail-safe position, where the main spool in the FIVA is moved to the position Cfi to T, Cva to P.

With regard to the safety of the ship's personnel and the engine, the highpressure fuel pipes are, as on the MC type engines, shielded by steel braiding.

8 Components

Pos. 101

Butterfly valve. Normally open. Used for shutting-off to the filter during overhauls at standstill.

Pos. 103

Double stage, 3-way cock. Situated between the Automatic back flushing filter and the Stand-by filter. Used when Automatic filter elements are to be cleaned manually during normal engine running.

Pos. 104

Mini-mess valve installed at the filter unit inlet (For mounting of portable pressure gauge).

Pos. 105

Single filter. 25 microns filter mesh.

Pos. 106

Automatic back flushing filter. Boll filter. The main purpose of this filter is to keep the hydraulic oil clean, thereby avoiding small particles damaging movable parts of the hydraulic components. 6-microns filter mesh. 10-microns filter mesh on the first engines built (2003 - 2005).

Pos. 107

Mini-mess valve installed at the filter unit outlet (for connection of portable pressure gauge).

Pos. 108

Mini-mess valve installed at the system inlet. (for connection of portable pressure gauge).

Pos. 110

Rubber Compensator (optional).

Pos. 115

Butterfly valve. Normally closed. Used during flushing at the commissioning of the engine. Used after major overhauls and when found necessary.

Pos. 130

A pressure transducer measuring the oil pressure on the suction side of the main supply pumps. The output from the transducer is sent to the ECS of the engine. The suction pressure is continuously shown on the HPS screen on the MOP. An alarm is activated if the suction pressure is too low.

Pos. 131

An orifice, $\varnothing$ 0.5 mm, for previously mentioned pressure transducer (130) is installed to protect the transducer against pulsations and ensure a steady amount of oil to the transducer.

Pos. 155

Mini-mess valve installed in the low-pressure line (for connection of portable pressure gauge).

Pos. 201

High pressure Axial Piston Pumps. Type Rexroth A4VSO. Driven mechanically either by a gear or electric motors.

Pos. 202

Mini-mess valve installed in the low pressure inlet before the pump (for connection of portable pressure gauge).

Pos. 203

Mini-mess valve installed in the high pressure pump outlet (for mounting of portable pressure gauge).

Pos. 204

Line break valve. Normally open. The valve protects the system in case of pilot line (Sp) failure.

Pos. 205

Safety coupling (el-motor, gear – Rexroth pump).

Pos. 206

Electric motor (driving the Rexroth pump).

Pos. 210

Electronically controlled proportional valve situated on the high pressure pump. The proportional valve controls the oil amount delivered by the pump. This is done by changing the swash plate angle. The larger the angle the more oil is delivered, a smaller angle gives less oil.

Pos. 210-2

On/Off valve for pump Nos.4 and 5 only. Only engines with more than 3 (three) engine driven pumps.

Pos. 215

Check valve – cartridge. Non return valve in use when the pump draws from the pressure side of the system (not used on engines with only electrically-driven pumps).

Pos. 220

A positional transducer situated on the pump. The transducer sends an electric current corresponding to the swash plate angle of the pump, thereby telling the ECS the exact amount of oil circulated by the pumps.

Pos. 226

(Only used on very few 1. edition ME engines). Pressure transducer on the start-up pump unit.

Pos. 227

(Only used on very few 1. edition ME engines). Orifice for pressure transducer pos. 226 above.

Pos. 230

Butterfly valve on the high pressure pump suction side. Normally open.

Pos. 235

Check valve. Only to be found in "Combined HPS" systems, and few "Gear Driven HPS" systems.

Pos. 236

Check valve. Only to be found in "Combined HPS" systems, and few "Gear Driven HPS" systems.

Pos. 240

Orifice. This component is only to be found in "Combined HPS" systems, and few "Gear Driven HPS" systems.

Pos. 241

Orifice. This component is only to be found in "Combined HPS" systems, and few "Gear Driven HPS" systems.

Pos. 276

Mini-mess valve installed on the start-up pump pressure side.

Pos. 277

Start-up pump. This position number is only shown on hydraulic diagrams for engines with "Combined HPS" systems where it is possible to use the start-up pumps as Back-up Pumps.

Pos. 277a

Throttle valve. This valve is only installed in connection with start-up pumps in "Combined HPS" systems where it is possible to use the start-up pumps as Back-up Pumps.

The valve is normally open and used in cases where failure on engine driven pumps or gear for engine driven pumps might occur. By manually closing this throttle valve, the pressure control function change from pressure relief valve 277b (adjusted to 225 bar) to pressure relief valve 277c (adjusted to 310 bar). In this way the oil amount delivered from the electrically driven Start-up/Back-up Pumps ensures a running of the engine at approximately 15% load (back-up power).

Should a failure situation occur, we recommend that you contact MAN Diesel & Turbo for a special running procedure for your specific engine.

Pos. 277b

Pressure relief valve. This relief valve is only installed in connection with start-up pumps in "Combined HPS" systems where it is possible to use the start-up pumps as Back-up Pumps. The valve function is as described under pos. 277a.

Pos. 277c

Pressure relief valve. This relief valve is only installed in connection with start-up pumps in "Combined HPS" systems where it is possible to use the start-up pumps as Back-up Pumps. The valve function is as described under pos. 277a.

Pos. 278

Electric motor. This position number does only appear on the "Combined HPS" systems where it is possible to use the start-up pumps as Back-up Pumps.

Pos. 279

Coupling house. This position number does only appear on the "Combined HPS" systems where it is possible to use the start-up pumps as Back-up Pumps.

Pos. 280

Coupling. This position number does only appear on the "Combined HPS" systems where it is possible to use the start-up pumps as Back-up Pumps.

Pos. 280a

Coupling part. This position number does only appear on the "Combined HPS" systems where it is possible to use the start-up pumps as Back-up Pumps.

Pos. 285

Inlet valve at start-up pump unit. Normally open. The valve does only exist in "Gear driven HPS and FIVA" systems and ELFI and ELVA systems.

Pos. 304

Non-return valve. The non return valve is installed on the high pressure side of the pumps to separate the pump from the pressure side. The forces in the oil in pipe P2 is extremely high during normal running (pressure is high, oil amount is high, forces in accumulators are high).

Should an electric motor, driving one of the pumps, suddenly stop (electric failure, broken clutch) the forces from the other pump, together with the forces mentioned above, will try to force the stopped pump in the wrong direction creating a violent stress and possibly destroying the pump. This is avoided when the nonreturn valve closes immediately after pressure drop at pump standstill.

Pos. 305

Non-return valve. The nonreturn valve (placed by the accumulator block inlet) is installed on the start-up pump pressure side to protect the pump against high pressure when the engine is running on the engine driven pumps.

Pos. 309

Check valve – cartridge. Non return valve.

Pos. 310

Pressure relief valve (opening pressure 310 bar)

Pos. 310a

Pilot valves arrangement situated on pos. 310 pressure relief valve.

Pos. 310b

Orifice.

Cyl. Bore	50	60	65	70	80	90	98	cm
Orifice dia.	8	10	10	12	15	18	22	mm

Pos. 311

Pressure relief valve. Normally closed. The pressure relief valve is mechanically adjusted to an opening pressure of 315 bar. If the pressure rises above 315 bar, the relief valve will open and lead the oil:

- the main tank (when running with electrically driven pumps).
- or
- the suction line (when running with gear driven pumps).

Pos. 312

Pressure relief valve. Normally closed. The pressure relief valve is mechanically adjusted to an opening pressure of 225 bar. The valve does only exists in ELFI and ELVA systems and "Gear driven HPS and FIVA" systems.

Pos. 315

Ball valve. Normally closed. Used when the system needs to be drained off during repairs, etc.

Pos. 316

Ball valve. Normally closed.

Must be opened for adjustment of pressure relieve valve 310.

Pos. 320

Pressure transducers. The system is supplied with three (3) transducers for redundancy reasons. During normal running, all three transducers send an analogue signal to the ECS. The average value is shown on the MOP.

Pos. 321

An orifice, $\varnothing$ 0.5 mm for the above pressure transducers (320), is installed to protect the transducers against pulsations and ensure a steady amount of oil to the transducers.

Pos. 335

Accumulators. Mounted on the Safety and Accumulator block or directly on the engine driven pumps to avoid oil pulsations in the hydraulic system and keeping the oil pressure steady at all engine loads. Manufacturer: HYDRO LEDUC.

Pos. 339

Mini-mess valves mounted at the main high pressure pipe (P1) for measuring the system pressure (for connection of portable pressure gauge). The valve does only exists in ELFI and ELVA systems and "Gear driven HPS and FIVA" systems.

Pos. 340

Mini-mess valves installed in the main high pressure pipe (P2) for measuring the system pressure. (for connection of portable pressure gauge). The valves does only exist in "Combined HPS and FIVA" systems and "EI-driven HPS and FIVA" systems. Both with and without separate LPS.

Pos. 355

Leak indicator. In the event of a leak from the inner pipe, and the amount is high

enough so that the small reservoir is filled, an alarm will be activated. This will not affect the running of the engine. However, but the engineer is now warned about the leak (searching for leaks is described in the procedure attached this document).

Pos. 360

Leak indicator. The Hydraulic Supply Unit is enclosed in a cabinet protecting against forceful oil spray if a leak should occur. In the event of a minor oil leak occurring inside the cabinet, a drip pan placed in the bottom of the cabinet will be filled and an alarm will be activated. The drip pan is fitted with an overflow pipe with a diameter size and a height in the drip pan that match the oil amount allowed to leak. This will not interfere with a safe oil delivery to the hydraulic system.

Pos. 361

Leak indicator. If the leakage described in Pos. 360 above increases, the drip pan will fill, and shut down of the engine will occur.

Pos. 405

Drain valve. Normally closed. Drain of oil to tank during repairs on HCU block. Opposite Drain valve 405 (see drawing). Return oil from the HCU block (during normal running) is led back to the main tank via an overflow pipe. This overflow ensures that the HCU block and the attached components are 'vented' and 'flooded' at all times.

Pos. 406

Drain valve.

Pos. 420

Inlet valve. Normally open. Main supply valve of highpressure oil to ELFI, ELVA or FIVA valves

 WARNING

To protect the accumulators from unnecessary stresses (fast acceleration of the membrane) and oil jets, the valve Pos. 420 must not be opened when the oil system is pressurized.

After check/overhaul or whatever situation where the valve Pos. 420 has been closed the opening procedure is:

- 1) The engine must be stopped (no oil pressure).
- 2) Open/Close all valves into normal running position.
- 3) Pressurise the system by starting the Start-up pumps.

Pos. 421

Drain valve. Normally closed. Drain used during maintenance of ELFI/ELVA, Fuel Oil Pressure Booster, Exhaust Valve Actuator, Accumulators.

Pos. 425

Mini-mess valve fitted on the HCU block measuring the system pressure (for connection of portable pressure gauge).

Pos. 440

ELFI Valve or FIVA valve. **EL**ectronic **F**uel Injection valve or **F**uel Injection **V**alve Actuation valve, which is capable of fast and precise control of the hydraulic oil flow to the fuel pump. The oil flow acts on the hydraulic piston and fuel injection plunger, generating the fuel injection pressure and hence the injection. Manufacturer: Curtis-Wright, Parker Hannifin, MAN Diesel & Turbo.

Pos. 445

Electric Linear Motor driving the ELFI valve (proportional type) and the fuel injection part in the FIVA valve. Manufacturer: Curtis-Wright.

Pos. 450

Accumulators. Mounted on the HCU block to boost flow during fuel injection and exhaust valve opening. See section 4 in this description. Manufacturer: HYDRO LEDUC.

Pos. 455

Mini-mess valve fitted on the HCU block measuring the oil pressure at the inlet to the ELFI and FIVA valve (for connection of portable pressure gauge).

Pos. 456

Mini-mess valve fitted on the HCU block measuring the oil pressure at the inlet to the ELVA valve (for connection of portable pressure gauge).

Pos. 465

Mini-mess valve fitted on the HCU block measuring the oil pressure at the outlet from the HCU block (for connection of portable pressure gauge).

Pos. 470 ELVA valve. **EL**ectronic **E**xhaust **V**alve **A**ctivation valve opens for the oil flow to the two-stage hydraulic actuator, which drives the pushrod oil to open the exhaust valve.

Manufacturer: Curtis-Wright

Pos. 475

High Response Valve. The High Response Valve is an electric on/off valve driving the ELVA valve.

Manufacturer: Curtis-Wright

Pos. 480

Airing Orifice.

Pos. 500

Fuel Oil Pressure Booster.

Pos. 501

Positional Transducer. Inductive sensor measuring the movement of the fuel plunger in the fuel oil pressure booster. Raises an alarm if the plunger movement is slower/faster than a predefined value stated in the ECS. The sensor has no influence on the opening/closing timing of the ELFI valve.

Pos. 502

Hydraulic piston.

Pos. 503

Umbrella.

Pos. 504

Fuel plunger.

Pos. 505

Fuel injection pipes.

Pos. 510

Fuel injection valves.

Pos. 515

Exhaust Valve Actuator.

Pos. 516

Hydraulic piston.

Pos. 517

Activation piston.

Pos. 520

High Pressure Pipe (push rod pipe).

Pos. 525

Exhaust Valve Top.

Pos. 526

Positional Transducer. Inductive sensor measuring the movement of the exhaust valve spindle. Activates an alarm if the spindle movement is opening too low or slower/ faster than a predefined value stated in the ECS. The sensor has no influence of the opening/closing timing of the ELVA valve.

Pos. 527

Check valve. Non return valve from exhaust valve top outlet.

Pos. 528

Orifice from exhaust valve top inlet.

Pos. 530

Non-return valve. Oil from the Low Pressure System is always delivered to the High Pressure Pipe. Due to system leakage, the valve ensure the actuator piston to return to "start-position" after exhaust valve actuation. (see also Pos. 541).

Pos. 531

Supply valve. Normally open. See Pos. 530 above. This valve must be closed during overhaul of the Exhaust Valve Actuator and High Pressure Pipe. Also to be closed if FIVA valve is changed.

Pos. 540

Mini-mess valve fitted on the Exhaust Valve Actuator top measuring the oil pressure in the High Pressure Pipe (for connection of portable pressure gauge).

Pos. 541

(Only some ME engines). Orifice $\varnothing 1.0$ mm. The Exhaust Actuator is equipped with 3 (three) drains.

The lower drain pipe drains the space between the Hydraulic Piston (516) and the Activation Piston (517). Although the tolerances between the piston and the liner in the Exhaust Valve Actuator are very narrow, a very small amount of oil will always escape through this drain.

The upper drain drains the High Pressure Pipe during overhauls. The amount of oil in the High Pressure Pipe is rather high and oil spill will be too high if the pipe is loosened and removed too quickly. There will also be substantial cleaning after overhaul. This drain drains the oil from the High Pressure Pipe to the main tank. When the bolts at the top flange of the High Pressure Pipe are loosened and a light push loosens the pipe (so that air can escape) the oil will (in a few minutes) be drained to the tank.

The middle drain is designed with an orifice (541). This orifice ensures a stable change of the oil in the top of the actuator. The movement and damping of the oil in the actuator generates thermal energy in the top section of the actuator. This energy results in an oil temperature rise (that may be harmful and stress the material), which can be removed by changing a small amount of oil in the top of the actuator.

Pos. 545

Mini-mess valve fitted in the Exhaust Valve Actuator bottom for measuring the oil pressure activating the actuator activation piston (for connection of portable pressure gauge).

Pos. 550

Mini-mess valve fitted in the Fuel Oil Pressure Booster bottom measuring the oil pressure activating the Fuel Oil Pressure Booster hydraulic piston (for connection of portable pressure gauge).

Pos. 555

Leak Indicator. Placed underneath the drip pan for all HCU units. An alarm will be activated if an oil leak is too large.

Pos. 560

Connection valve. Normally open. Must be closed when working on cylinder lubricators.

Pos. 565

Mini-mess valve fitted in the HCU block measuring the oil pressure activating the ME cylinder lubricator (for connection of portable pressure gauge).

The valve exists in all hydraulic systems – except the ELFI and ELVA systems.

Holes Pos.701, 702 and 'not numbered' (not shown on diagrams)

Functional description of drain holes Pos. No. 701, 702 and 'not numbered' all situated on both front-end and aft-end of the HCU Block.

As seen on Drawing 4555-0160, the HCU blocks have 3 drain holes on the sides. 702 on the aft end side and hole 701 and hole 'not numbered' on the fore end side. (Engines with port side manoeuvring side)

The hole 701 is a drain/peep hole connected through bores to the underside of the Fuel Oil Pressure Booster. Should the inner sealing ring under the Fuel Oil Pressure Booster leak, system oil is detected in the drain 701.

The hole 'not numbered' is a drain/peep hole from the drain surrounding the Fuel Oil Pressure Booster. (Eventually leaking oil is collected here and drained away to avoid oil filth)

The hole 702 is a drain/peep hole connected through bores to the underside of the Exhaust Valve Actuator. Should one or more of the three sealing rings in the Exhaust Valve Actuator leak, system oil is detected in the drain 702.

ME Cylinder Lubricator (no pos.number)

Functional description of the Level Switch located on the HCU Block at the inlet pipe to the Cylinder Lubricator on ME Engines. (Inclusive the 3-way cock fitted on the inlet pipe to the Level Switch).

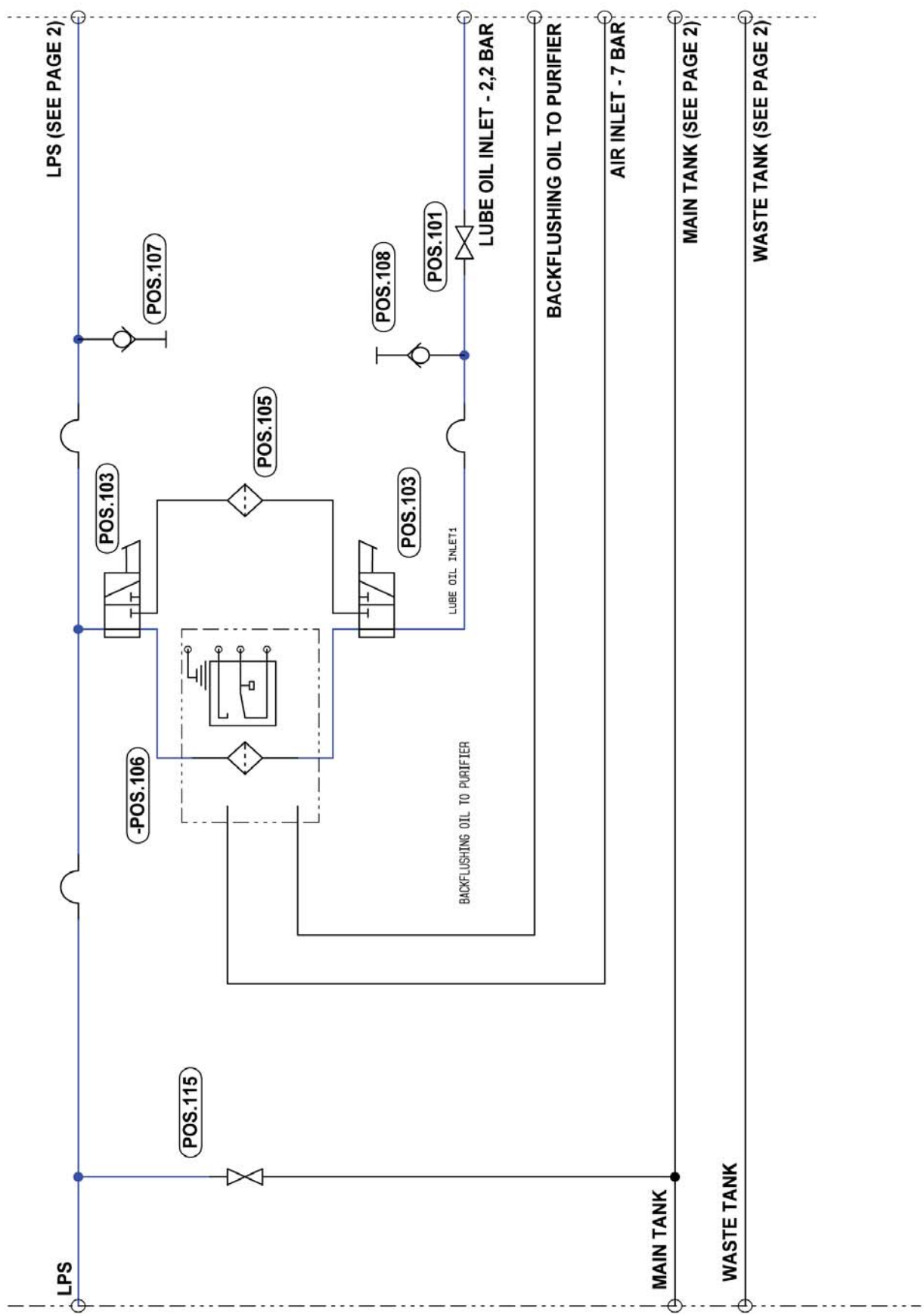
As shown on Drawing 4555-0165, a level switch is placed on the cylinder lubricating oil inlet pipe to the cylinder lubricator.

The function of the level switch is to keep the lubricator filled and ensure an oil flow to the lubricator at all times. If the feeler in the level switch is exposed (low oil level in the house) an alarm will be activated and a slow-down of the engine will occur.

The force of gravity and heated inlet lubricating oil pipes from the gravity tank to the lubricators keep the level switch and, thereby, the lubricator filled. The lubricating oil is kept at 45 degrees Celcius in the tank, and the inlet main pipe is insulated and heat traced to keep the same temperature at the inlet of the lubricator on the HCU block.

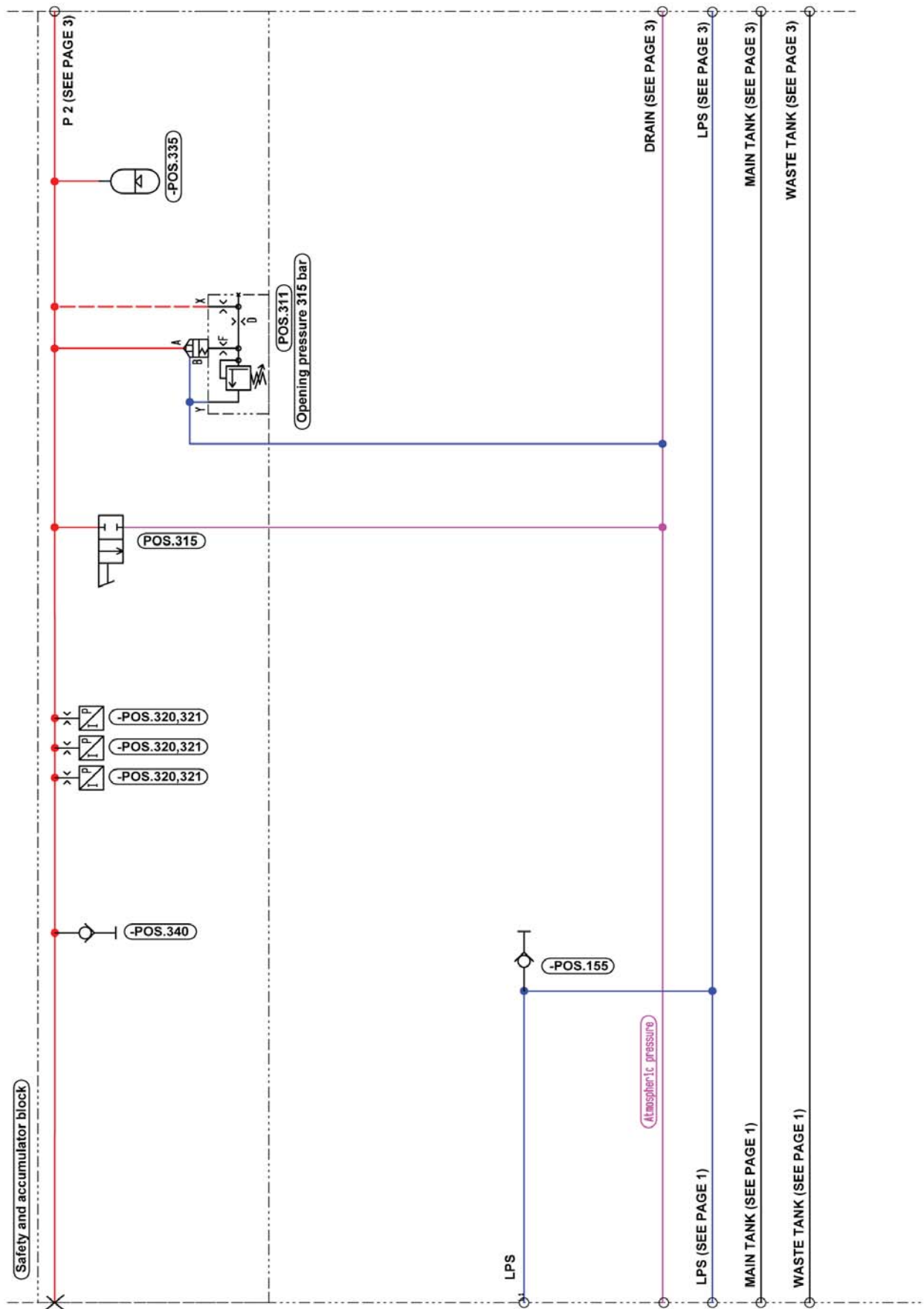
The 3-way cock on the inlet pipe before the level switch is closed when overhauling the lubricator (or level switch). When closing the 3-way cock, the level switch is vented to open air to ensure that the level switch and inlet pipe to the lubricator is pressure free and empty before overhaul (at the same time, the alarm is activated and the slow down function is checked).

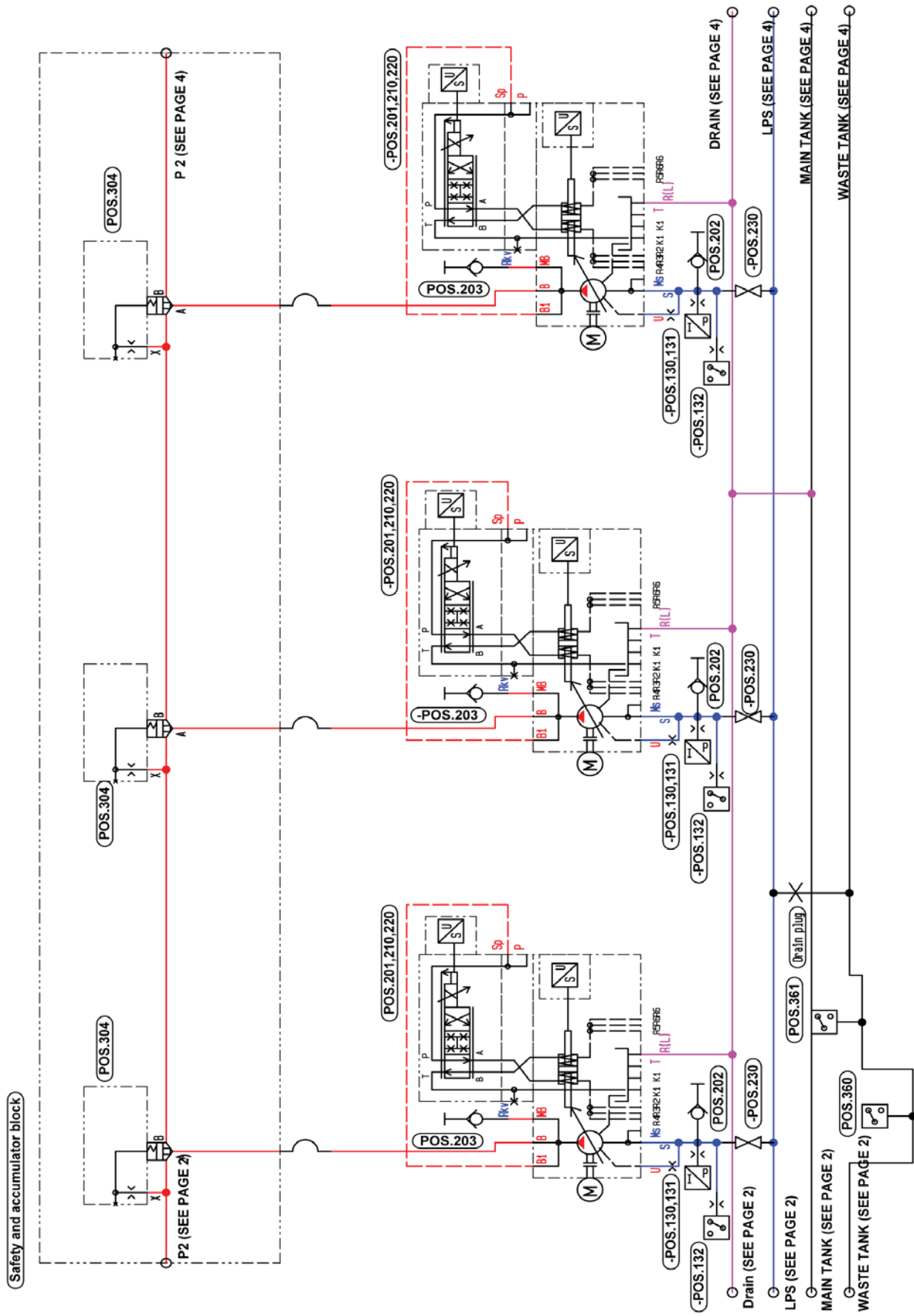
If the 3-way cock is closed by mistake during engine running, the venting to open air will ensure (because of normal consumption) that an alarm of no cylinder lubrication in the lubricator concerned is activated.



El Driven HPS, Common LPS, FIVA, ME Version 5, Rexroth Pumps
- 300 bar

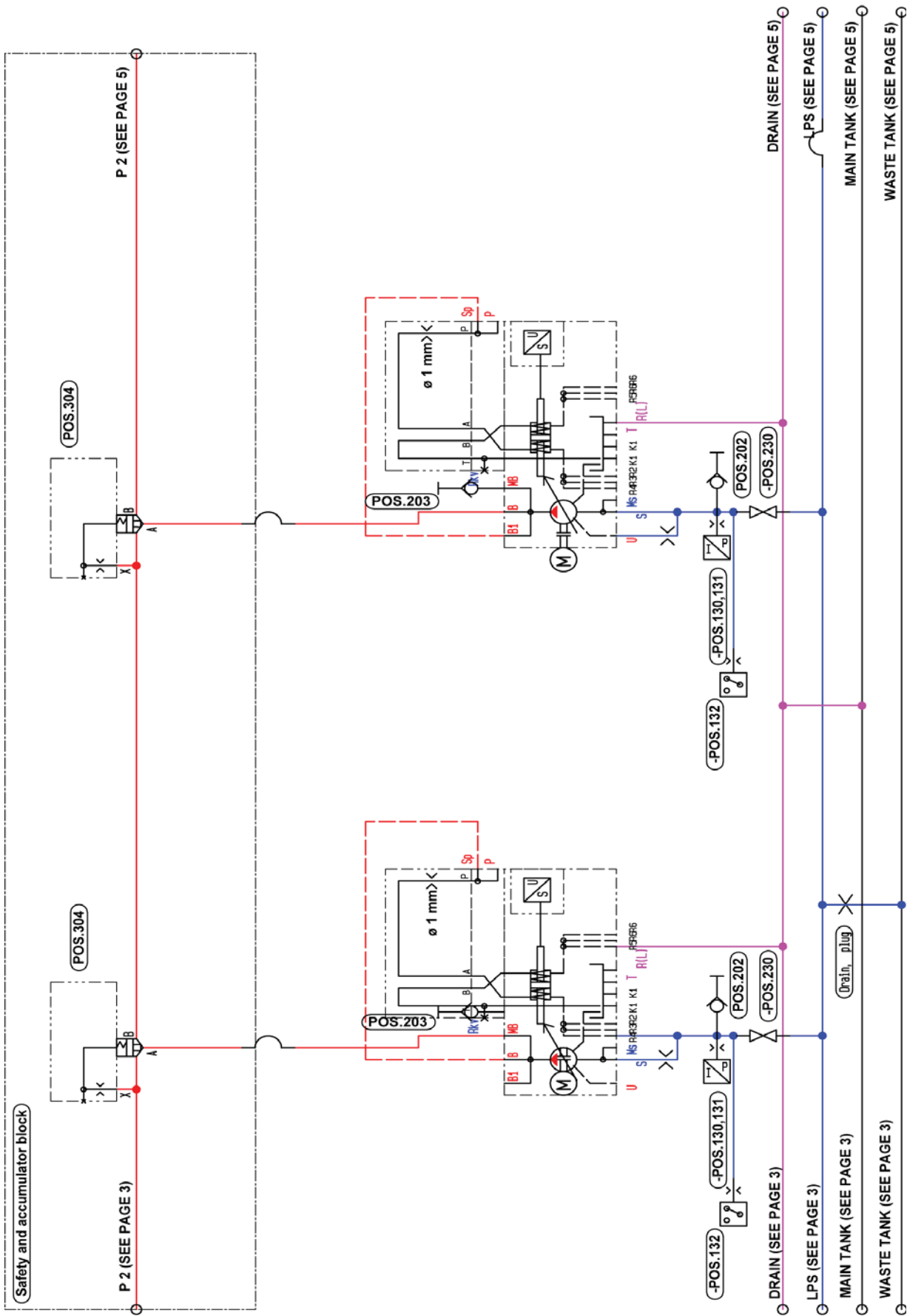
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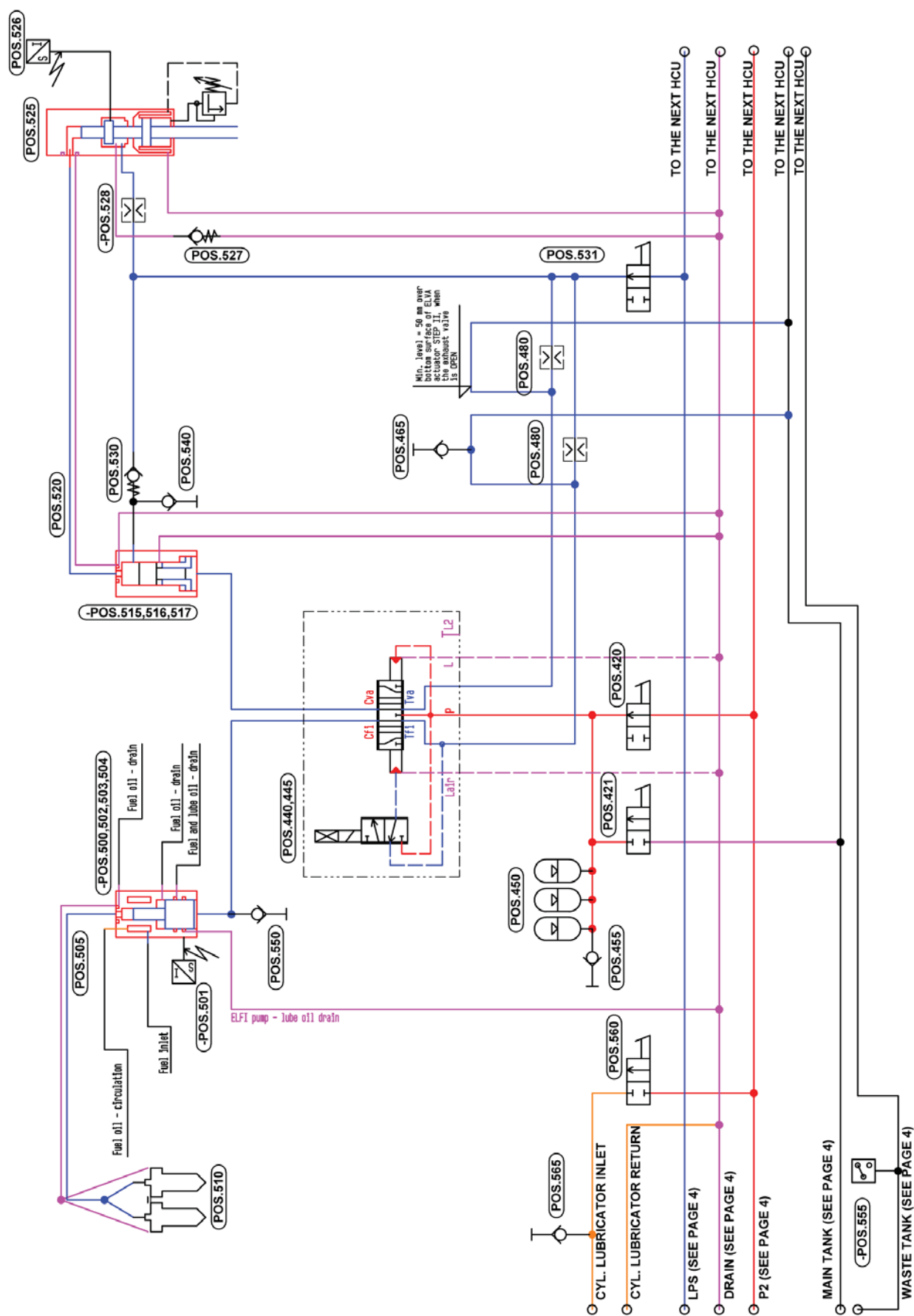




El Driven HPS, Common LPS, FIVA, ME Version 5, Rexroth Pumps
- 300 bar

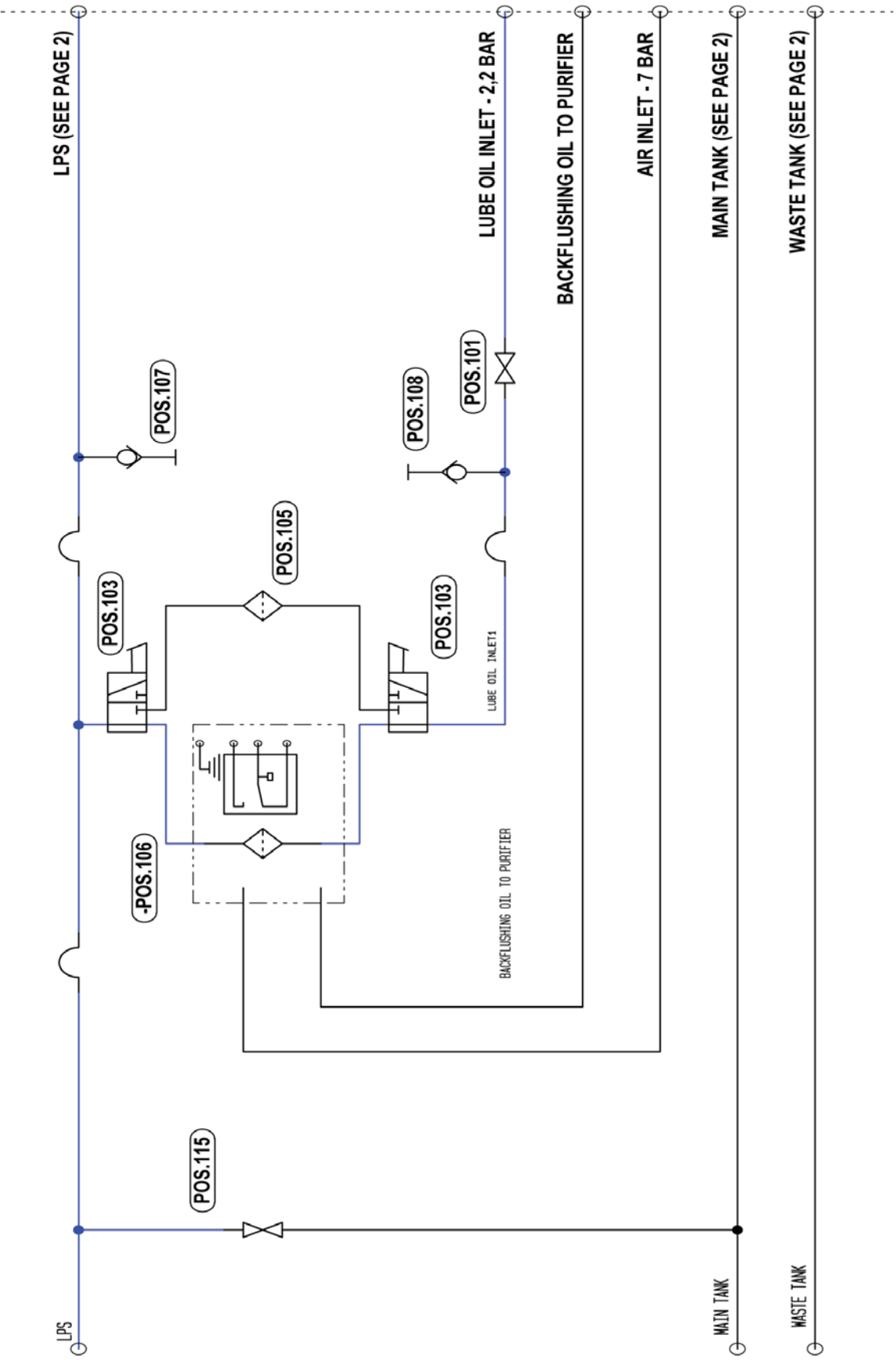
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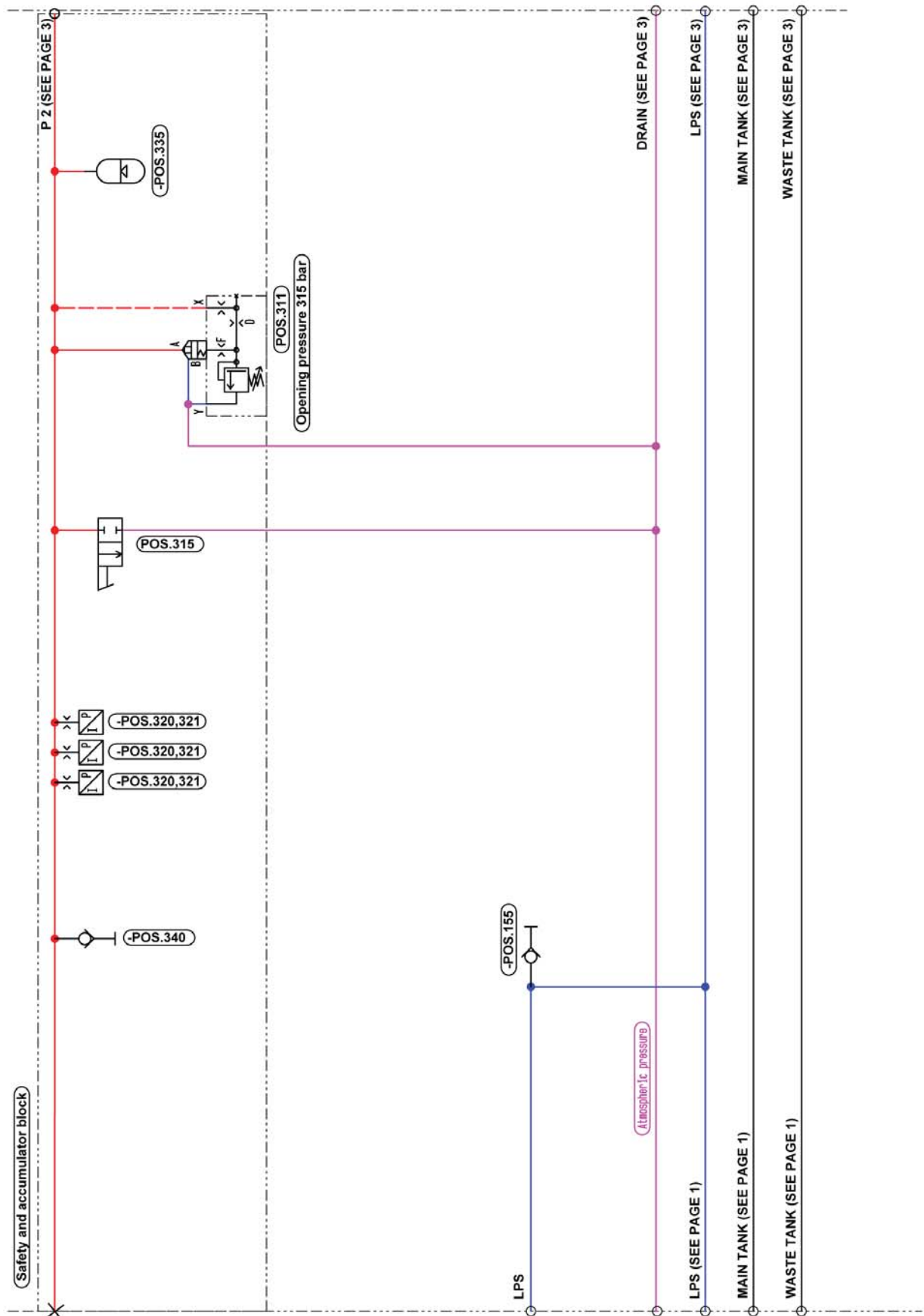


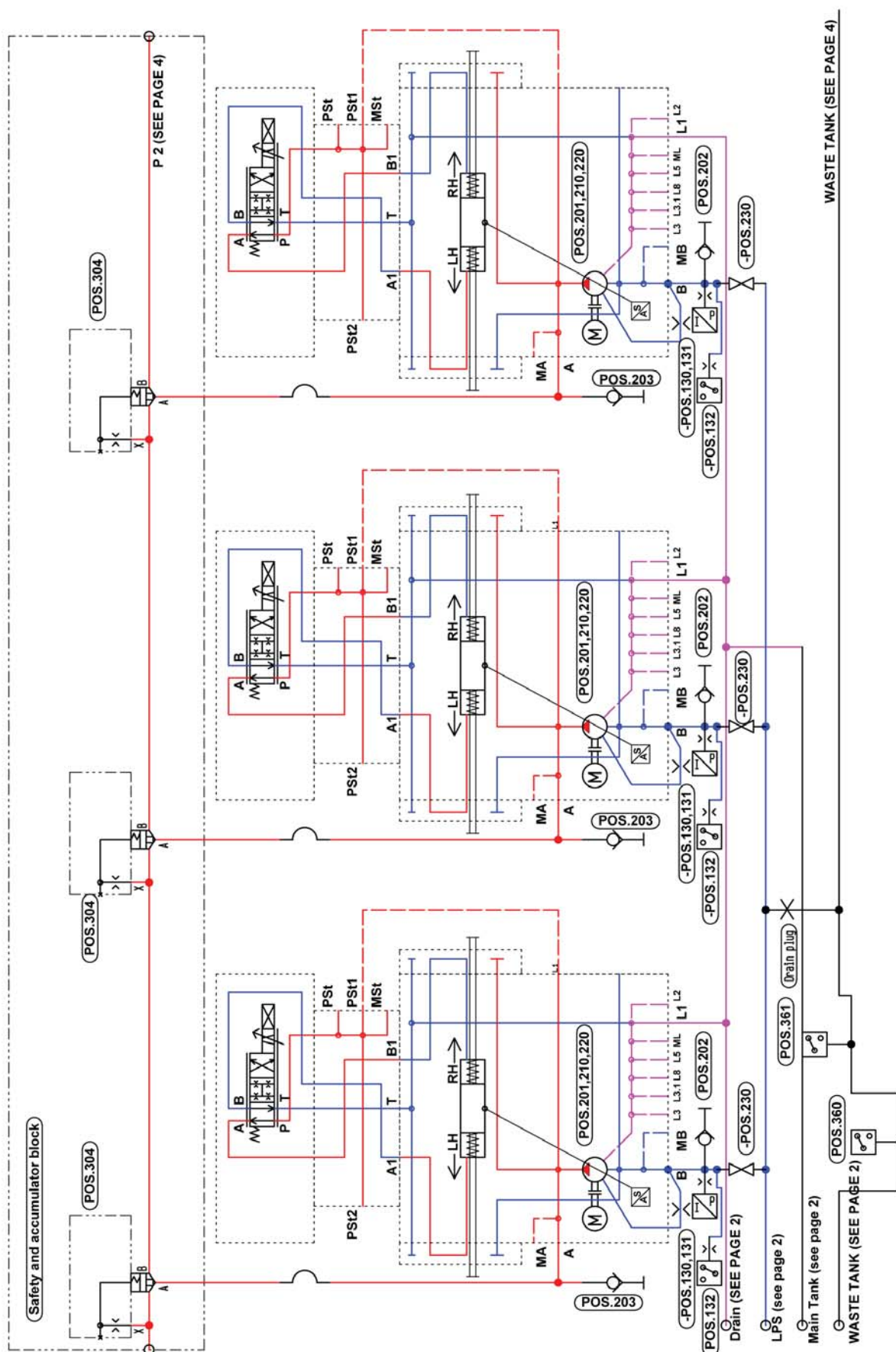


EI Driven HPS, Common LPS, FIVA, ME Version 5, Rexroth Pumps
- 300 bar

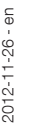
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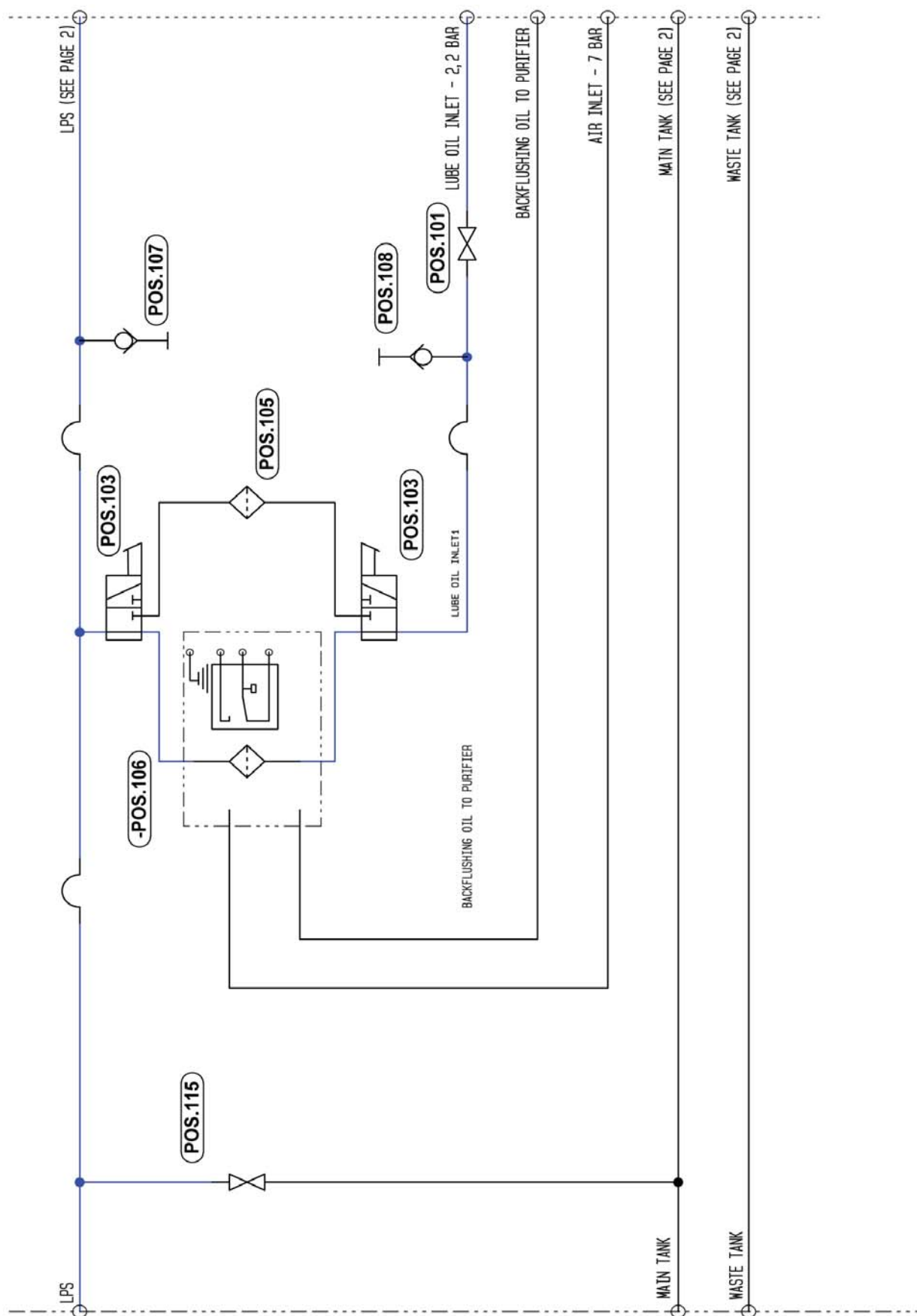


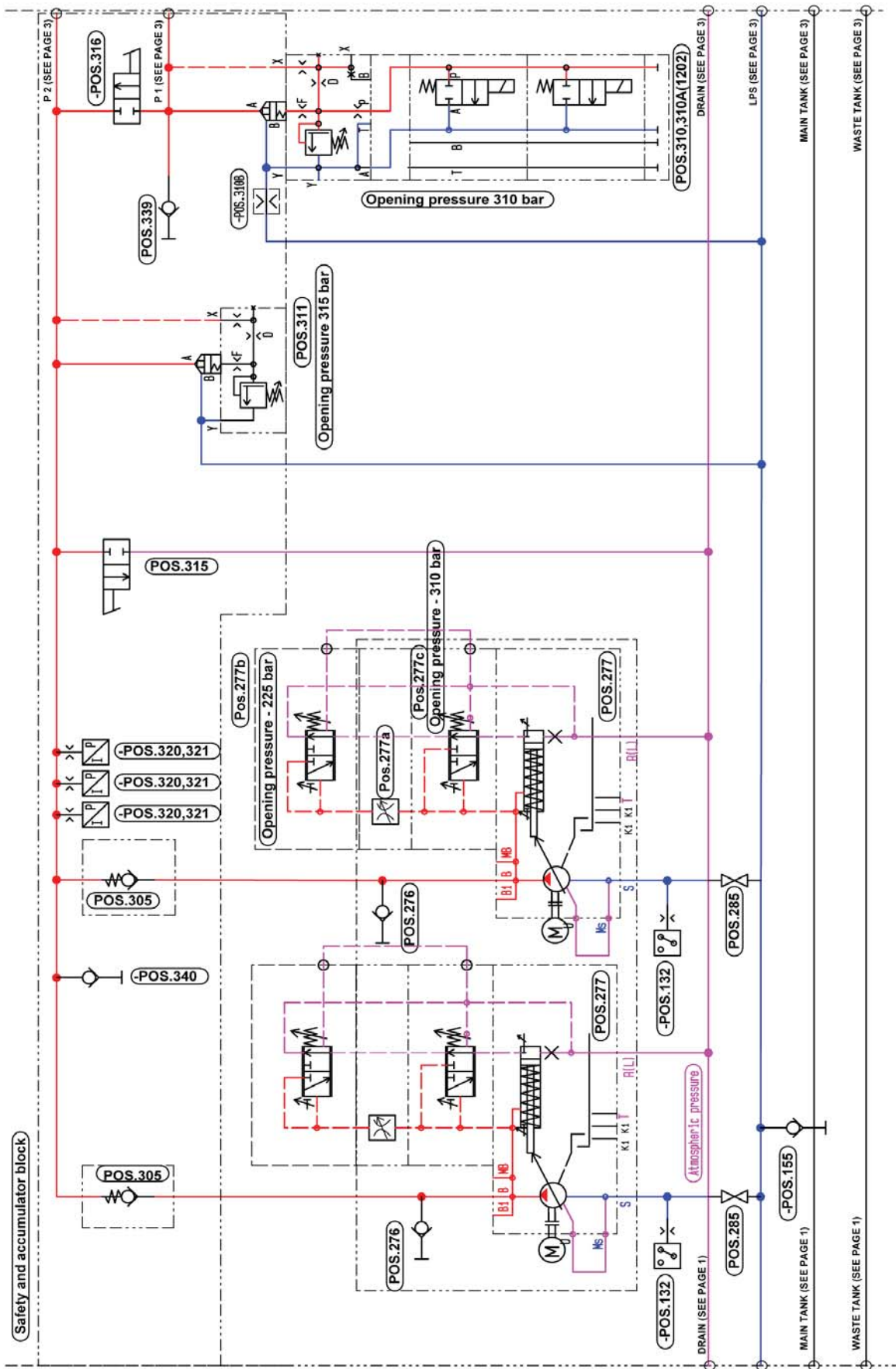


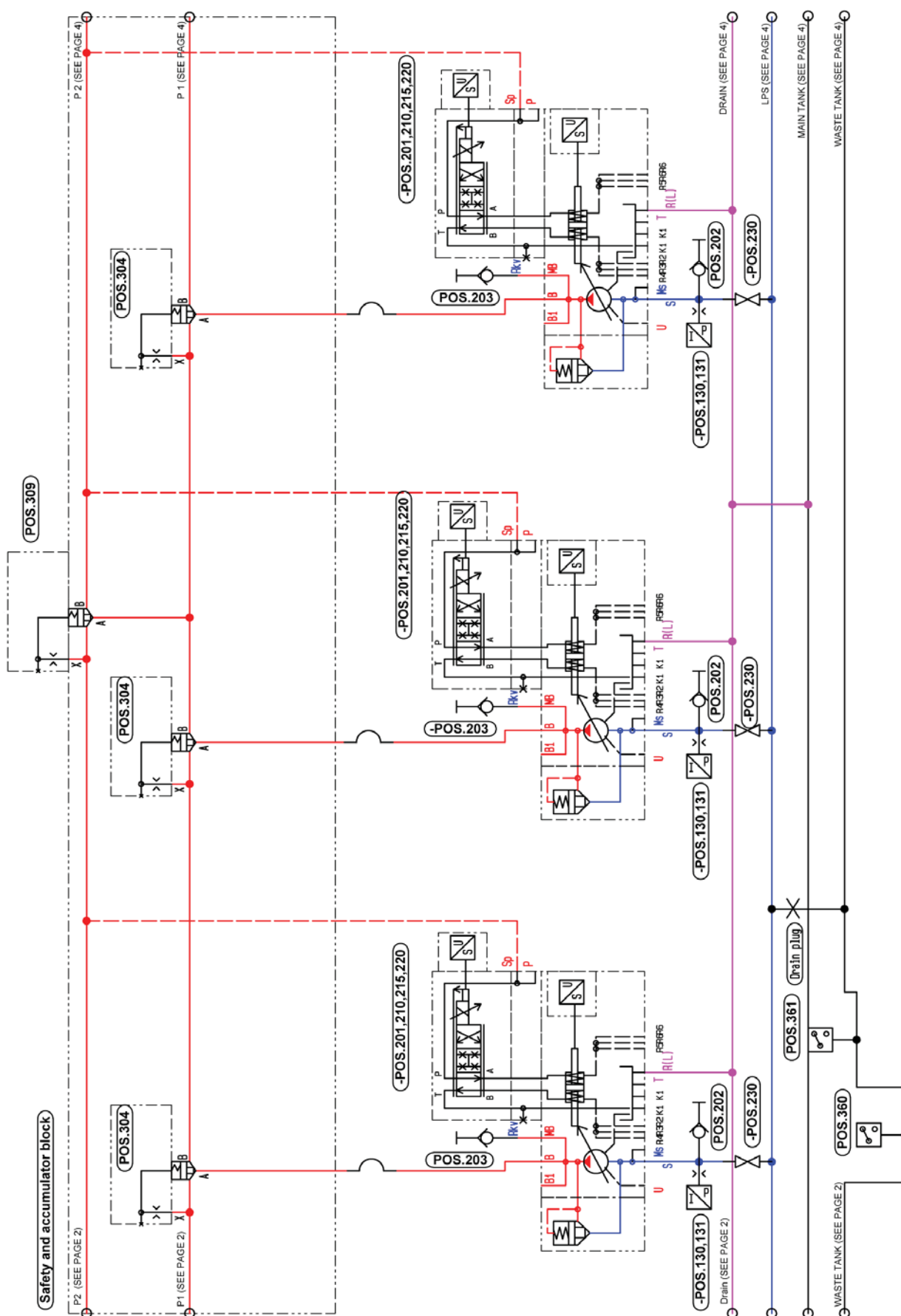
Drawing
4555-0125-0002
EI Driven HPS, Common LPS, FIVA, ME Version 5, Eaton Pumps - 300 bar



Drawing
4555-0125-0002

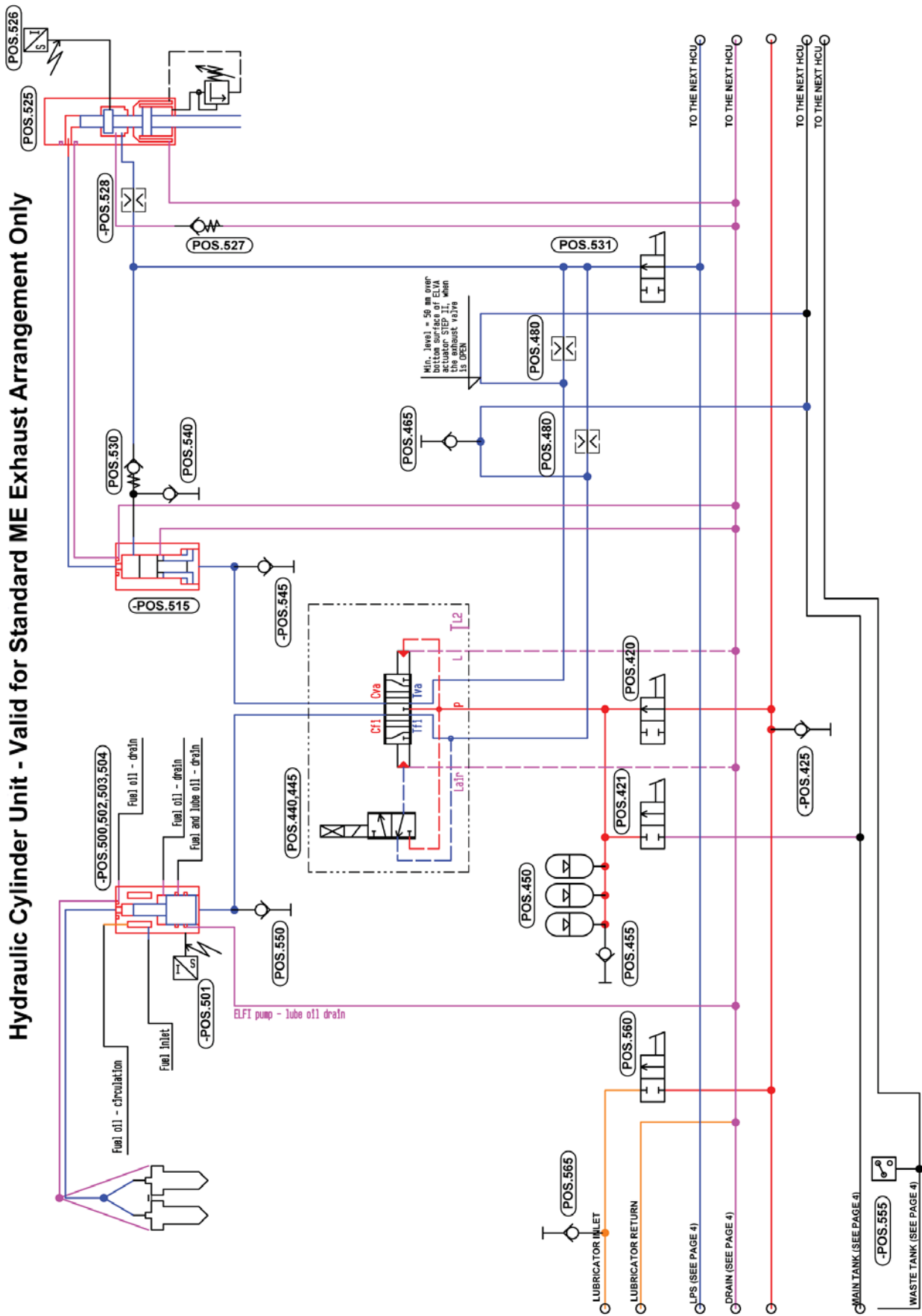




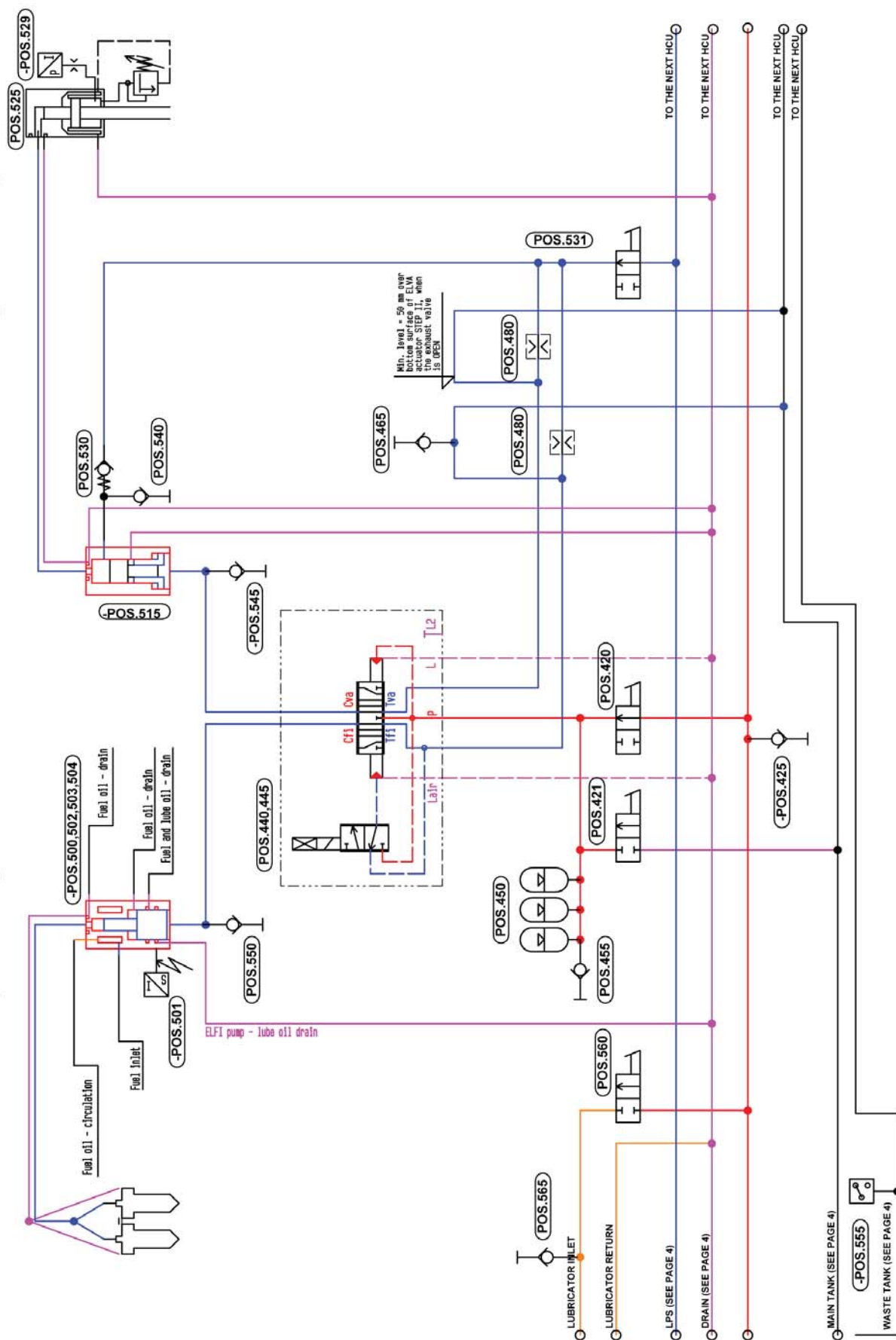


Combined HPS, Common LPS and FIVA - 300 bar

Drawing
4555-0135-0001

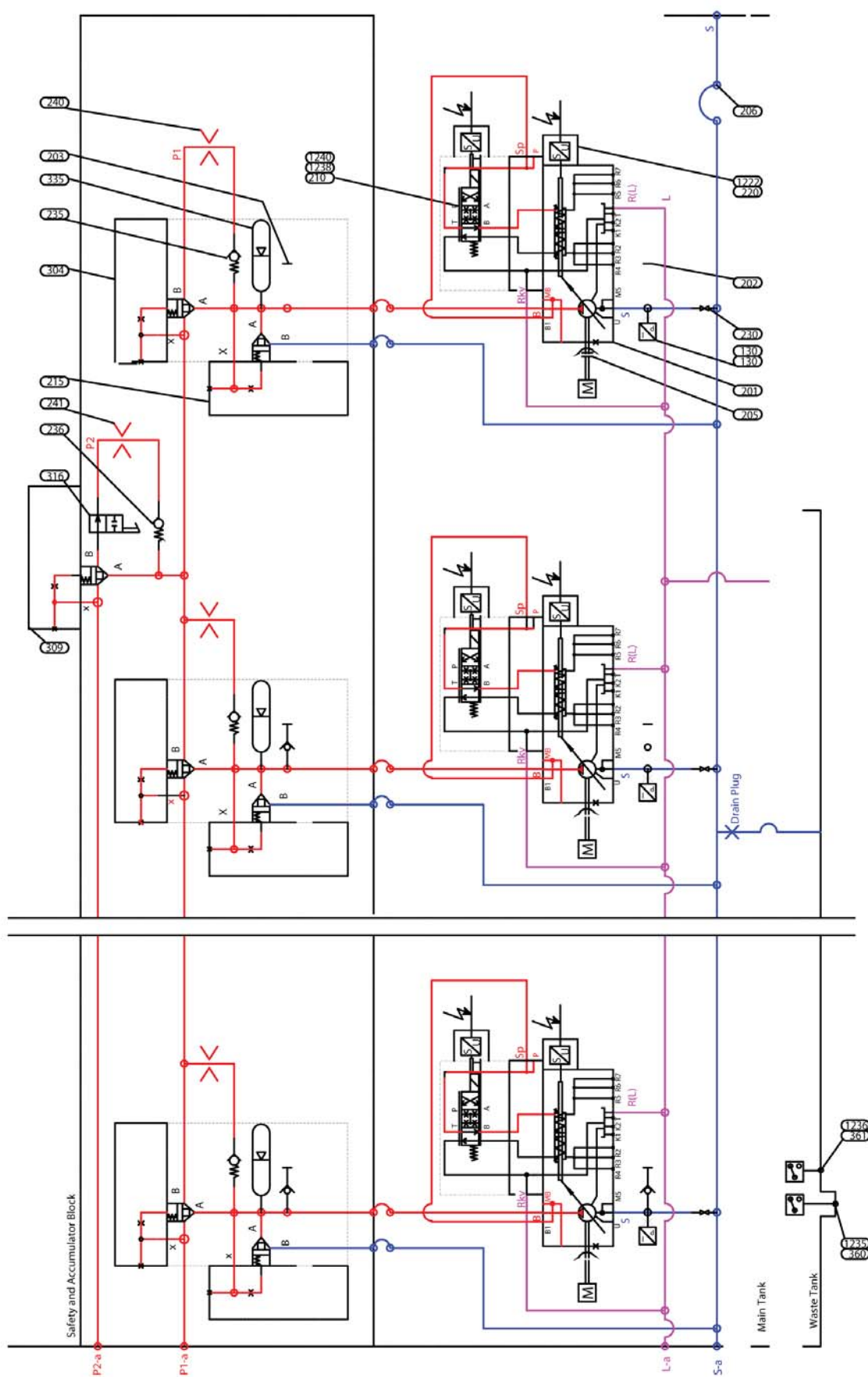


Hydraulic Cylinder Unit - Valid for Low Force Exhaust Arrangement Only



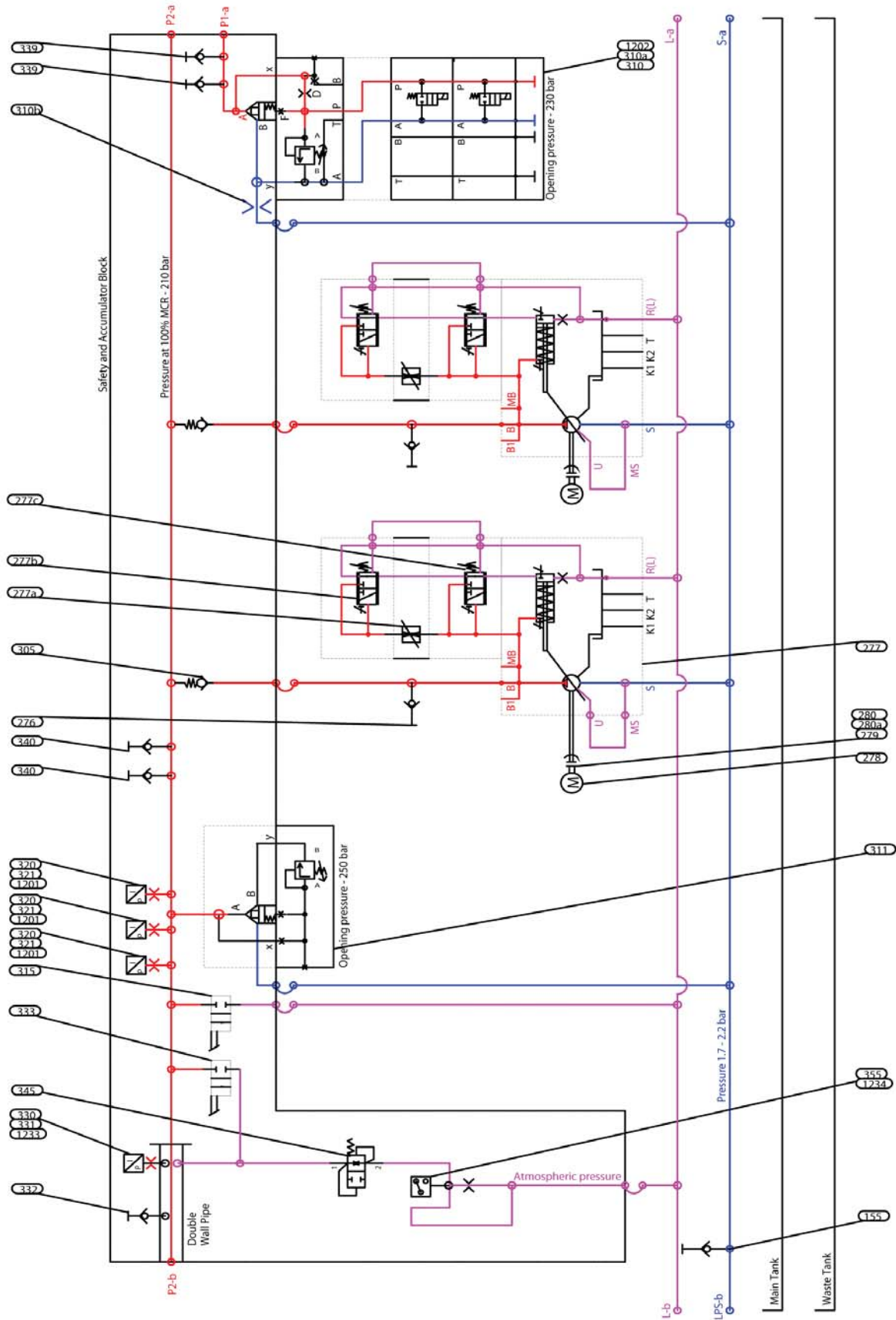
Combined HPS, Common LPS and FIVA - 300 bar

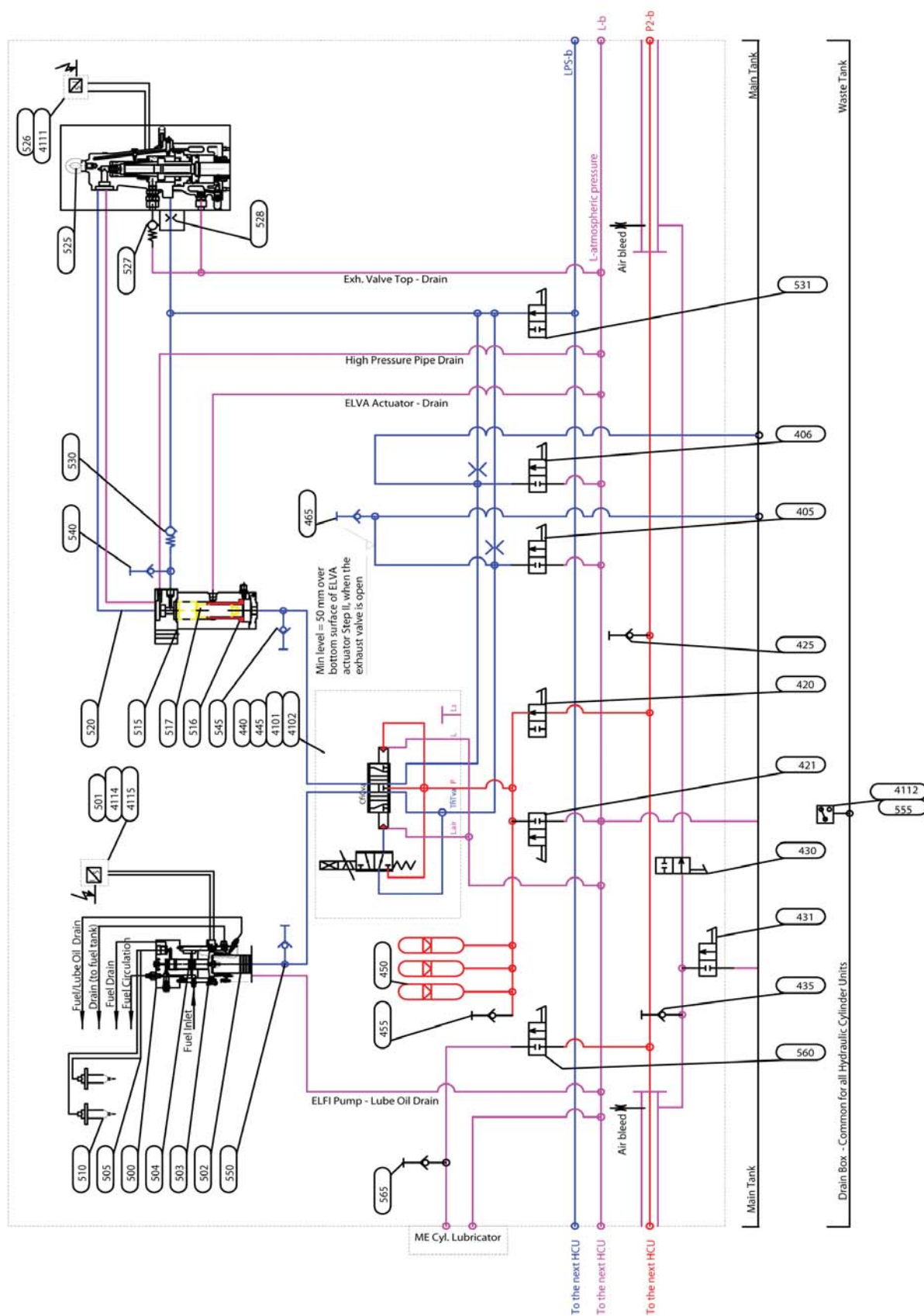
Drawing
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Combined HPS, Separate LPS and FIVA - 300 bar

Drawing
4555-0140-0001

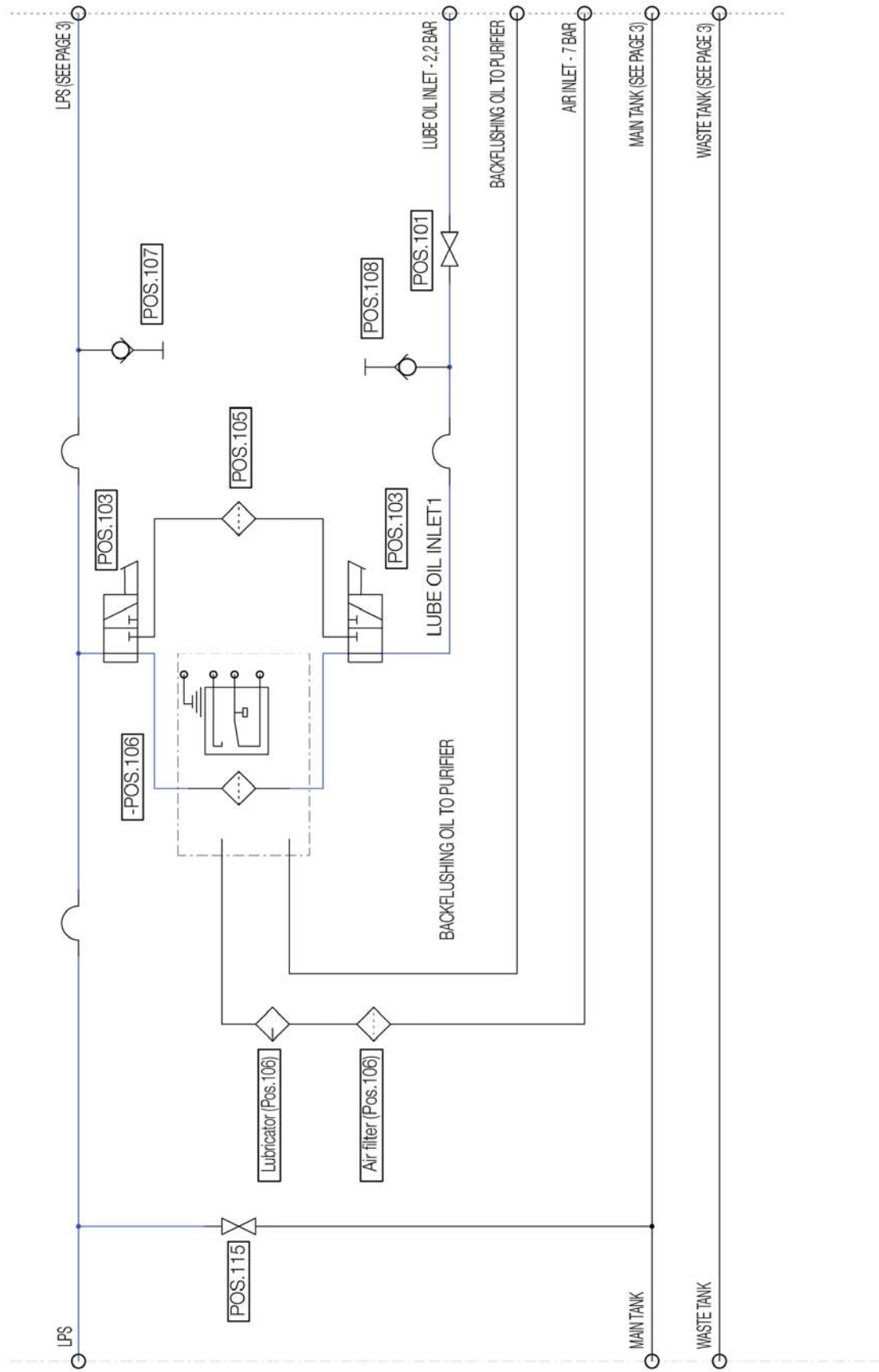




Combined HPS, Separate LPS and FIVA - 300 bar

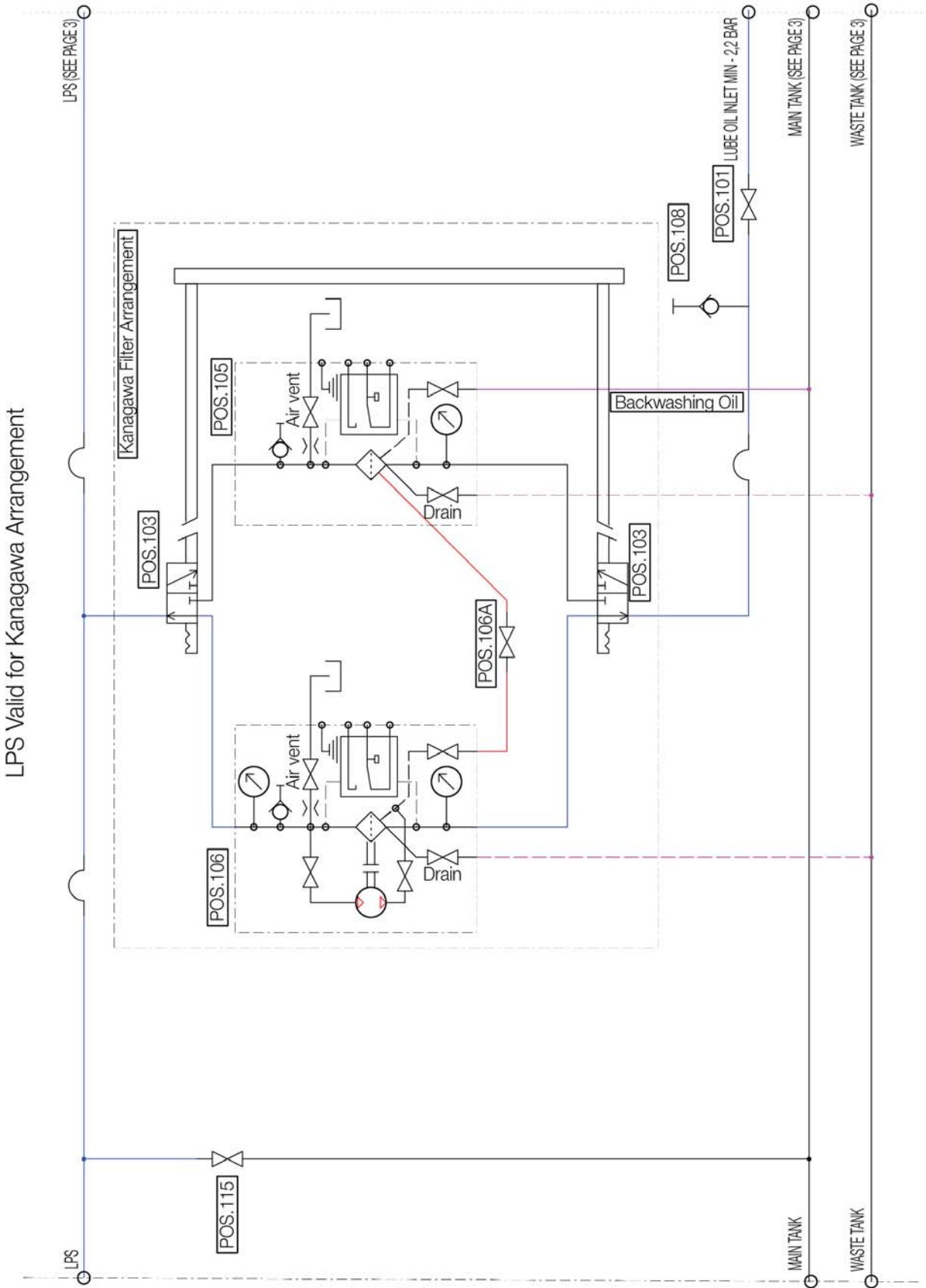
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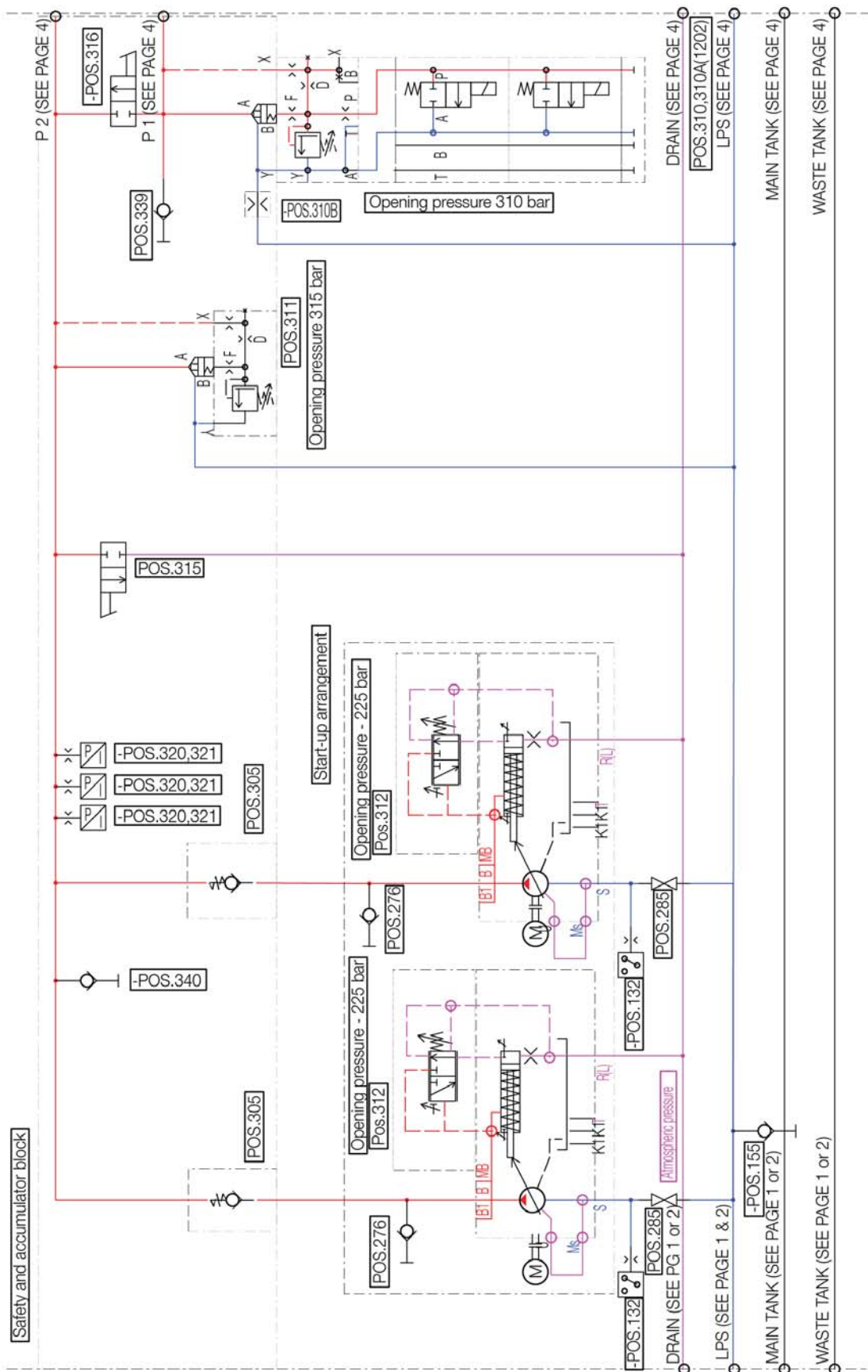
LPS Valid for Bollfilter Arrangement



Drawing
4555-0146-0003

**Gear Driven HPS and FIVA, Common LPS, ME Version 5, Rexroth
Pumps - 300 bar**

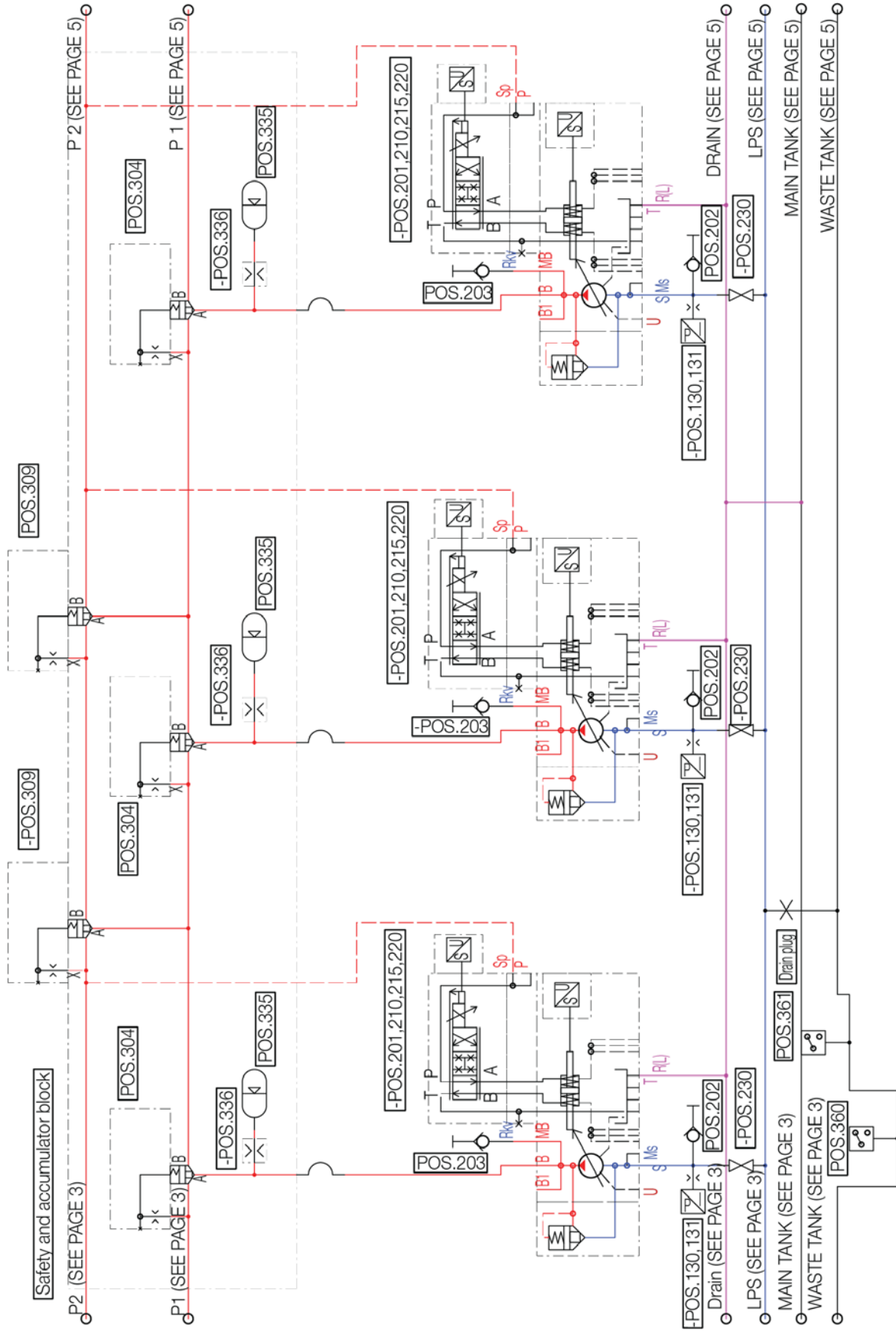


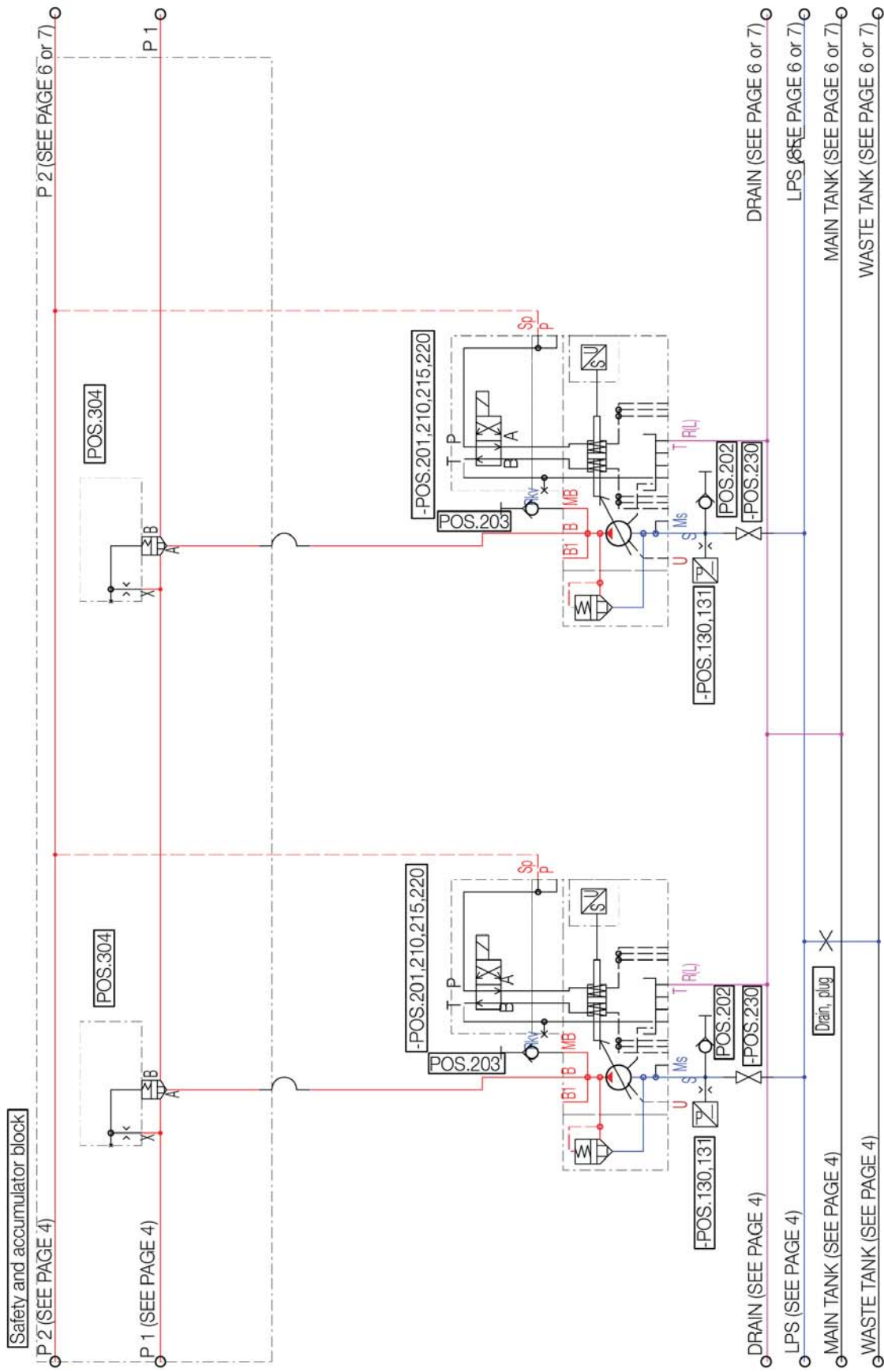


Gear Driven HPS and FIVA, Common LPS, ME Version 5, Rexroth Pumps - 300 bar

Drawing
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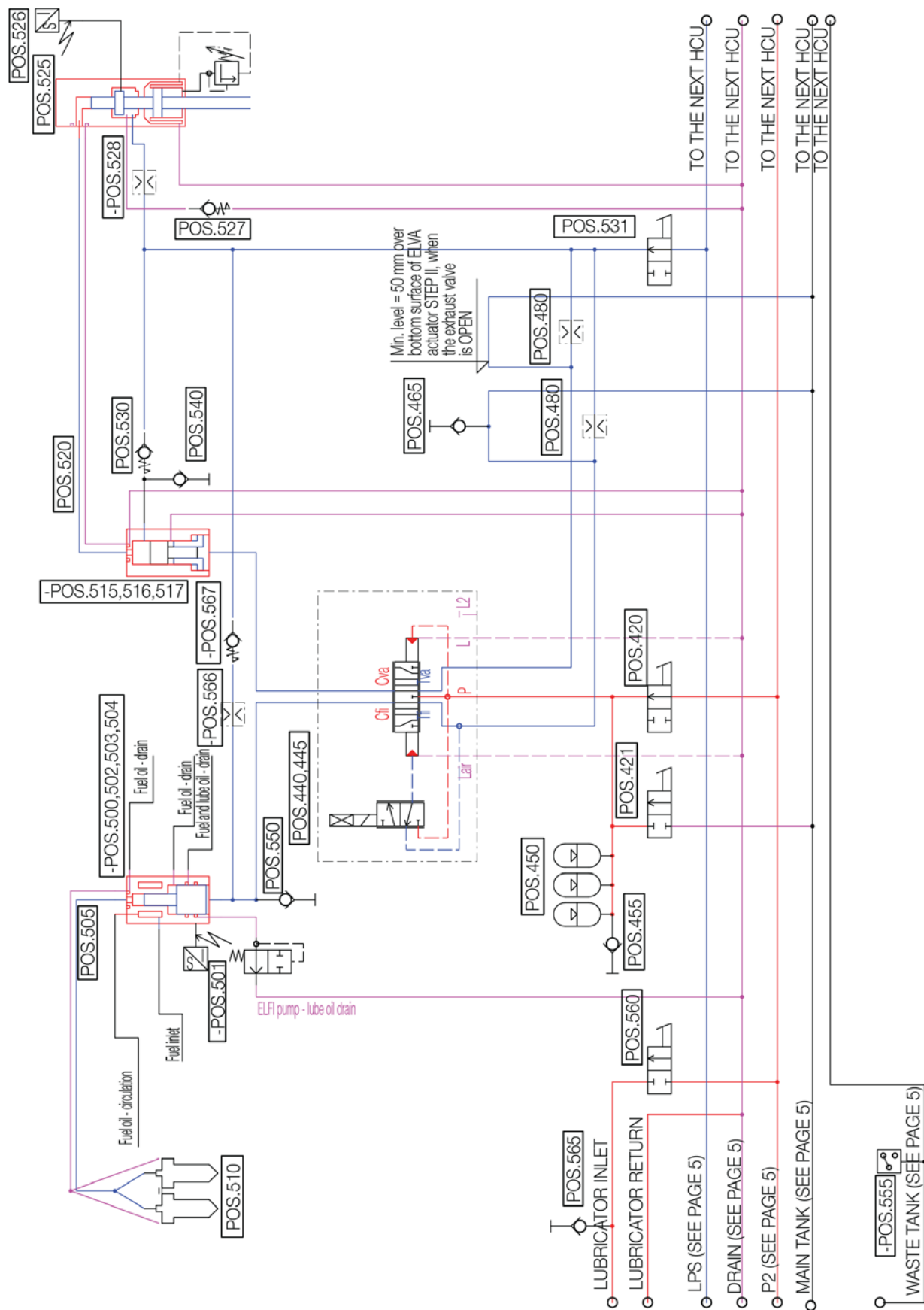
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Gear Driven HPS and FIVA, Common LPS, ME Version 5, Rexroth
Pumps - 300 bar

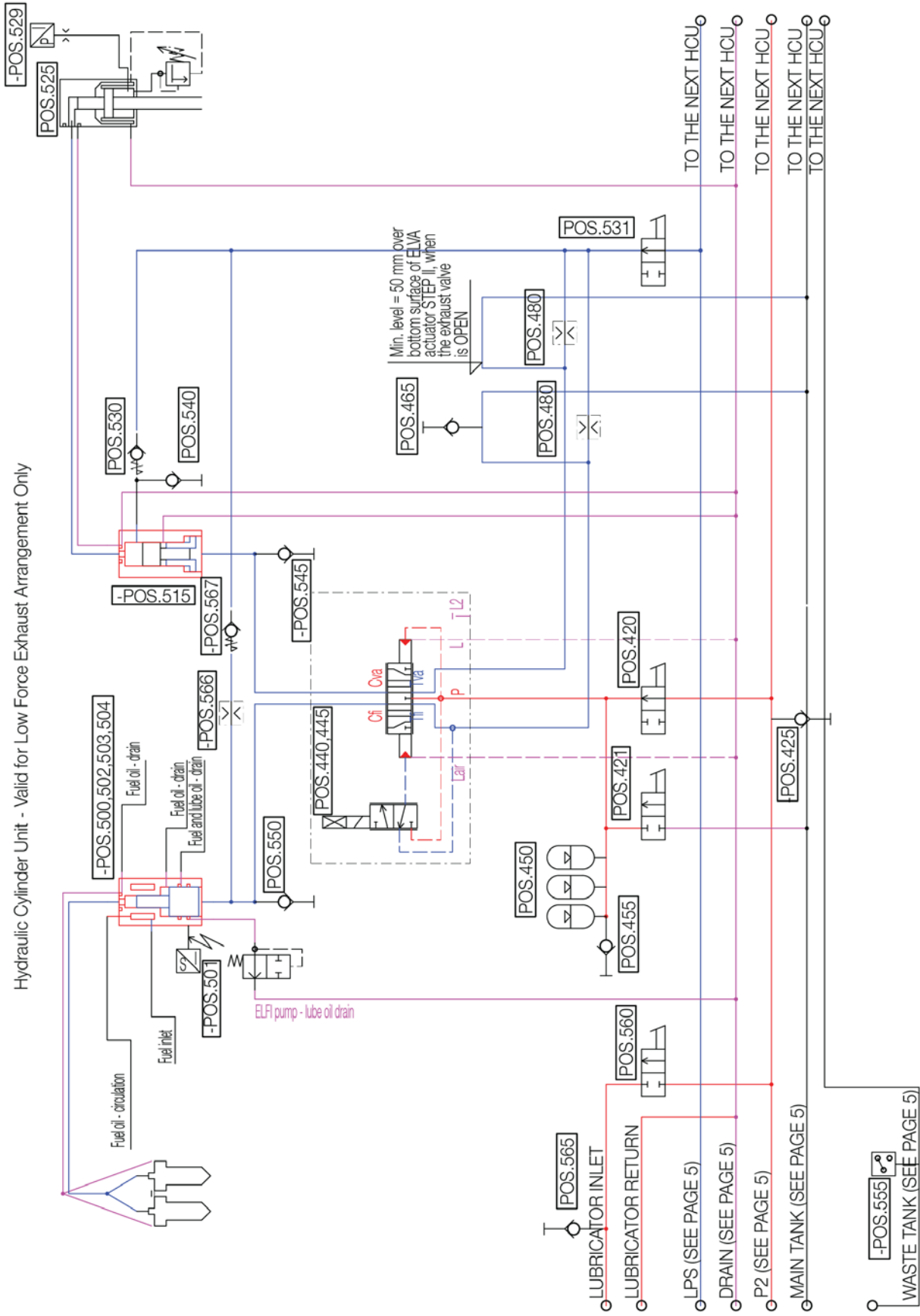




Gear Driven HPS and FIVA, Common LPS, ME Version 5, Rexroth Pumps - 300 bar

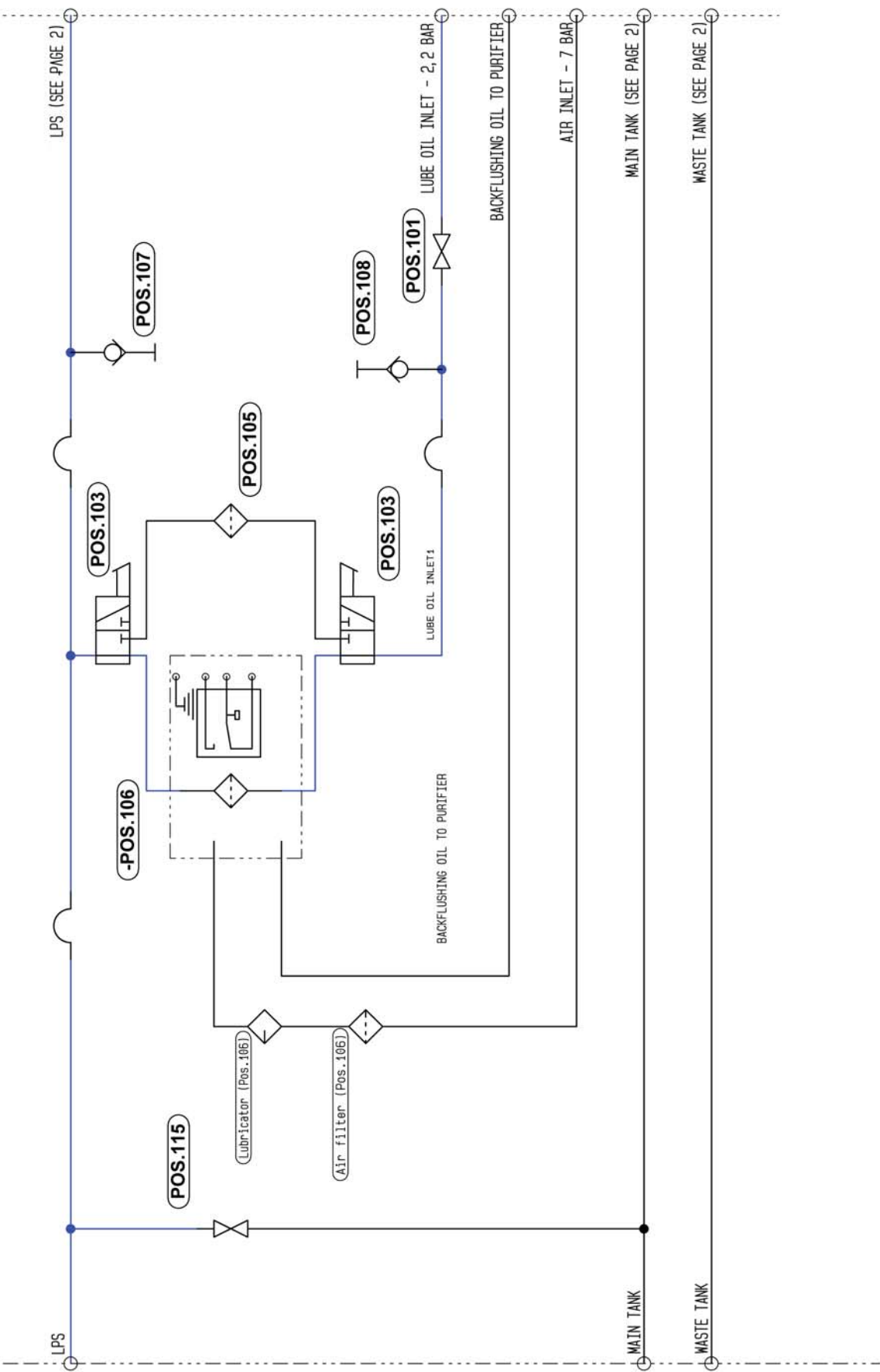
Drawing
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Gear Driven HPS and FIVA, Common LPS, ME Version 5, Rexroth Pumps - 300 bar

Drawing
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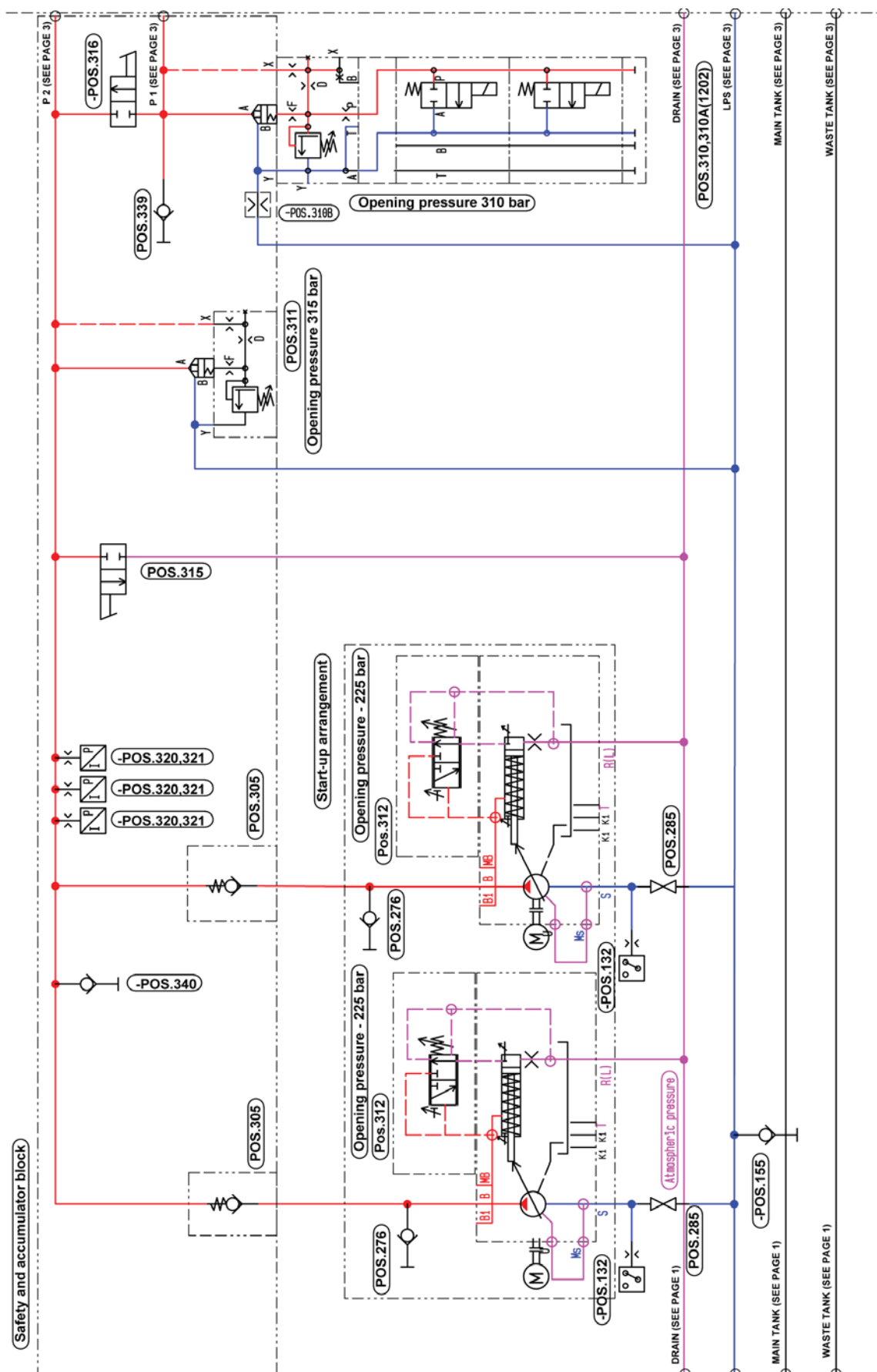


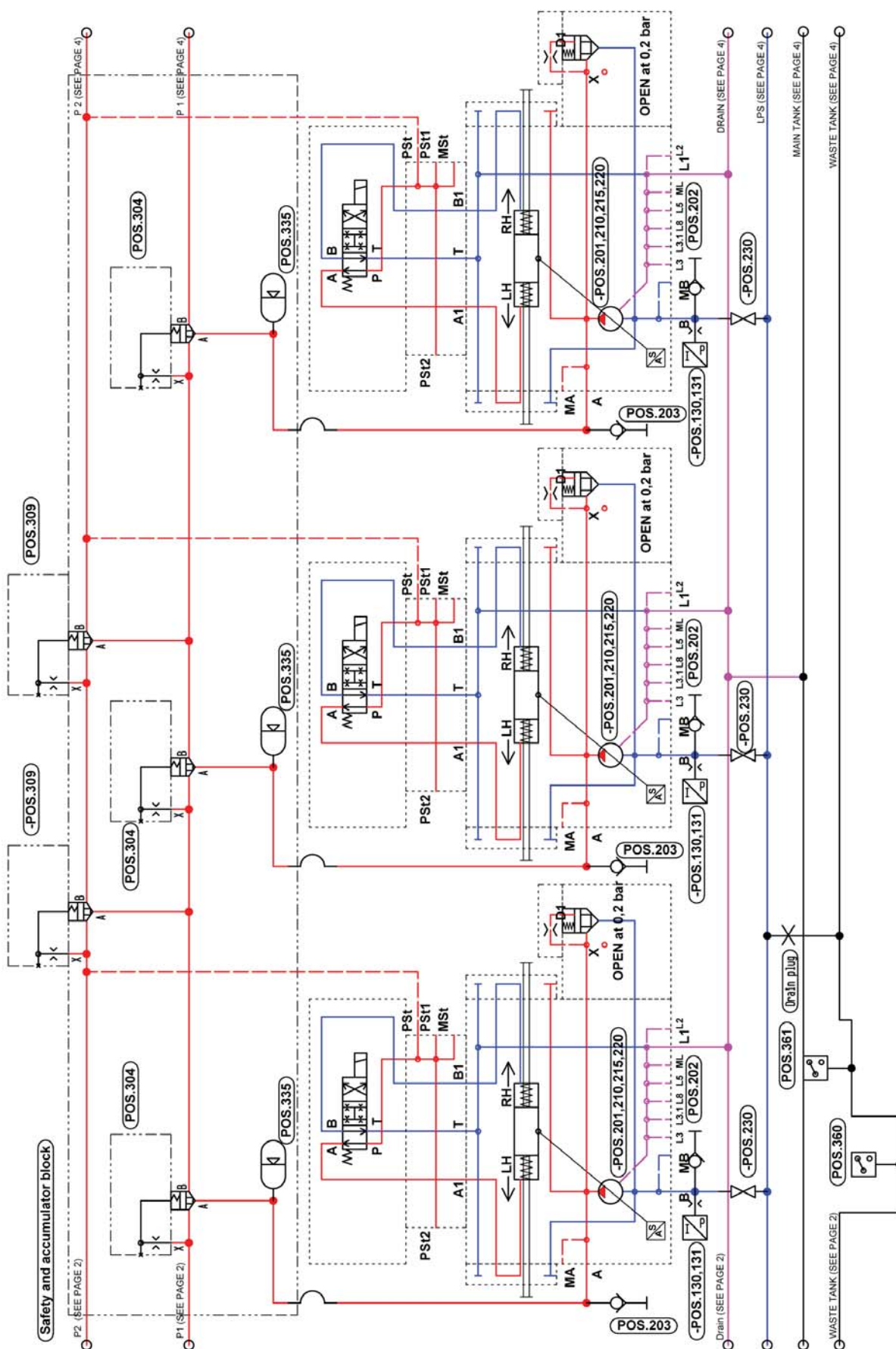
Gear Driven HPS and FIVA, Common LPS, Eaton Pumps - 300 bar

Drawing
4555-0147-0002

Gear Driven HPS and FIVA, Common LPS, Eaton Pumps - 300 bar

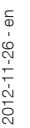
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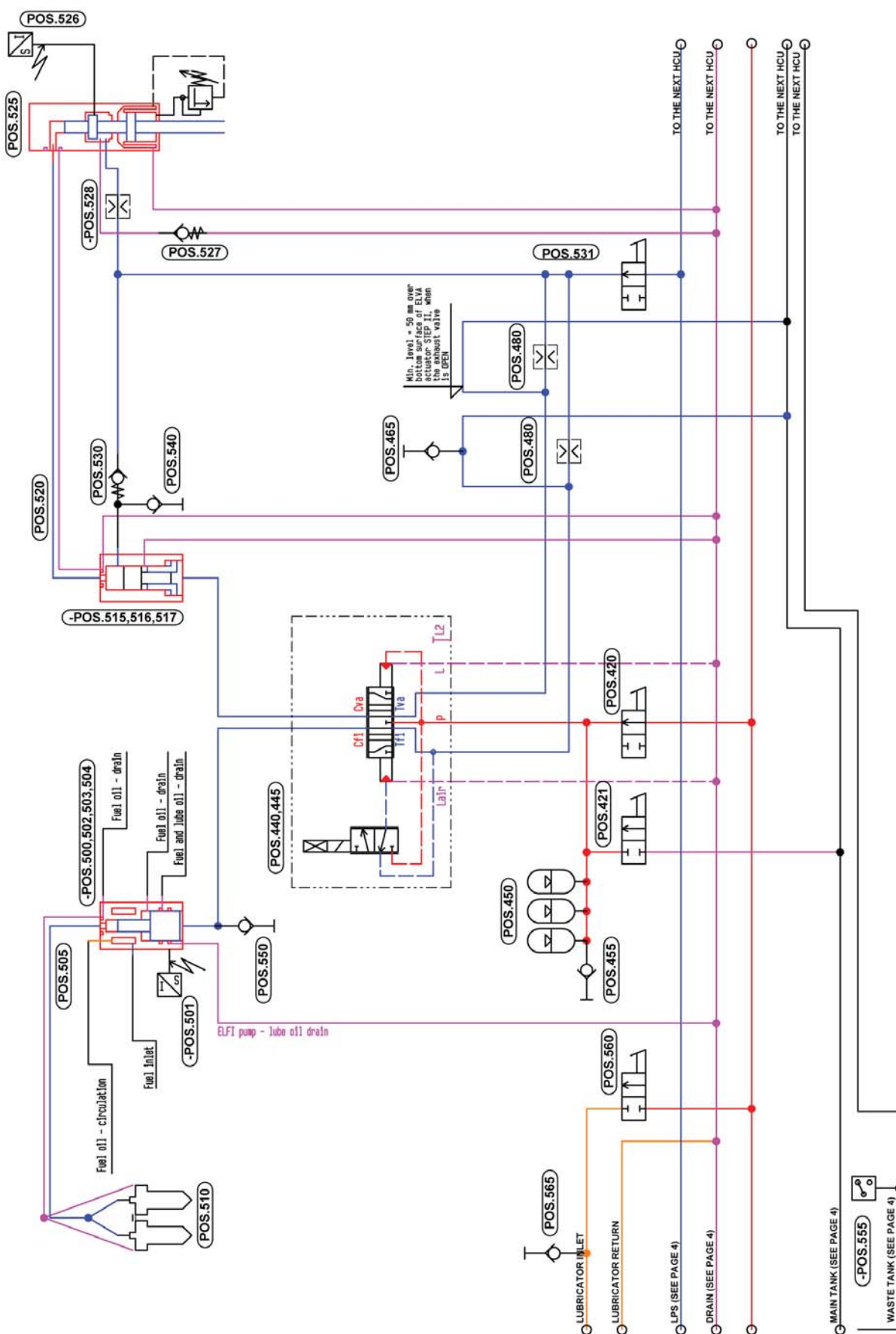




Gear Driven HPS and FIVA, Common LPS, Eaton Pumps - 300 bar

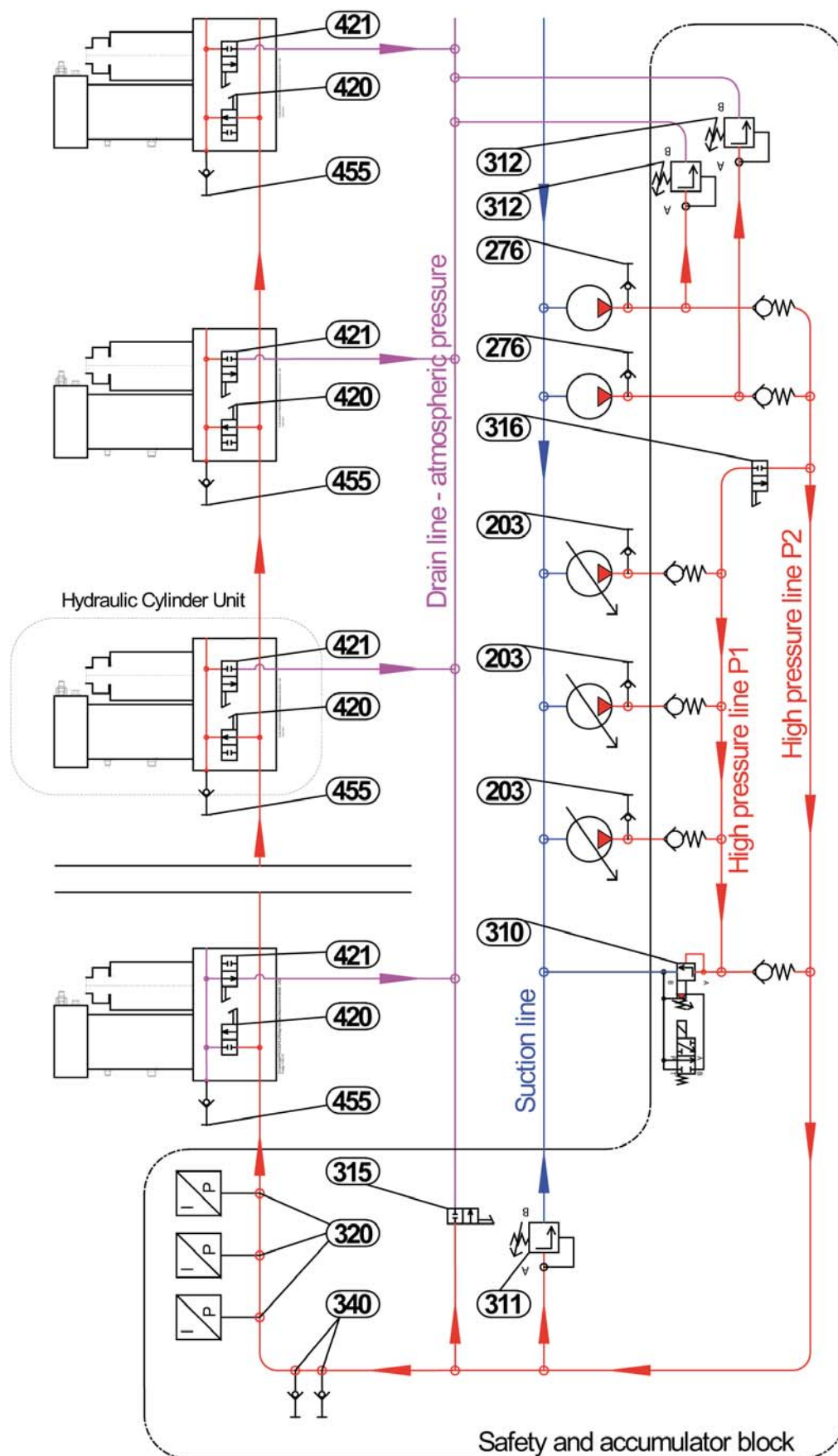
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Gear Driven HPS and FIVA, Common LPS, Eaton Pumps - 300 bar

Drawing
4555-0147-0002

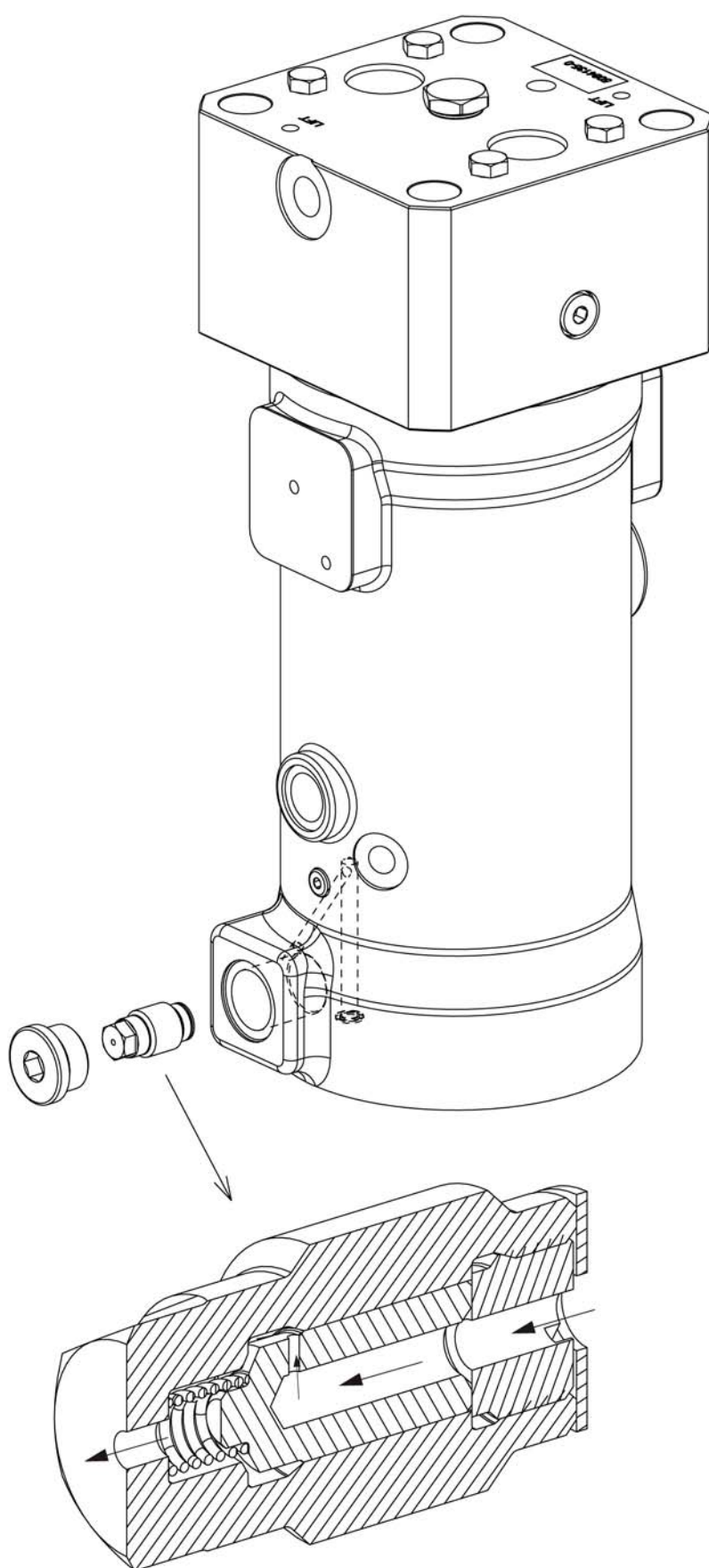


Detection of Malfunction and Leaks in Hydraulic System

Drawing
4555-0150-0001

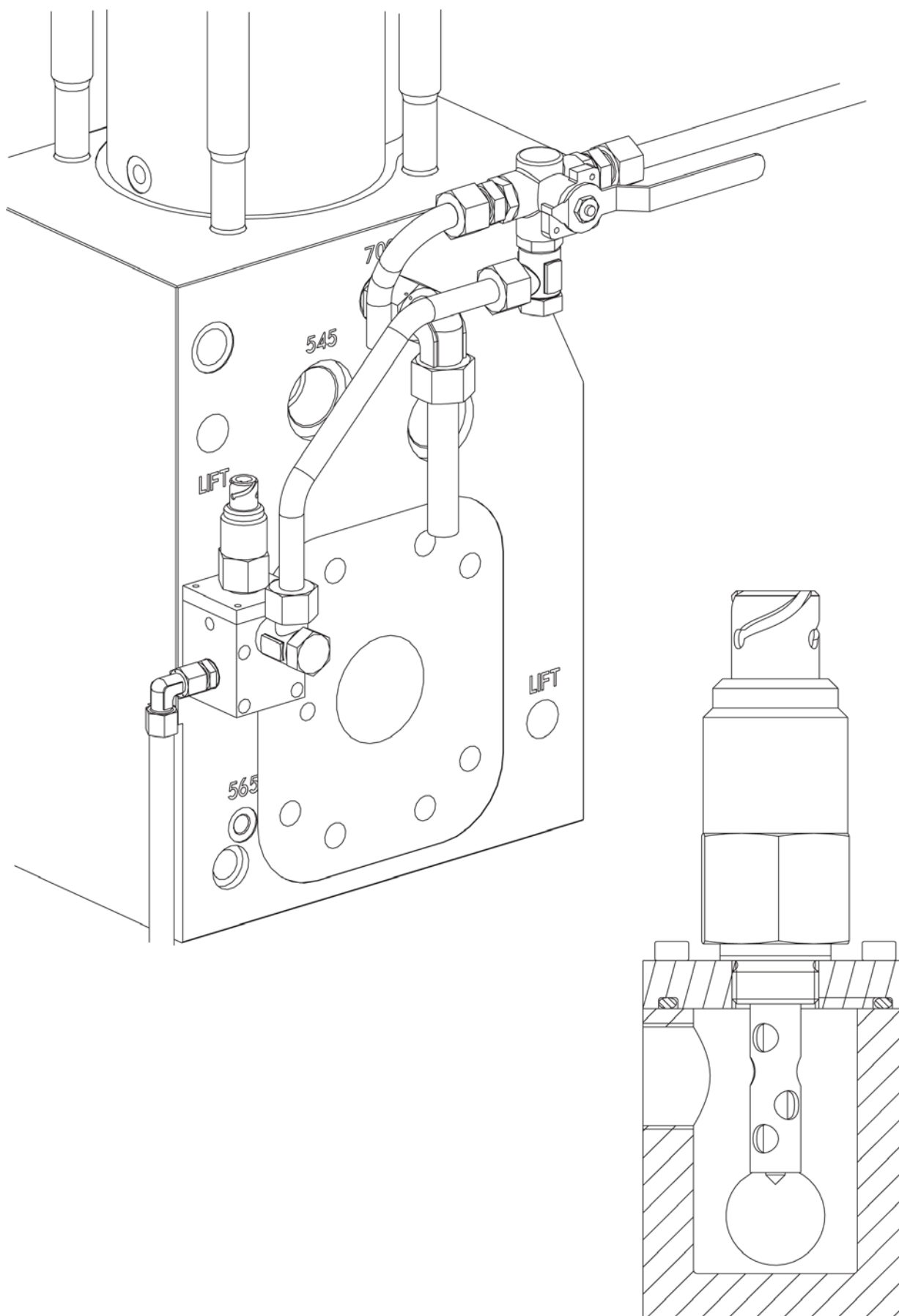
Basic Procedures

Item	Function	Possibilities	Remarks
Measuring point 276	Pressure in START-UP system arrangement.	Pressure adjustment at valve 310, 311 and 312. Investigation of pressure building time. Investigation of pumps, pressure and displacement ability.	See the pressure at the MOP (Engine STAND-BY). Normal pressure adjusted to 225 bar.
Measuring point 203	Delivery pressure at the gear driven pumps.	Investigation of delivered pressure. Investigation of gear driven pumps, pressure and displacement ability.	You can always see this pressure at the MOP. Normal pressure = System pressure.
Measuring point 340	System Pressure.	Investigation of pressure and possible leakages.	You can always see this pressure at the MOP.
Leak detection. Measuring point 276 and 340	Procedure for leak detection on entire system.	Investigation of pressure and possible leakages. Investigation of pressure building time.	Stop the engine. Start the pressure building procedure with the START-UP pump arr. Normally the pressure will increase to a pressure adjusted at the START-UP pump arrangement. (225 bar) If not, cut-out the Hydraulic Cylinder Unit, one by one, by closing valve 420. When the pressure increase to expected level, the leakage position has been found.
Leak detection. Measuring point 455	Procedure for leak detection on one Hydraulic Cylinder Unit.	Investigation of pressure drop time.	Stop the engine. Use the START-UP arrangement to build up the pressure. CLOSE valve 420 at the first HCU and investigate the pressure drop time. CLOSE valve 420 at the next HCU and investigate the pressure drop time. Compare the pressure drop time between all HCU's. The HCU with the fastest pressure drop time is the one leaking the most. BEFORE opening valve 420, stop the START-UP pumps and wait for the system to depressurize.



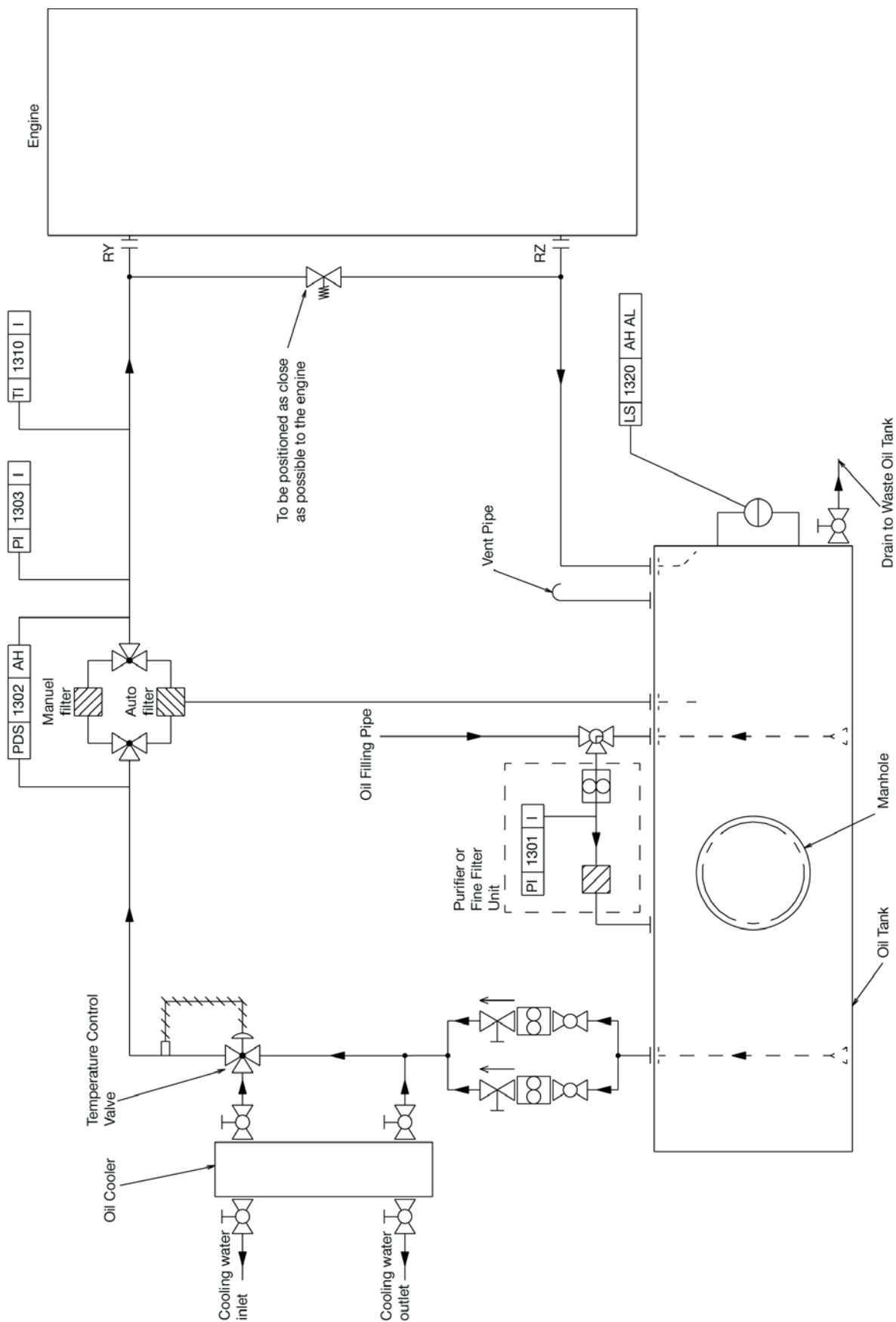
Throttle Valve on Fuel Oil Pressure Booster

Drawing
4555-0155-0002



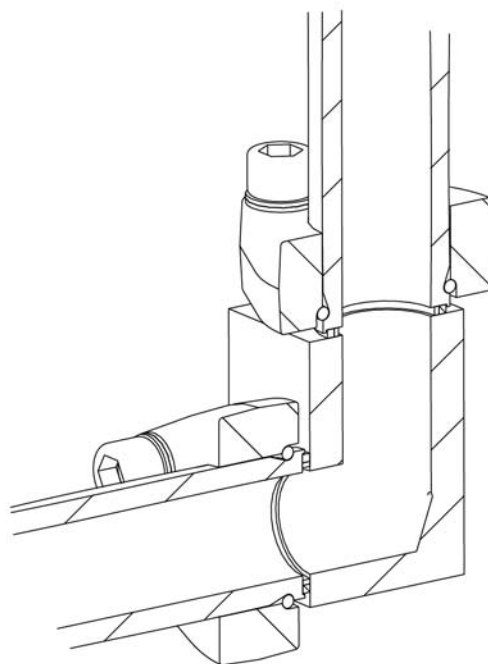
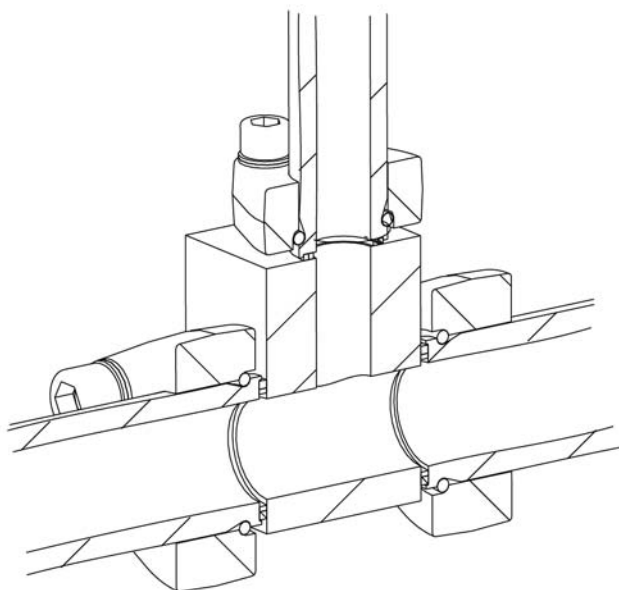
Level switch on ME Cylinder Lubricator

Drawing
4555-0165-0001



Hydraulic Control Oil System (Separate LPS)

Drawing
4555-0170-0001

Single wall piping

Piping

Drawing
4555-0171-0002

Safety**Precautions**

for detailed sketch
see 0545-0100

○	Hydraulic power unit stopped and blocked
○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off safety air supply - Not ME Engines
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply

**Data**

Ref.	Description	Value	Unit
T45-24	Hydraulic actuator	100	kg
T45-28	Top Flange	30	kg
T76-01	Hydraulic pressure, dismantling	1400-1650	bar
T76-02	Hydraulic pressure, mounting	1500	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
7670-0100	011	Hydraulic pump, pneumatically operated
7670-0100	047	Hose with unions, 1500 mm
7670-0100	059	Hose with unions, 3000 mm
7670-0100	106	5-way distributor block, complete
7670-0200	-	Torque spanners
7670-0300	-	Lifting tools, etc
7670-0410	066	Slide caliper

NOTICE

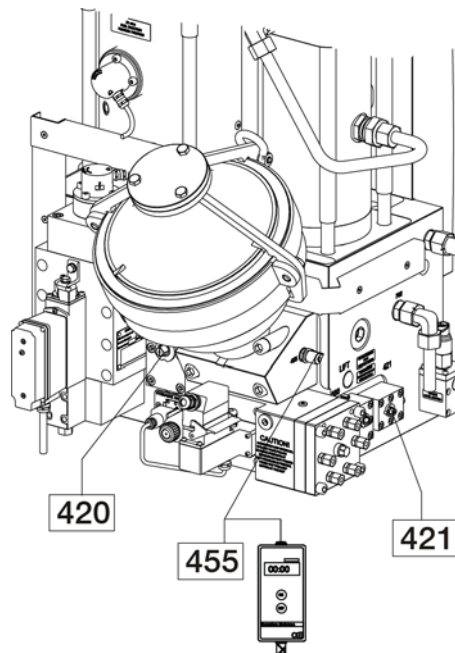
Great care must be taken to ensure that the area around the workplace is clean before and during any dismantling of the hydraulic system.

1. Preparation

Stop the engine and shut off the oil supply.

Close valve **420** and open valve **421** on the hydraulic block for the cylinder concerned.

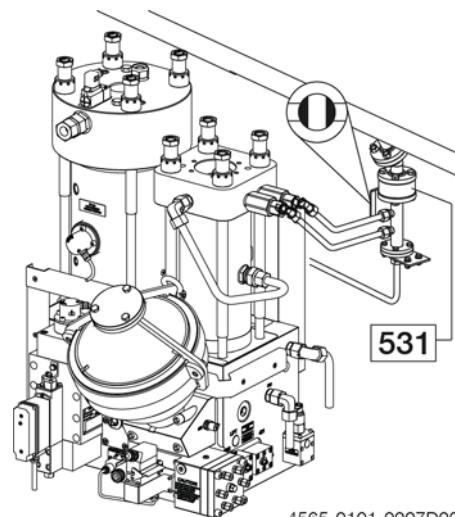
Mount a pressure gauge at minimess point No. **455**. Check the pressure to make sure that the hydraulic cylinder unit is pressure free.



4565-0501-0010C01

2. Valve 531

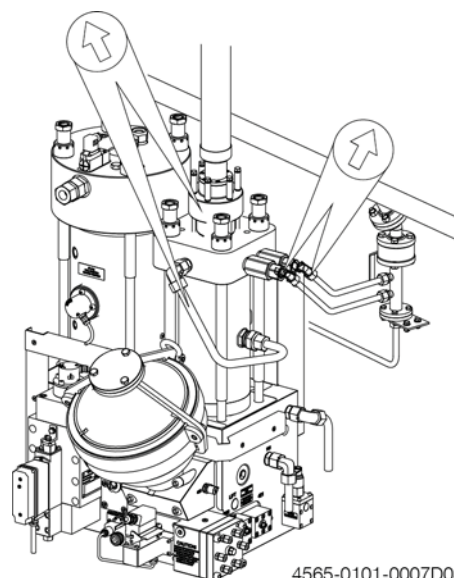
Close valve **531** for the actuator oil supply.



4565-0101-0007D02

3. High-pressure pipe Remove the hydraulic high-pressure pipe.
See work card 2265-0101.

Remove the oil pipes.



4. Actuator top cover Remove the pipes and nuts protecting the threads.

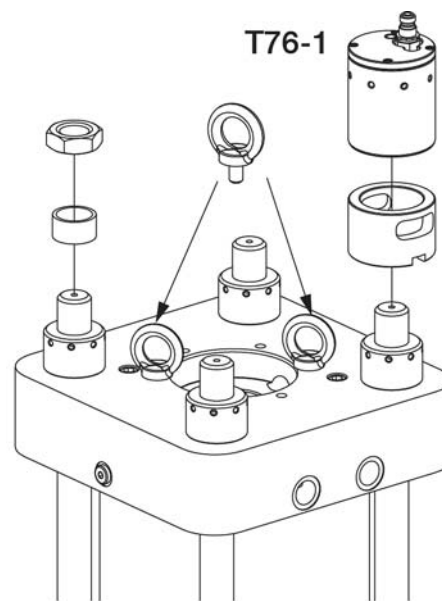
Mount the spacer rings and the hydraulic jacks on the nuts.

Pump up the hydraulic jacks to the dismantling pressure.
See data.

Loosen and remove the nuts.

For use of hydraulic tools, see work card 7665-0101.

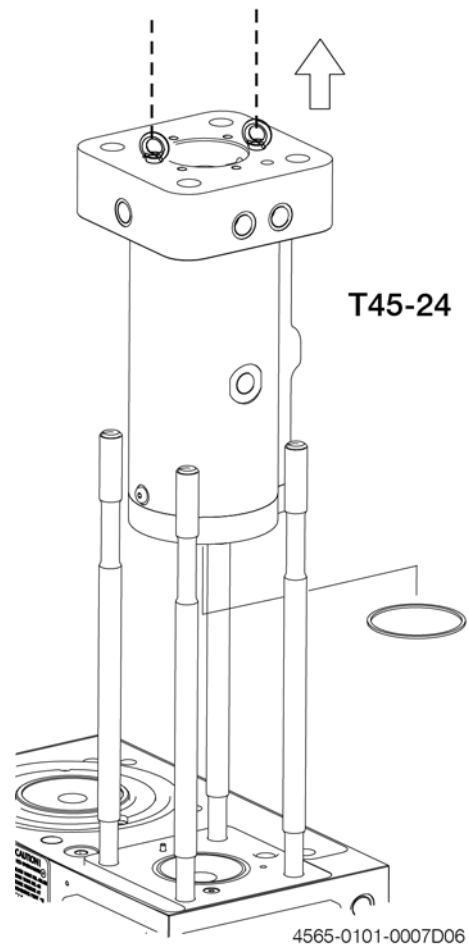
Mount two eye bolts in the top flange of the actuator.



5. Actuator unit

Lift the actuator clear of the hydraulic block.

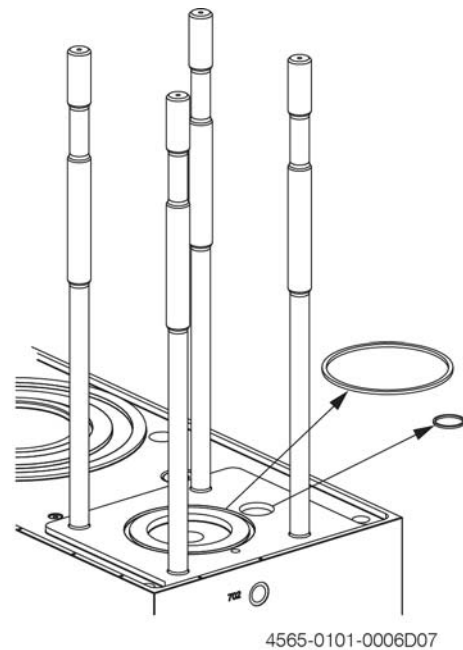
Remove the sealing rings from the bottom of the actuator, and discard it.



6. Sealing ring

Remove and discard the sealing ring.

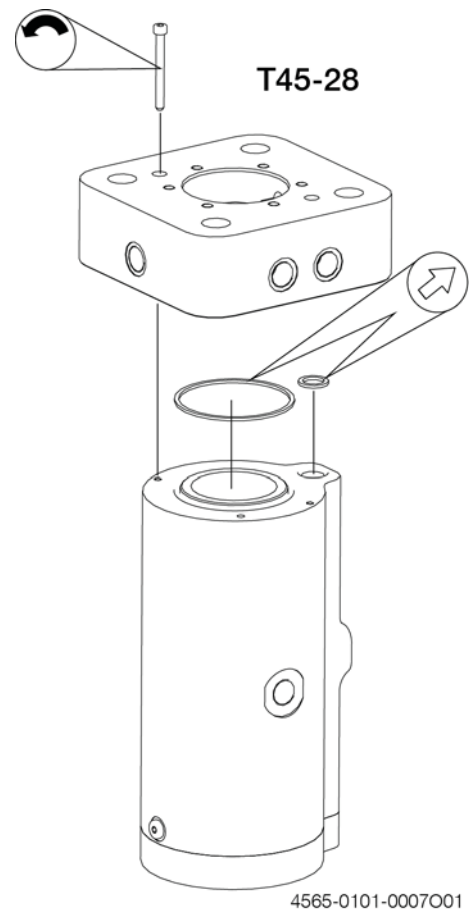
Clean the face on the hydraulic block.



1. Top cover

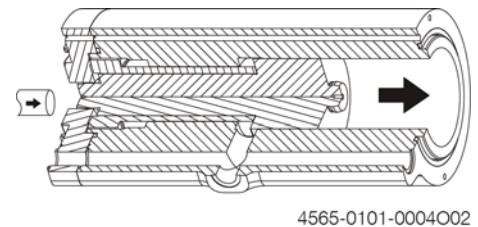
Remove the two screws which retain the top cover to the actuator housing.

Lift away the top cover and discard the sealing rings.



2. Dismount the piston

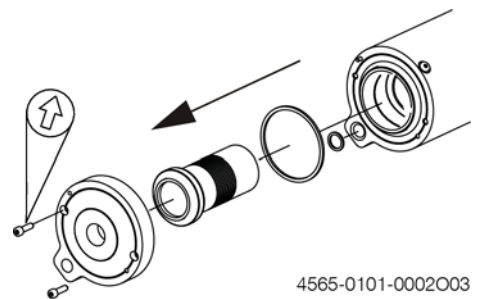
Place the actuator housing on the side. Push out the inner piston with a brass mandrel.



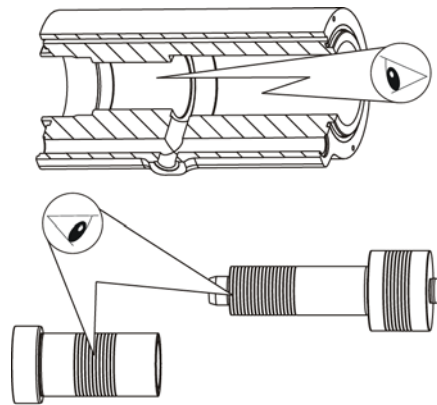
3. Bottom plate

Remove the bottom plate and the outer piston from the oil cylinder.

Remove and discard the sealing rings.

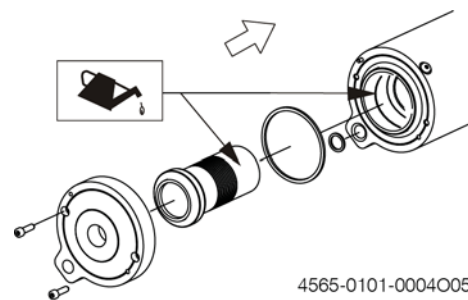


4. Check and clean Clean all parts and check all running surfaces for abnormal wear and scores.



4565-0101-0004O04

5. Mount outer piston Lubricate the cylinder inside with lubricating oil.
- Mount the outer piston in the actuator housing.
- Mount new sealing rings.
- Mount the retaining tool.



4565-0101-0004O05

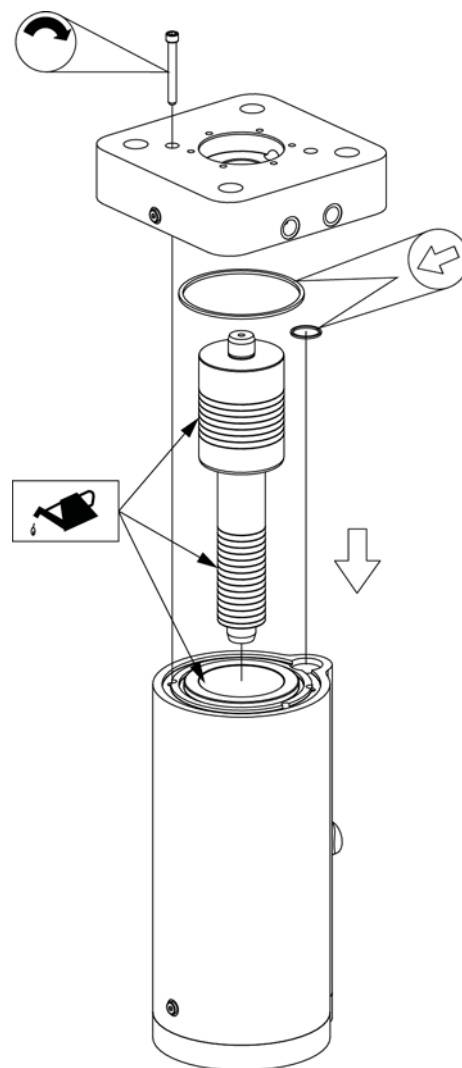
6. Mount top cover

Lubricate the upper piston on all sliding surfaces.

Mount the piston in the actuator housing.

Mount new sealing rings.

Mount the top cover and tighten the screws.



4565-0101-0006006

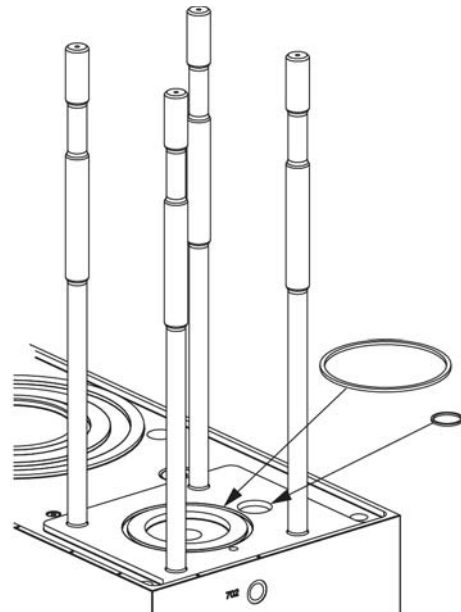
NOTICE

Great care must be taken to ensure that the area around the workplace is clean before and during assembly of the hydraulic system.

1. Sealing rings

Mount new sealing rings on the oil cylinder bottom piece.

Check that the face on the HCU is clean.



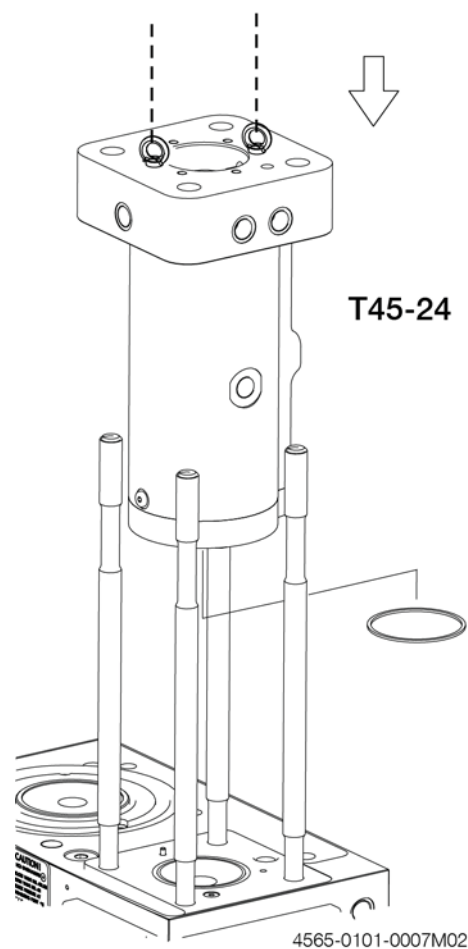
4565-0101-0006M01

2. Mount sealing rings & land actuator

Check the oil hole and the face of the hydraulic block, and the bottom of the hydraulic actuator, to see that they are clean and free of impurities.

Mount two eye bolts in the top of the actuator assembly and a new sealing ring in the bottom groove.

Carefully land the actuator on the hydraulic block.



3. Tighten nuts

Remove the eye bolts.

Screw the nuts on to the studs.

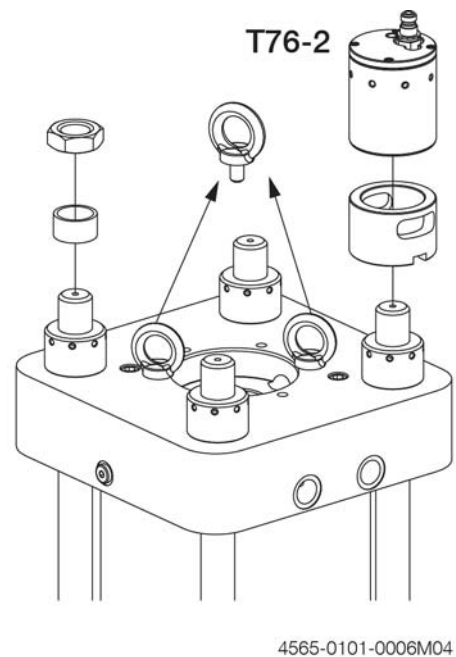
Mount the spacer rings and the hydraulic jacks over the nuts.

Pump up the jacks to the tightening pressure, as specified *in data*.

Tighten the nuts, and remove the hydraulic jacks and the spacer rings.

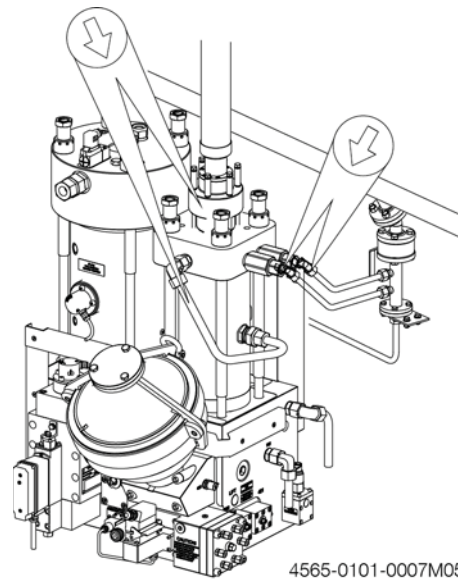
For use of hydraulic tools, see work card 7665-0101.

Mount the pipes on and the nuts protecting the thread.



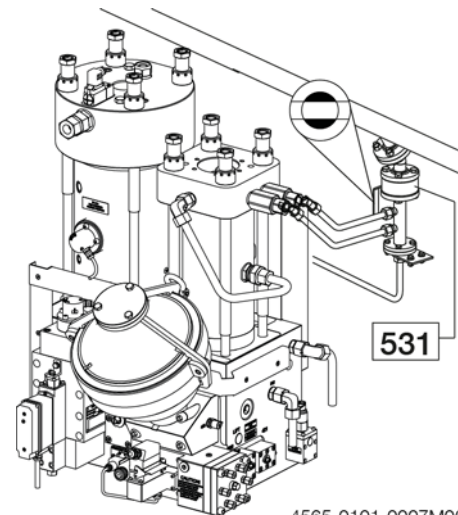
4. Mount the oil pipe Mount and tighten the oil pipe for oil supply.

Mount the hydraulic high-pressure pipe.
See work card 2265-0101.



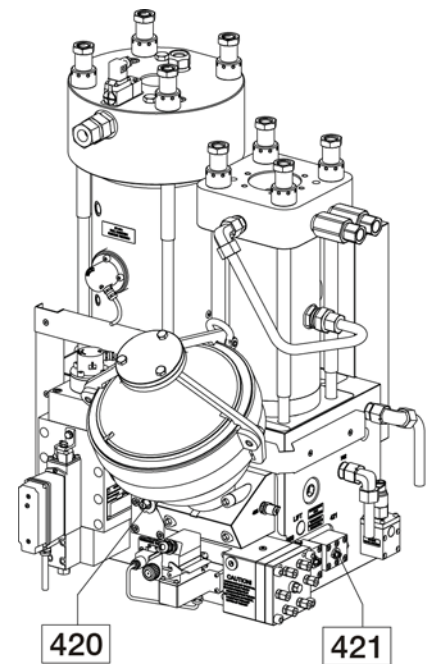
4565-0101-0007M05

5. Open oil supply Open valve **531** for actuator oil supply.



4565-0101-0007M06

6. Pressurise system Close valve **421**, and open valve **420** on the hydraulic block.



4565-0601-0010M02

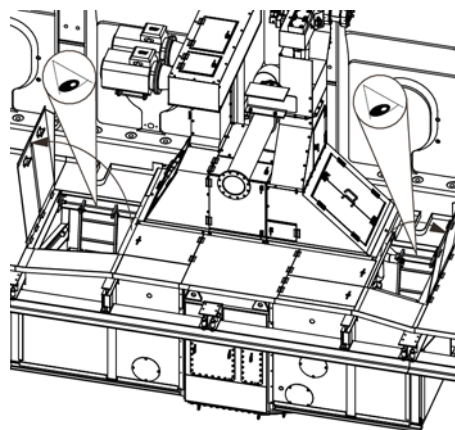
1. Preliminary steps Check that start-up and booster pumps are stopped before any part of the hydraulic system is disassembled.

NOTICE

Great care must be taken to ensure that the area around the workplace is clean before and during any dismantling of the hydraulic system.

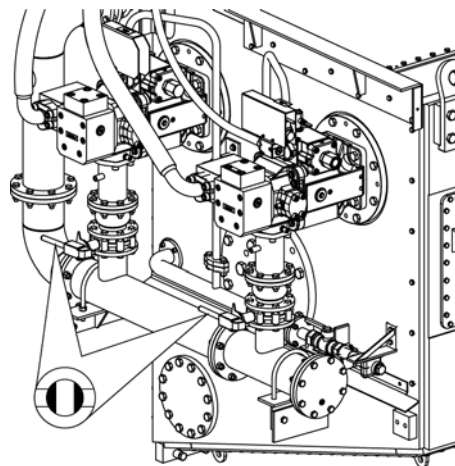
2. Open the access to the pumps Open the floor plate access hatch on the gallery above hydraulic pumps.

The pump casing can now be accessed from above.



4565-0201-0003D01

3. Close the suction valve Close the suction valve for the relevant pump.



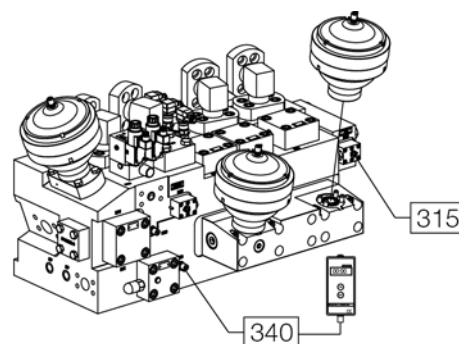
4565-0201-0003D02

4. Release the hydraulic pressure from the system

Mount a pressure gauge on the »minimess« coupling No. 340. Check the pressure.

Open valve 315 to release the hydraulic pressure from the system.

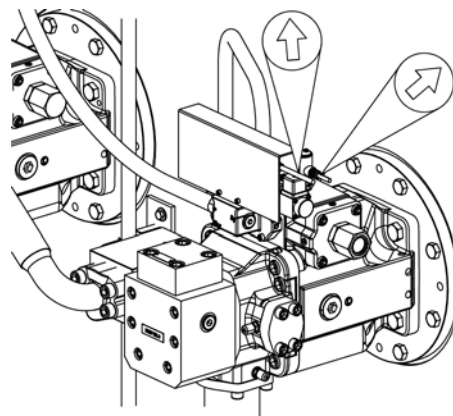
Check on the pressure gauge that the system is pressure free.



4565-0201-0003D03

5. Remove the electrical connections

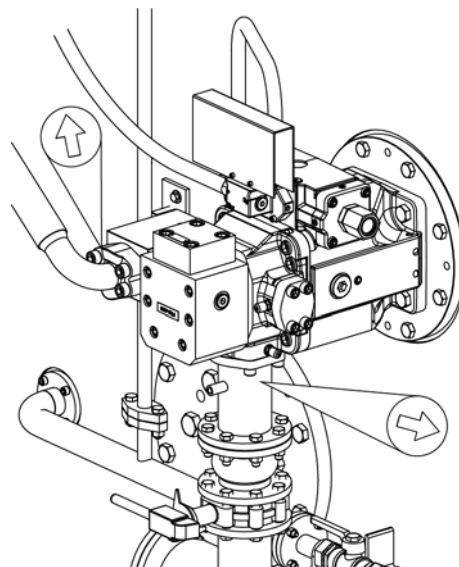
Unscrew the shield protecting, the solenoid valve and remove the electrical connections to the solenoid valves.



4565-0201-0003D04

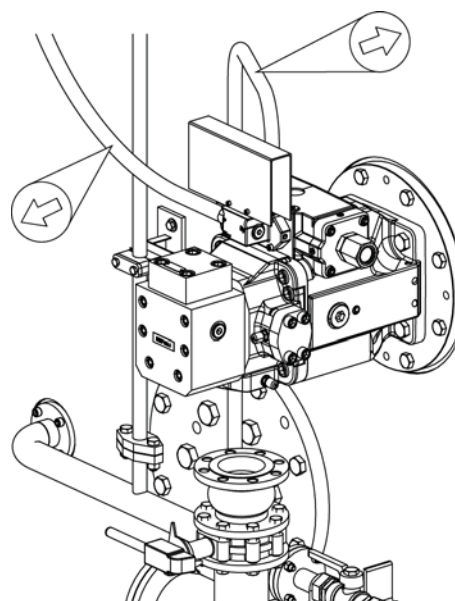
6. Unscrew the bolts from the flange on the suction pipe

Unscrew the bolts from the discharge pipe and remove the HP-hose.



4565-0201-0003D05

7. Servo oil pipes Unscrew the servo oil pipes.



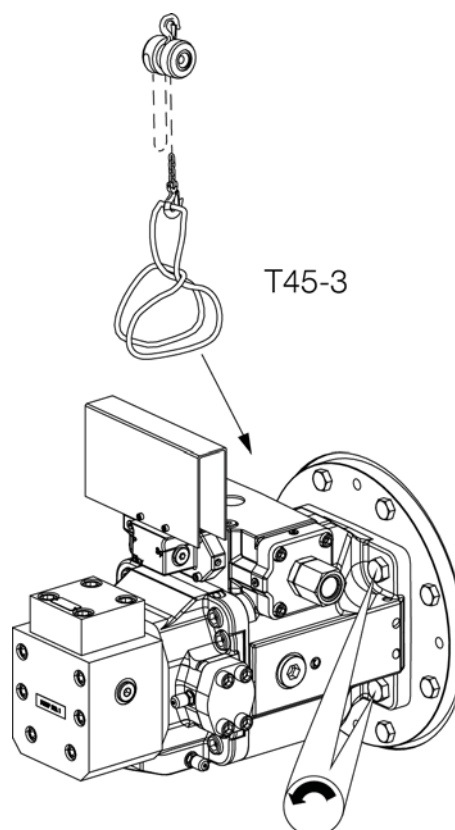
4565-0201-0003D06

8. Before lifting the pumps Suspend a tackle above the hydraulic pump and put a strap around the pump.
Hook the tackle on to the strap and tighten up.

NOTICE

The pump must be in balance when it is lifted.

Unscrew the screws in the end-flange..



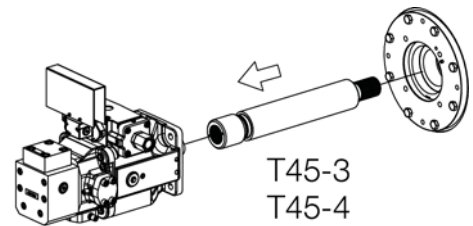
4565-0201-0003D07

9. Pull out the pumps

Carefully pull out the pump and the internal drive shaft.
See data.

For overhaul of the pump, send it to an authorized MAN Diesel & Turbo workshop.

The internal drive shaft also functions as an overload protection. If it is necessary to renew the drive shaft, contact MAN Diesel & Turbo for advice.

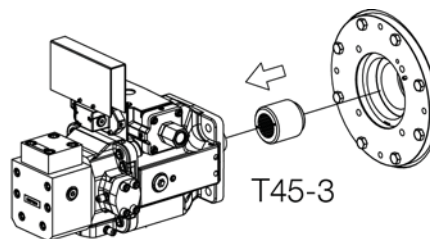


4565-0201-0003D08

1. Dismantle the hydraulic pump

This procedure is to be performed if the drive shaft has been overloaded and subsequently has to be overhauled.

Remove the broken end of the internal drive shaft.

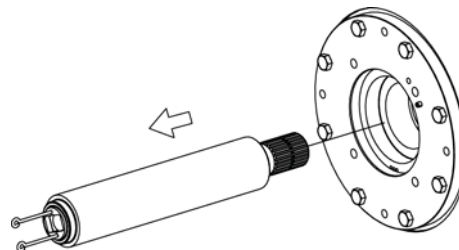


4565-0201-0003O01

2. Pull out the drive shaft

Screw two pieces of threaded rod into the threaded holes in the drive shaft and pull it out.

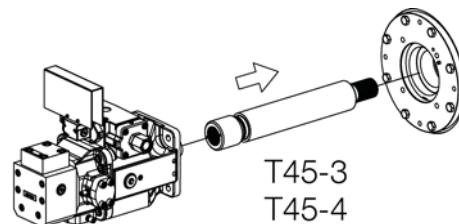
Discard the broken drive shaft.



4565-0201-0003O02

3. New drive shaft

Mount a new internal drive shaft and the hydraulic pump.



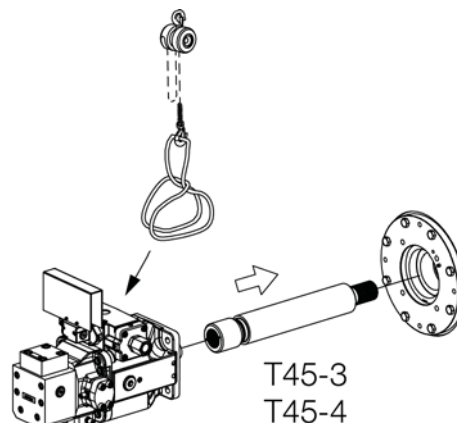
4565-0201-0003O03

1. First

Mount the intermediate shaft in the gearbox. Suspend a tackle above the gear box and put a strap around the hydraulic pump.

NOTICE

Great care must be taken to ensure that the area around the workplace is clean before and during assembly of the hydraulic system.

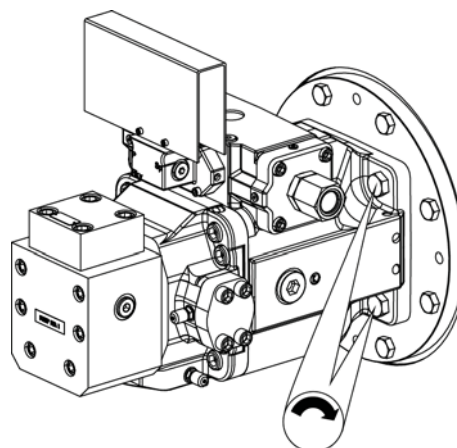


4565-0201-0003M01

Lift up the pump in position, and carefully push in the pump to engage the pump shaft with the drive shaft.

2. Mount and tighten the nuts

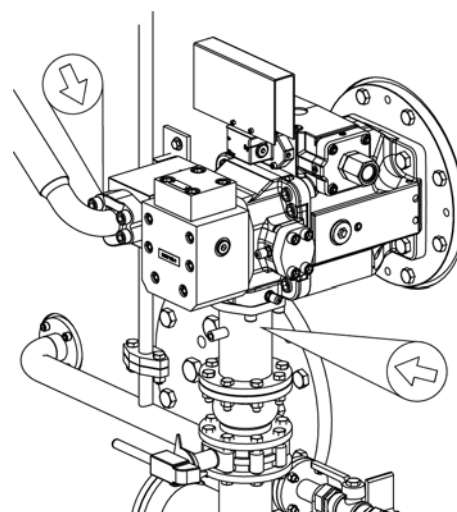
Mount and tighten the nuts on the pump flange.



4565-0201-0003M02

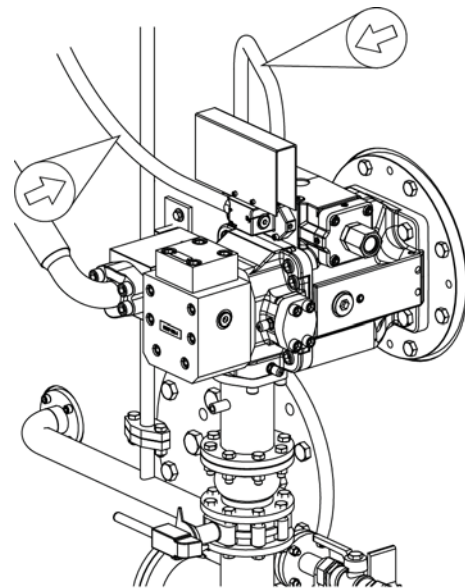
3. Mount the bolts in the flange on the suction pipe

Mount the discharge pipe and tighten the bolts.



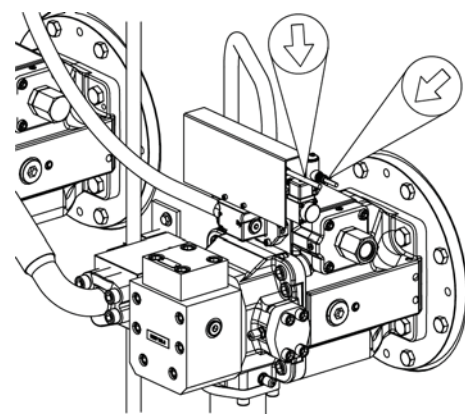
4565-0201-0003M03

4. Servo oil pipes Mount the servo oil pipes.



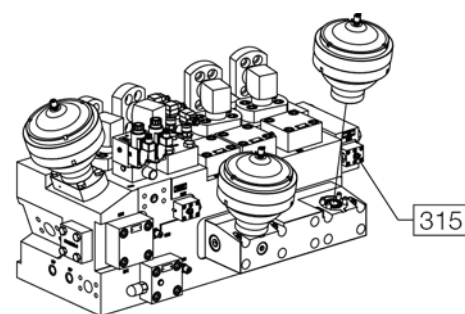
4565-0201-0003M04

5. Mount the electrical connections Mount the electrical connections to the solenoid valves and to the angle encoder.



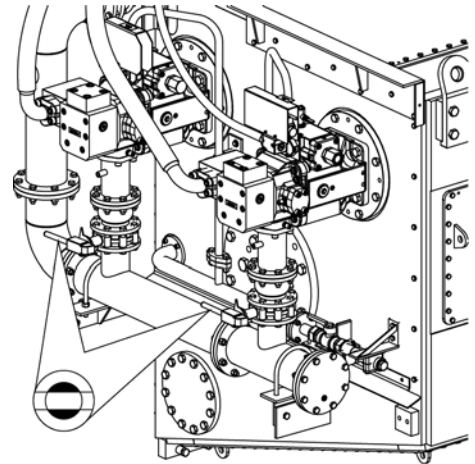
4565-0201-0003M05

6. Close valve 315 Close valve 315 on the flange in the front end of the HCU line.



4565-0201-0003M06

7. The suction valve
- Open up the suction valve for the relevant pump.
- Re-mount the cover and cross member.



4565-0201-0003M07

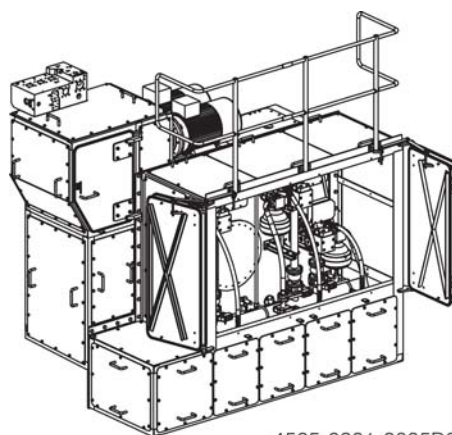
8. Close the gallery access
- Close the access covers plating on the gallery.

1. Preliminary steps Check that start-up and booster pumps are stopped before any part of the hydraulic system is disassembled.

NOTICE

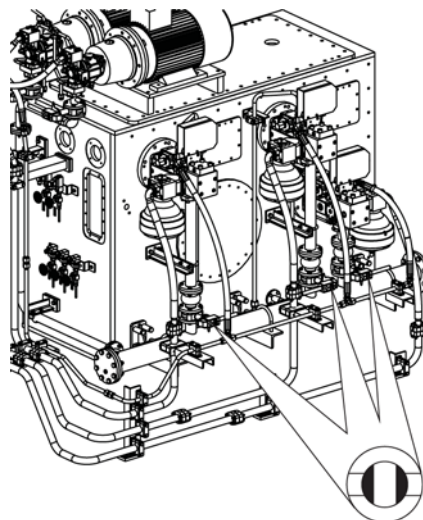
Great care must be taken to ensure that the area around the workplace is clean before and during any dismantling of the hydraulic system.

2. Open the access to the pumps Open the access hatch to the hydraulic pumps.



4565-0201-0005D01

3. Close the suction valve Close the suction valve for the relevant pump.



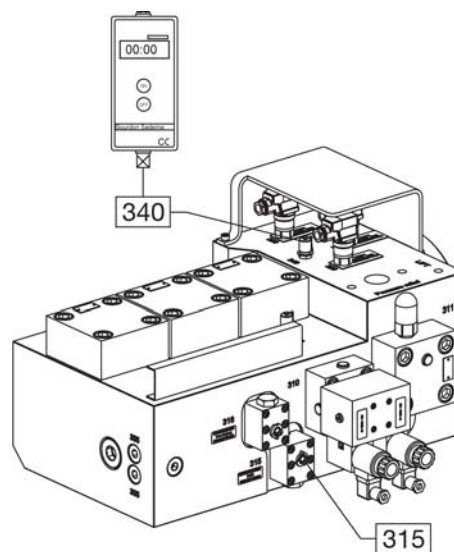
4565-0201-0005D02

4. Release the hydraulic pressure from the system

Mount a pressure gauge on the »minimess« coupling No. 340. Check the pressure.

Open valve 315 to release the hydraulic pressure from the system.

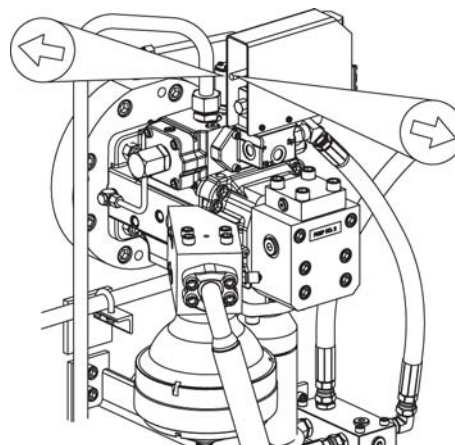
Check on the pressure gauge that the system is pressure free.



4565-0201-0004D03

5. Remove the electrical connections

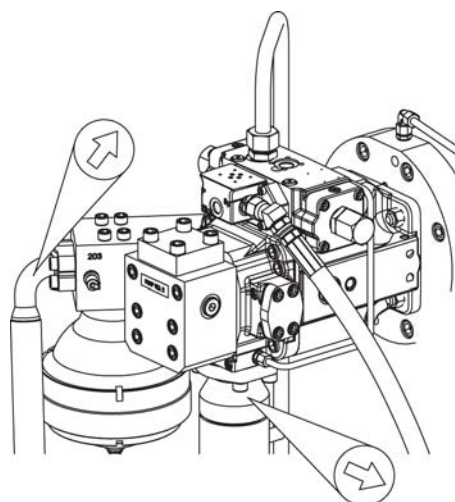
Unscrew the shield protecting, the solenoid valve and remove the electrical connections to the solenoid valves.



4565-0201-0004D04

6. Unscrew the bolts from the flange on the suction pipe

Unscrew the bolts from the discharge pipe and remove the HP-hose.

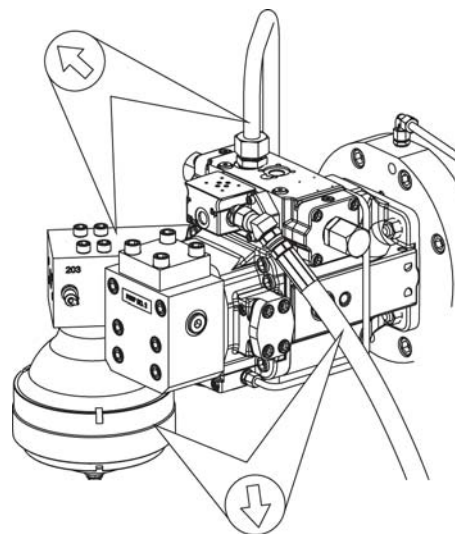


4565-0201-0004D05

7. Servo oil pipes

Unscrew the servo oil pipes and remove the pipes.

Remove the accumulator and the block connected.



4565-0201-0004D06

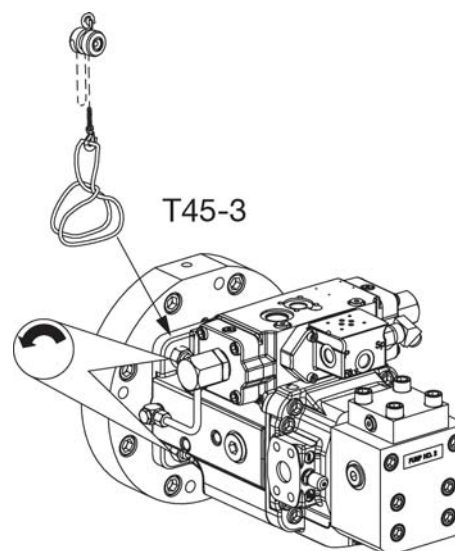
8. Before lifting the pumps

Suspend a tackle above the hydraulic pump and put a strap around the pump.

Hook the tackle on to the strap and tighten up.

NOTICE

The pump must be in balance when it is lifted.



4565-0201-0004D07

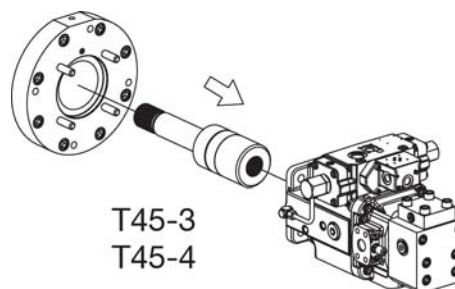
Unscrew the four nuts from studs in the end-flange.

9. Pull out the pumps

Carefully pull out the pump and the internal drive shaft. *See Data.*

For overhaul of the pump, send it to an authorized MAN Diesel & Turbo workshop.

The internal drive shaft also functions as an overload protection. If it is necessary to renew the drive shaft, contact MAN Diesel & Turbo for advice.

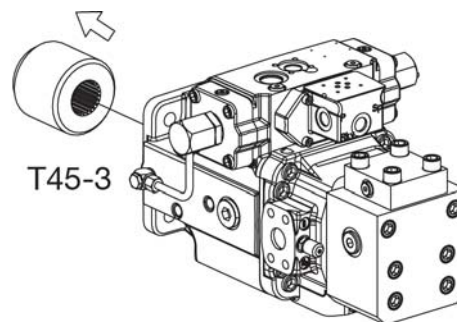


4565-0201-0004D08

1. Dismantle the hydraulic pump

This procedure is to be performed if the drive shaft has been overloaded and subsequently has to be overhauled.

Remove the broken end of the internal drive shaft.

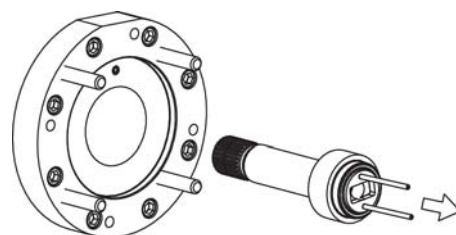


4565-0201-0004O01

2. Pull out the drive shaft

Screw two pieces of threaded rod into the threaded holes in the drive shaft and pull it out.

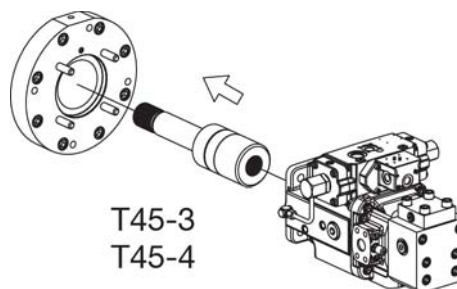
Discard the broken drive shaft.



4565-0201-0001O02

3. New drive shaft

Mount a new internal drive shaft and the hydraulic pump.



4565-0201-0004O03

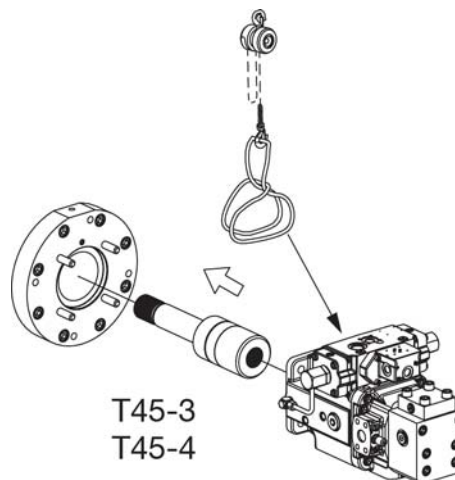
1. First

Mount the intermediate shaft in the gearbox. Suspend a tackle above the gear box and put a strap on the hydraulic pump.

NOTICE

Great care must be taken to ensure that the area around the workplace is clean before and during assembly of the hydraulic system.

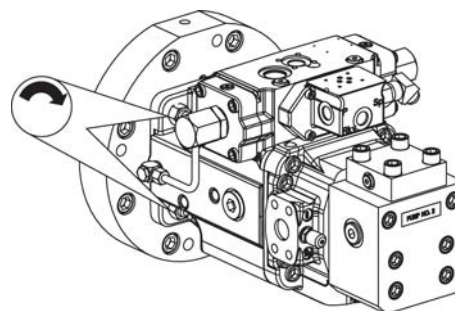
Lift up the pump in position, and carefully push in the pump to engage the pump shaft with the drive shaft.



4565-0201-0004M01

2. Mount and tighten the nuts

Mount and tighten the nuts on the pump flange.

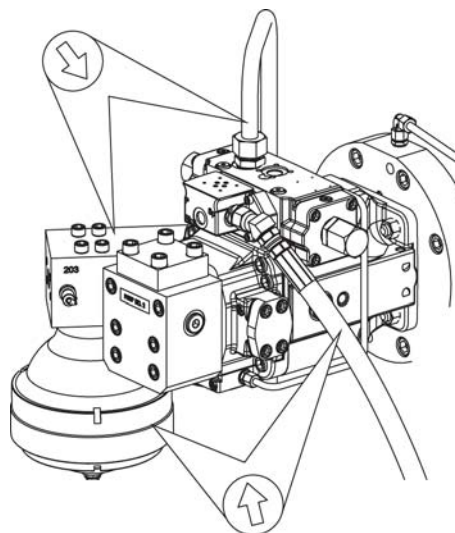


4565-0201-0004M02

3. Servo oil pipes

Mount the servo oil pipes.

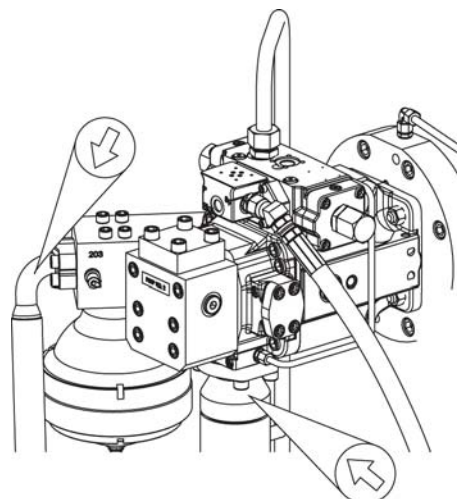
Mount the block with accumulator.



4565-0201-0004M03

4. Mount the bolts in the flange on the suction pipe

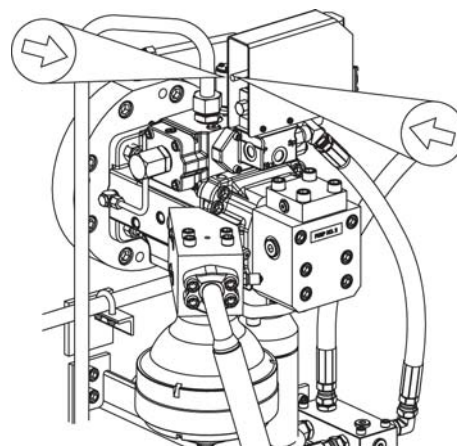
Mount the bolts in the flange on the suction pipe. Mount the discharge pipe and tighten the bolts.



4565-0201-0004M04

5. Mount the electrical connections

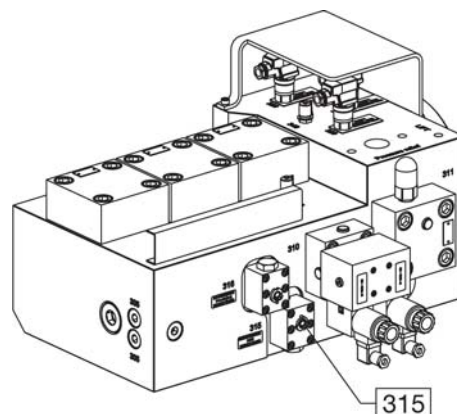
Mount the electrical connections to the solenoid valves and replace the protective shield.



4565-0201-0004M05

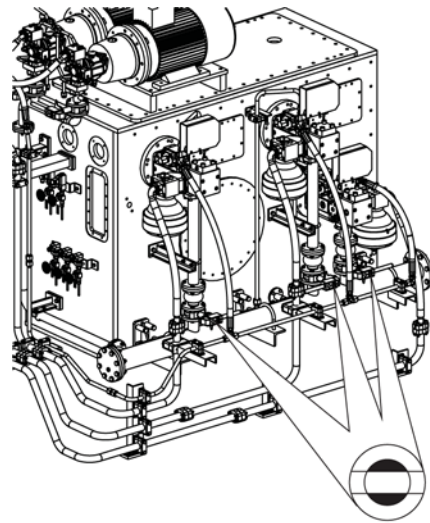
6. Close valve 315

Close valve 315 on the flange in the front end of the HCU line.



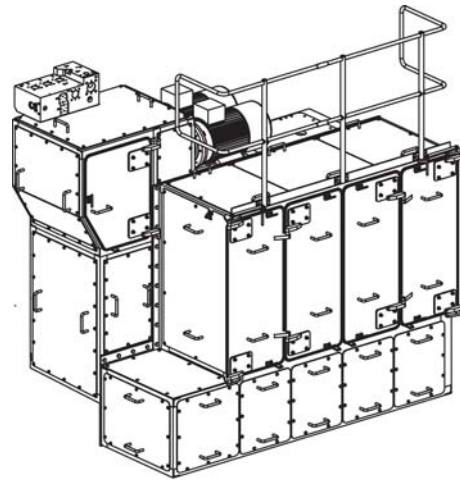
4565-0201-0004M06

7. The suction valve Open up the suction valve for the relevant pump. Re-mount the cover and cross member.



4565-0201-0005M07

8. Close the gallery access Close the access covers plating on the gallery.



4565-0201-0005M08

Safety

Precautions

for detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Engage turning gear
○	Shut down hydraulic power supply



Data

Ref.	Description	Value	Unit
T45-12	Main hydraulic pipe flanges tightening torque	160	Nm
T45-15	Hydraulic hose with flange tightening torque	50	Nm

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

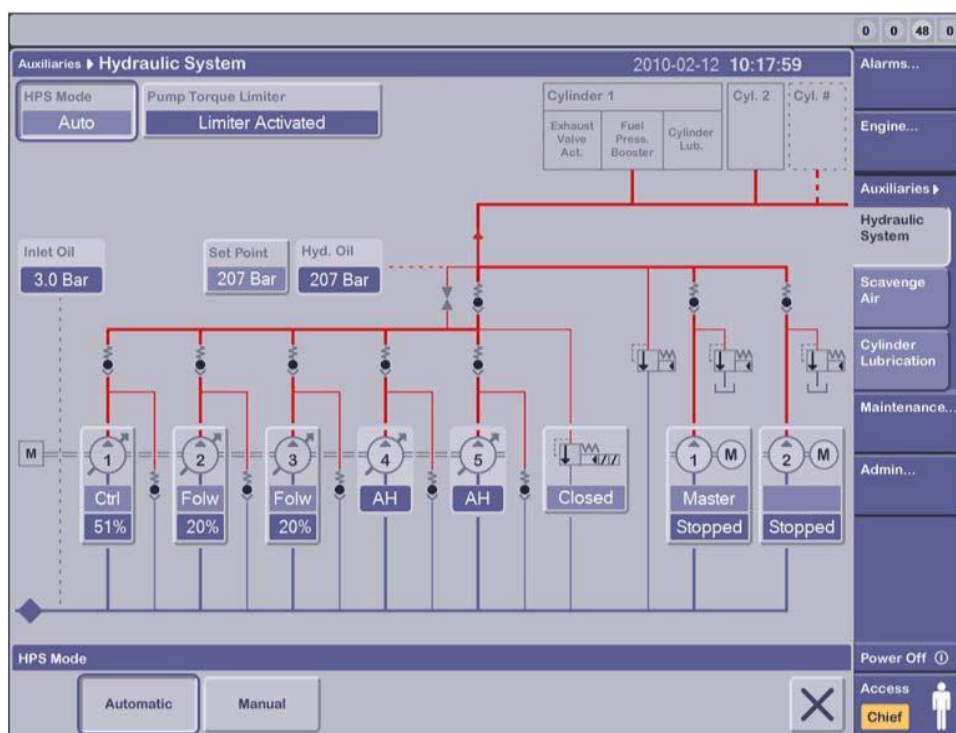
Plate	Item No.	Description
4270-0010	333	Flushing valve
7670-0200	-	Torque spanners
7670-0410	054	Feeler gauge set

Remember

The integrity of the hydraulic system can be checked by observing the Hydraulic Pressure Decay Time on the Main Operating Panel when stopping the engine.

If the graph moves into the yellow or red area, the leak has to be located and stopped.

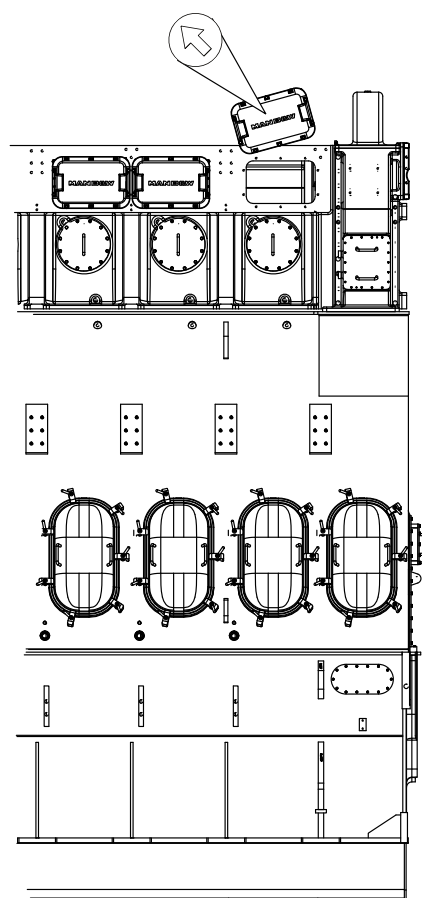
Leakage during operation may be observed by poor engine performance or visible leaks on the engine.



4565-0301-0016C01

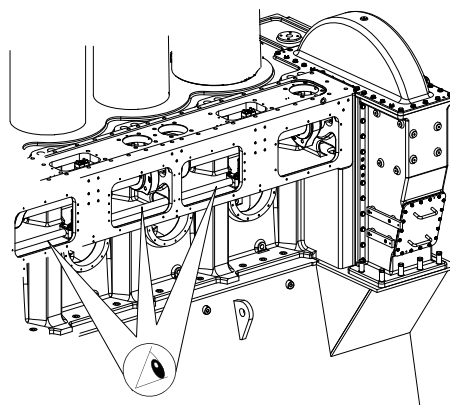
Main High Pressure Pipe

Remove the cover to access the main high-pressure pipe.



4565-0301-0001O01

Check for visible leaks Check the high pressure pipe connections for visible leaks.

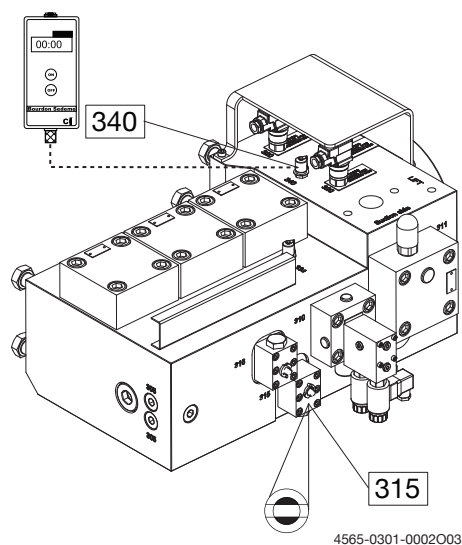


4565-0301-0001O02

**CAUTION**

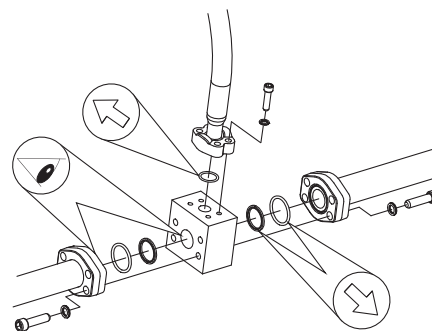
Do not use your hands to detect leakages! If necessary use a mirror on a stick.

- Pressure free system** Mount a pressure gauge on the “minimess” coupling No. 340.
- Check the pressure.
- Open valve 315 to relieve the system of hydraulic pressure.
- Check on the pressure gauge that the system is pressure free.



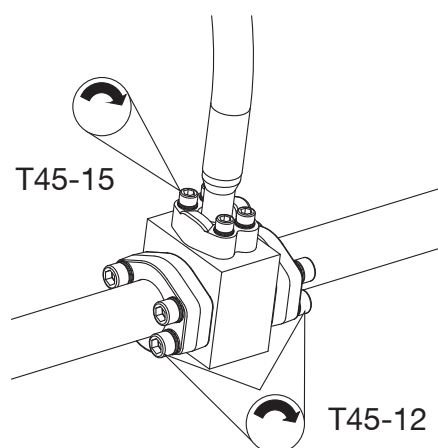
4565-0301-0002O03

- Remove the bolts** Loosen and remove the bolts from the pipe flanges on the high pressure pipe or hose concerned.
- Remove the sealing rings and clean the pipe flanges.
- Inspect the flange and pipe visually.



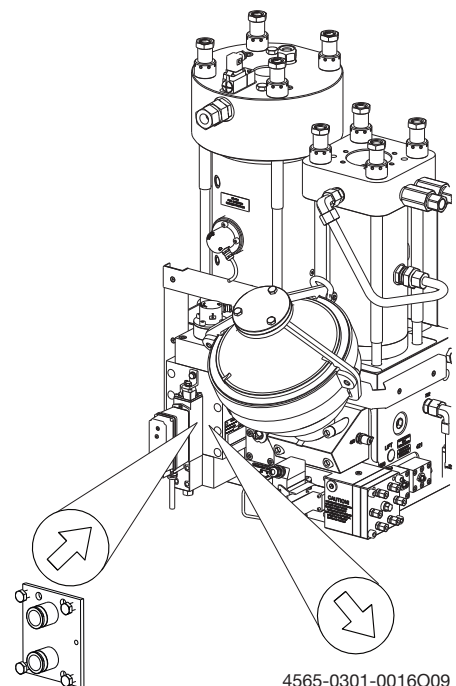
4565-0301-0015O04

- Remount** Mount the high pressure pipes and new sealing rings, *see Data*.



4565-0301-0015O05

Put covers back	Put covers back into place.
Valve 315	Close valve 315.
Test the pipe system	After renewing sealing rings or hoses on the high pressure system it is recommended to test the pipe system according to the "checking" section.
Flushing of HCU block	If large components on the HCU block has been renewed or if there is suspicion that the HCU block has been contaminated, it is recommended to flush it.
Remove the FIVA valve	Prior to flushing, remove the FIVA valve as described in <i>workcard</i> 4565-0601. Mount the flushing valve on the HCU block. Connect a hose to the flushing valve in order to lead the flushing oil away.

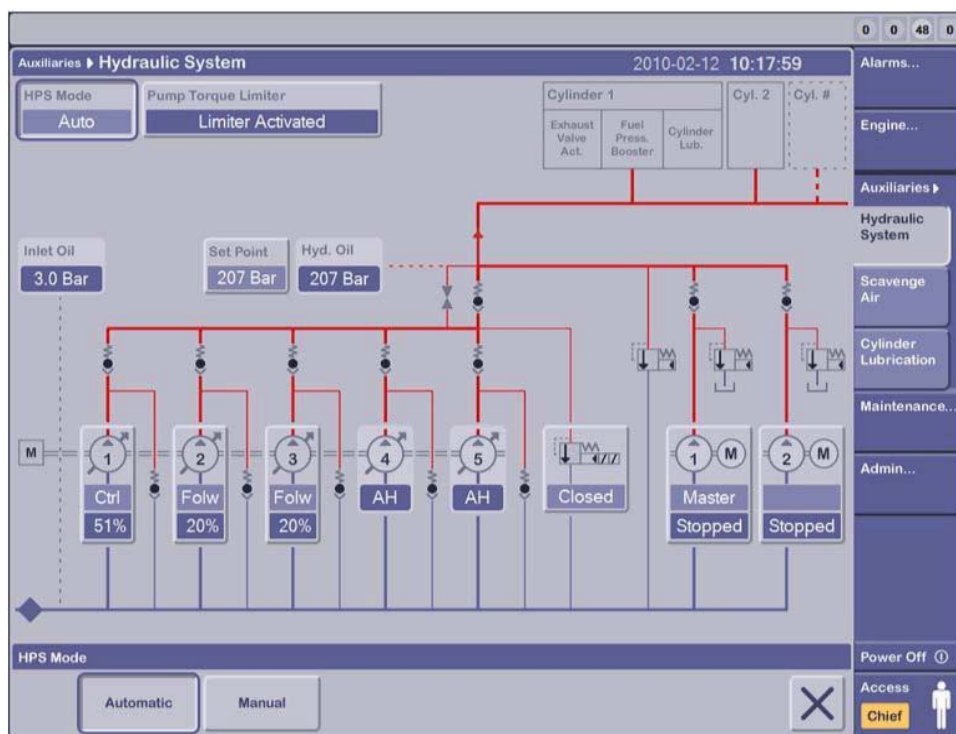


4565-0301-0016O09

Check the integrity of the hydraulic system

Check that the integrity of the hydraulic system has been restored.

See the checking section.



4565-0301-0016C01

Hydraulic System • Overhaul

Work Card
4565-0301-0016

Safety
Precautions

*for detailed sketch
see 0545-0100*

○	Stop the Engine
○	Shut down hydraulic power supply



Data

Ref.	Description	Value	Unit
-	Table is empty on purpose. No Data needed.	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
7670-0410	-	Pressure gauge



WARNING

All dismantling and assembly work of components on the hydraulic cylinder unit must be performed only on a depressurised HCU.

1. HCU Depressurising

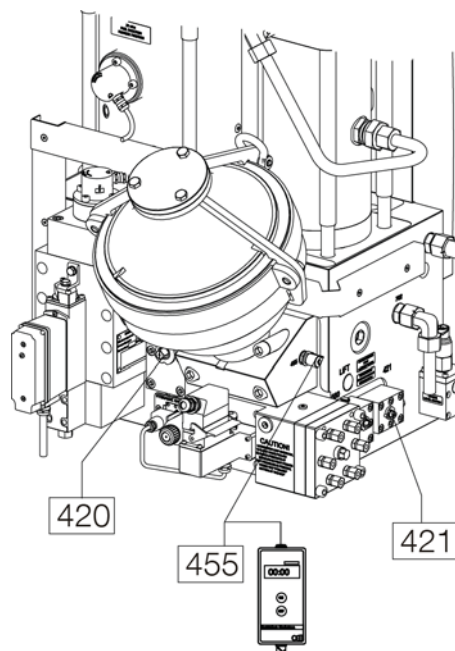
Connect a pressure gauge at minimess point **455**. Check the pressure.

Close high-pressure inlet valve **420** and low-pressure inlet valve **531**.

To view the location of valve 531, please see the hydraulic diagram.

Open high-pressure outlet valve **421** and drain valves **405** to drain all oil out of the HCU block.

Check that the system is free of pressure.

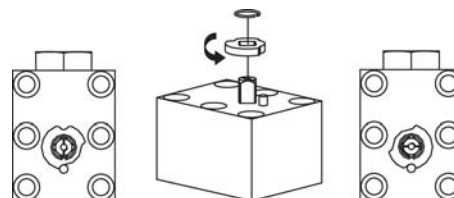


4565-0501-0010C01

2. How to secure the valve position

Turn the square to the closed position and lift off the locking disc.

Turn the locking disc 180°, and place it on the square again to lock the valve.



4565-0501-0001C03

3. HCU Pressurising

Connect a pressure gauge at minimess point **455**. Check that the system is not pressurised.

NOTICE

To protect the accumulators from unnecessary stress. Never open valve **420** when the main hydraulic system is pressurised.

Close high-pressure outlet valve **421** and drain valves **405**.

Open high-pressure inlet valve **420** and low-pressure inlet valve **531**.

Safety Precautions

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply
○	Shut down hydraulic power supply



Data

Ref.	Description	Value	Unit
T45-42	Accumulator	35 / 55	kg
T45-43	N2 Charging pressure	136	bar at 20°
T45-45	Pressure Adjustment Table		
-	Accumulator temperature t°C:		
-	0° C	124	bar
-	10° C	130	bar
-	20° C	136	bar
-	30° C	142	bar
-	40° C	148	bar
-	50° C	154	bar
-	60° C	160	bar
-	70° C	166	bar
-	80° C	172	bar
-	90° C	178	bar
-	100° C	185	bar
-	Filling pressure must be as stated above		
-	Check pressure within ± 5 bar.		
T45-46	assembly off-set 4-liter accumulator	9	mm
T45-47	assembly off-set 10-liter accumulator	10	mm
T45-48	Screw, flange to accumulator	120	Nm
T45-49	Screw, flange to hydraulic cylinder unit	130	Nm

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
4570-0540	-	Test equipment for accululators
4570-0550	-	Tools for accumulator
7670-0200	-	Torque spanners
7670-0300	-	Lifting tools, etc
7670-0410	066	Slide caliper



1. Check of Accumulators on Hydraulic Cylinder Unit

Check of the hydraulic accumulator can only be done with stopped engine and with stopped start-up and booster pumps.

Connect a pressure gauge at minimess point **455**. Check the pressure.

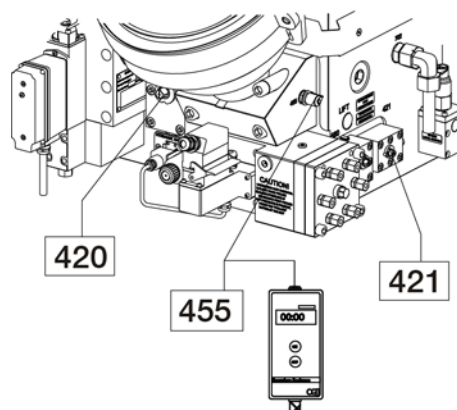
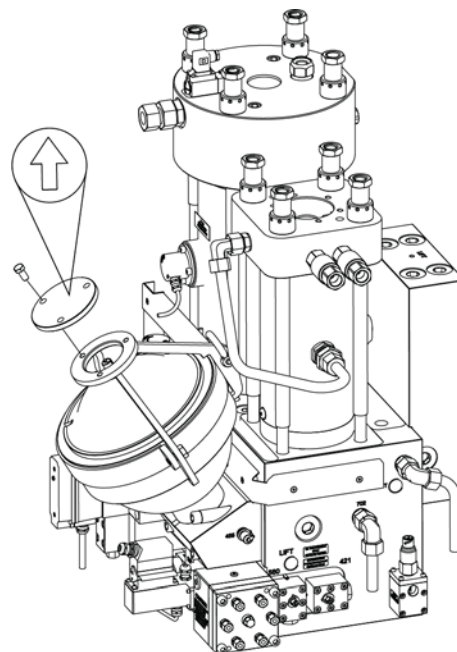
Close the high pressure inlet valve **420** and open the high pressure outlet valve **421** to drain all oil out of the accumulator.

Check that the system is pressure free.

Depressurise HCU block.
See work card 4565-0501.

Check the nitrogen pressure.

For correct pressure, *see data T45-43.*



4565-0551-0013C01

2. Check of accumulators on hydraulic power supply unit

Check of accumulators on the accumulator block can only be performed on a stopped engine and with stopped start-up and booster pumps.

Connect a pressure gauge at minimess point **340**. Check the pressure.

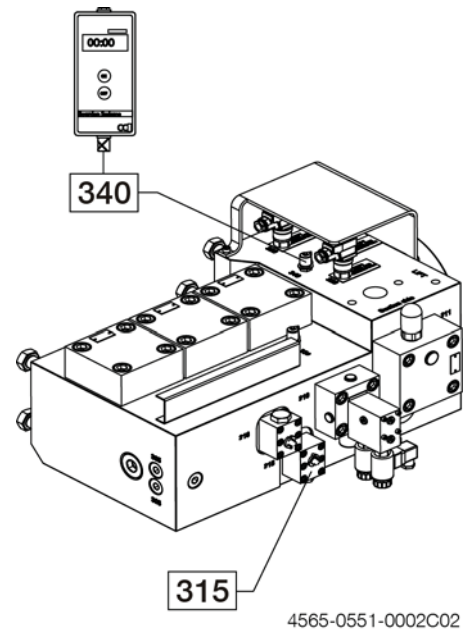
Open valve **315** to de-pressurise the hydraulic system and drain all oil out of the accumulators.

Check that the system is pressure free.

Check the nitrogen pressure.

For correct pressure, *see data T45-45*.

For use of pressure setting tool, see checking procedure, step 3.



3. Refilling the accumulator

Assemble the reducing valve as shown in the figure, and mount the reducing valve on the nitrogen cylinder. If necessary, use a threaded adaptor.

Before mounting the filling hose on the accumulator, check that the accumulator top is clean.

Check that valves **A** and **D** are closed.

Mount the filling hose on the relevant accumulator with the union nut **E**.

It is now possible to read the actual nitrogen pressure in the accumulator on the digital gauge **C** on the filling valve.

If the accumulator needs to be refilled with nitrogen, open valve **A** and adjust the outlet pressure on spindle **B** to 1-2 bar above the pressure stated in the Pressure Adjustment Table. *See data T45-45.*

Keep valve **A** open until the accumulator is filled.

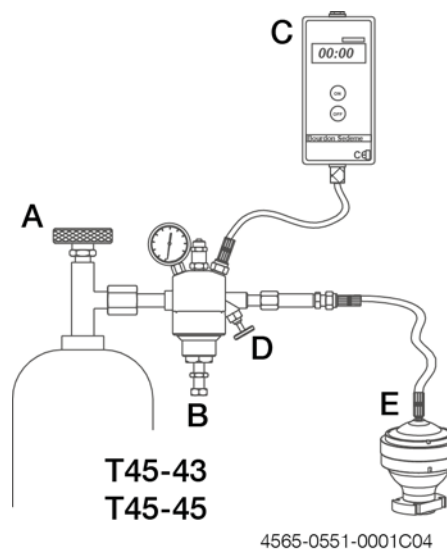
Close valve **A**.

Wait five minutes for the temperature to stabilise.

Check the pressure in the accumulator on gauge **C** according to the Pressure Adjustment Table. *See data T45-45.*

Adjust the pressure in the accumulator at bleed screw **D**.

Unscrew the union nut **E** to remove the filling valve from the accumulator.

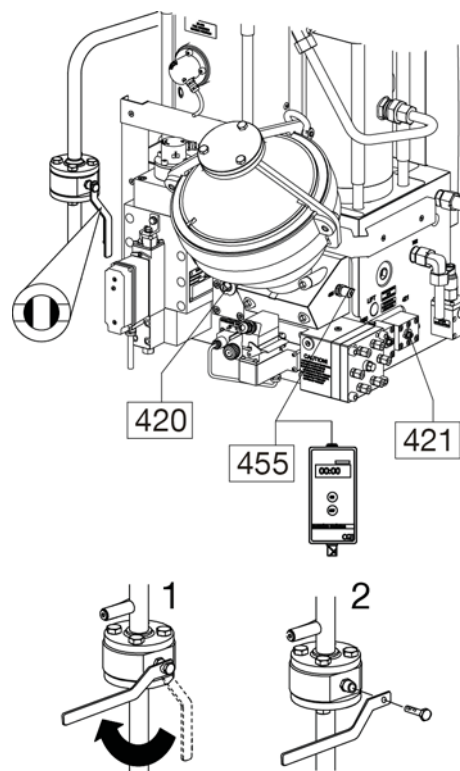


1. Dismantling of accumulators from hydraulic cylinder unit

Depressurise HCU block.
See work card 4565-0501.

NOTICE

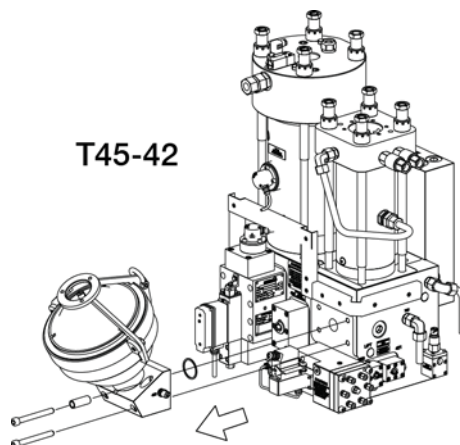
Great care must be taken to ensure that the area around the workplace is clean before and during any dismantling of the hydraulic system.



4265-0701-0009D01

2. Dismantling

Dismantle the accumulator flange from the hydraulic cylinder unit.

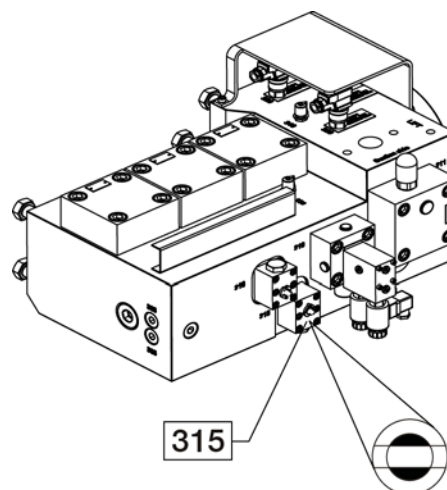


4565-0551-0013D02

3. Dismantling of accumulators from hydraulic power supply unit

Dismantling of accumulators from the hydraulic power supply unit can only be performed on a stopped engine and with stopped start-up and booster pumps.

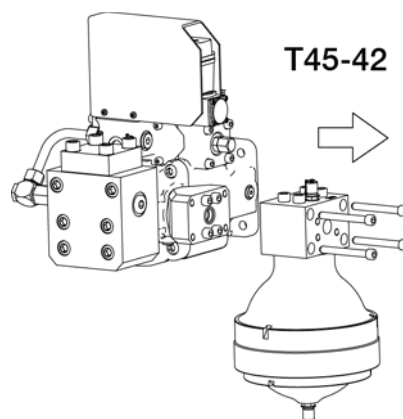
Open valve **315** to de-pressurise the hydraulic system and drain all oil out of the accumulators.



4565-0551-0002D05

4. Removal of accumulator

The accumulators on the hydraulic power supply unit are dismantled by unscrewing the screws from the accumulator flange on the hydraulic pump accumulator block. The accumulator can then be lifted away.



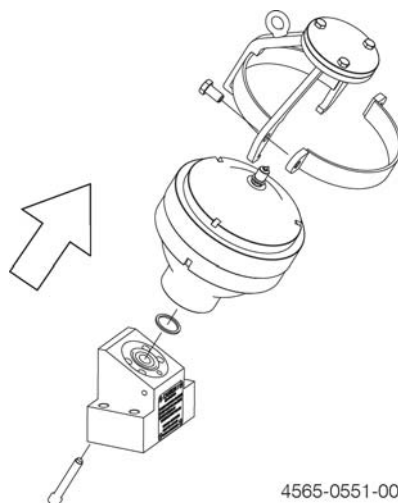
4565-0551-0013D04

NOTICE

The tools provided for opening the accumulators vary according to whether the maker of the accumulator is Daeshin or Leduc.

1. Strip accumulator Dismantle the accumulator flange from the hydraulic cylinder unit.

Dismantle the lifting bracket from the accumulator.



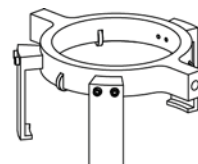
4565-0551-0008001

2. Drain nitrogen Use the pressure adjustment tool to drain the accumulator of nitrogen gas. *See checking procedure.*

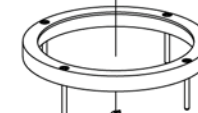
3. Tools for Leduc Accumulator The lower piece of the Leduc accumulator is gripped by the pin wrench, which is equipped with three teeth which grip the slots on the lower part of the accumulator.

The ring for the Leduc accumulator fits on the upper perimeter of the accumulator, thus holding the accumulator securely in the pin wrench. This ensures that the accumulator is held motionless while the upper part of the accumulator is loosened and removed.

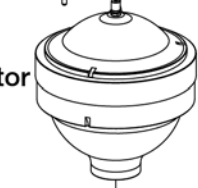
Hook Wrench



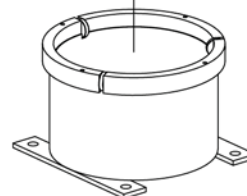
Ring for Leduc Accumulator



Leduc Accumulator



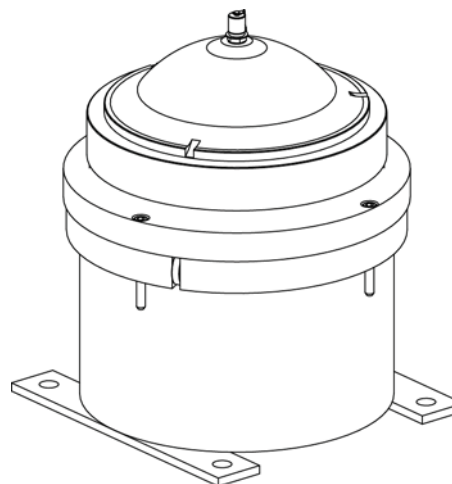
Pin Wrench



4565-0551-0011002

4. Securing the accumulator tool

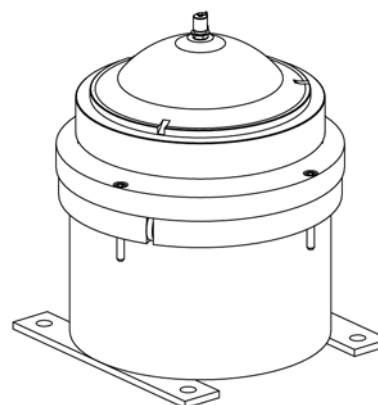
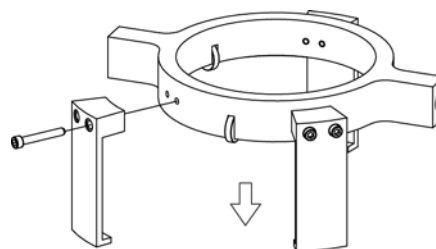
Make sure that the lower half of the accumulator tool is securely fastened to the engine room deck. This can be done by screwing or welding the flanges of the accumulator tool onto the engine room deck in a convenient place.



4565-0551-0011O03

5. Mounting the hook wrench

After the accumulator is securely mounted within the pin wrench, the hook wrench is mounted on the top of the accumulator. In order to perform this operation, one of the claws has to be removed. The two claws must reach below the ridge on the accumulator. Once the two claws are in place and the tool is centred, the third claw is to be re-mounted.

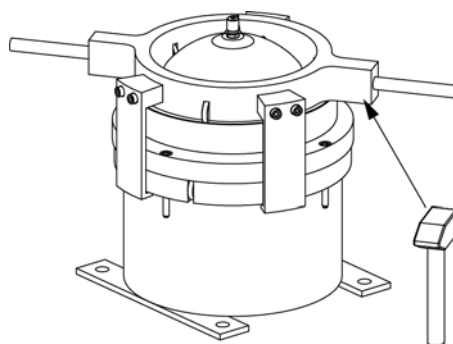


4565-0551-0011O04

6. Removing the upper part of the accumulator

Insert a piece of pipe in the holes at the end of the wings of the hook wrench to provide leverage.

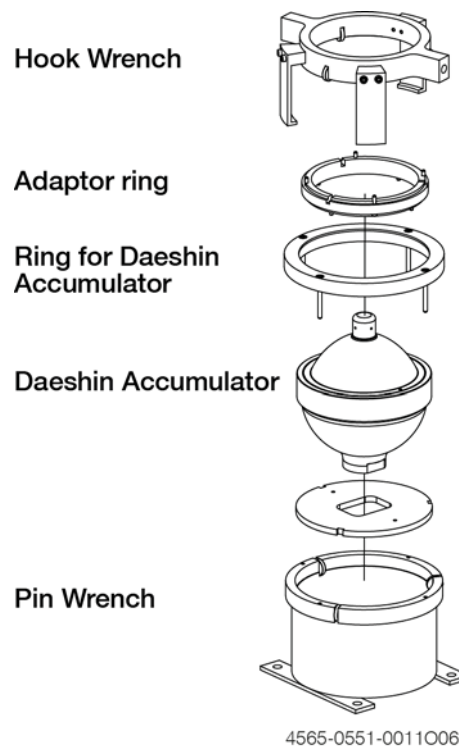
If the upper piece binds, it can be loosened by tapping a few times with a hammer on the wings of the hook wrench.



4565-0551-0011O05

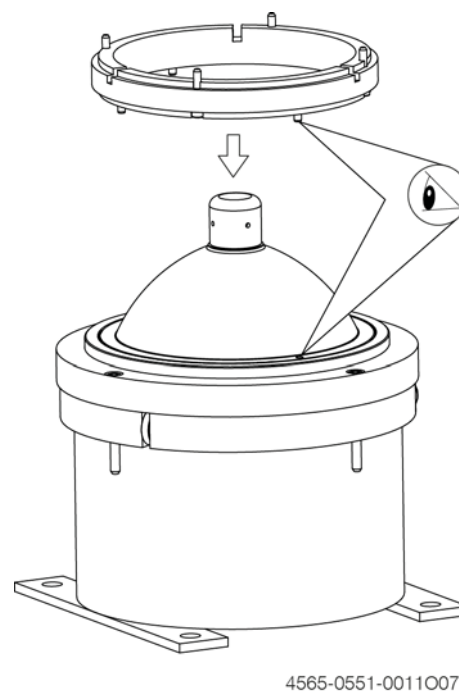
7. Tools for Daeshin accumulator

For the Daeshin accumulator, the accumulator is held motionless through means of a specially designed plate which grips the bottom of the accumulator. The plate is fixed to the bottom of the pin wrench. The accumulator is then mounted in the pin wrench and held in place by the ring, as was the case for the previously described procedure.

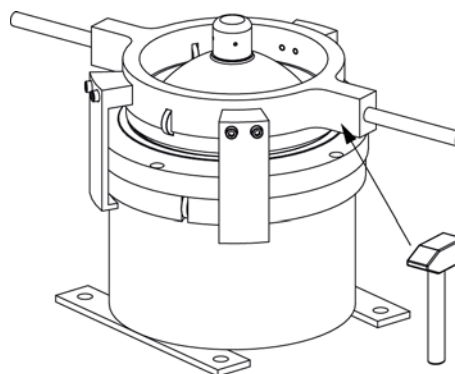


8. Securing the adaptor ring

The adaptor ring is equipped with slots in the upper surface which are gripped by the hook wrench. The lower part of the adaptor ring is equipped with some pins which fit into the upper surface of the accumulator.

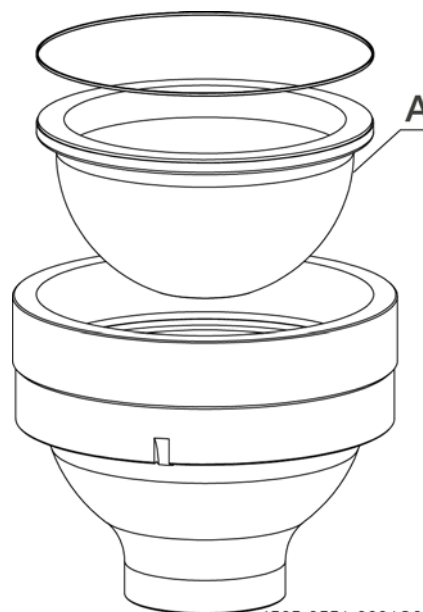


9. Removing the upper part of the accumulator
- The upper part of the accumulator can then be unscrewed through mounting the hook wrench in the same manner as previously described. Insert a piece of pipe in the holes at the end of the wings of the hook wrench to provide leverage. If the upper piece binds, it can be loosened by tapping a few times with a hammer on the wings of the hook wrench.



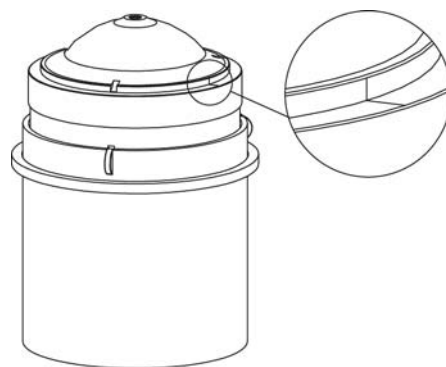
4565-0551-0011008

10. Dismantling
- Remove the defective diaphragm A.



4565-0551-0001006

11. Cleaning
- Clean both accumulator halves thoroughly, especially the threads, and make sure that the parts are dry afterwards.
12. Assembly without diaphragm
- Assemble the two accumulator halves without mounting the diaphragm. Tighten until the halves are in contact.
- Mark the relative position of the accumulator halves.



4565-0551-0001008

13. Assembly with diaphragm

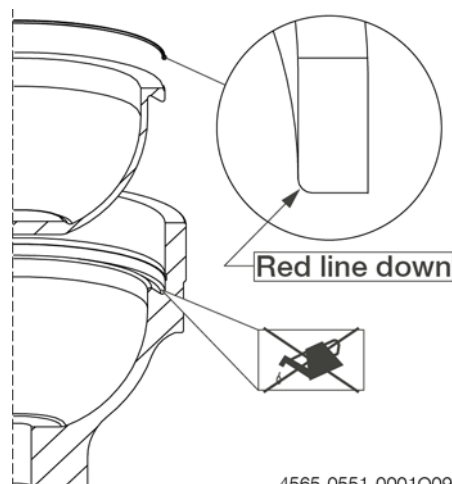
Disassemble the accumulator and install the new diaphragm and anti-extrusion ring with the red chamfered edge facing downwards.

NOTICE

Check that the new diaphragm is made of the same material as the old one.

Do not lubricate the diaphragm lip seating.

Lubricate the upper part of the diaphragm lip and the accumulator threads with molybdenum disulphide grease

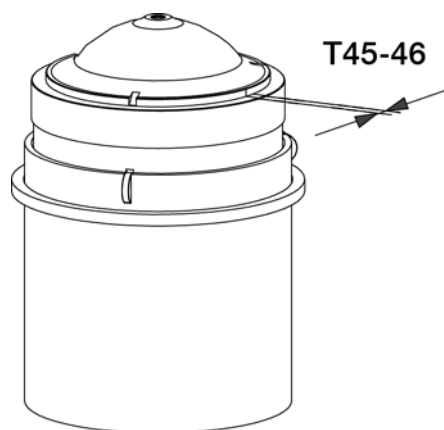


4565-0551-0001009

14. Assemble accumulator

Assemble the accumulator.

Tighten until the marks previously made are off-set according to *data T45-46*.



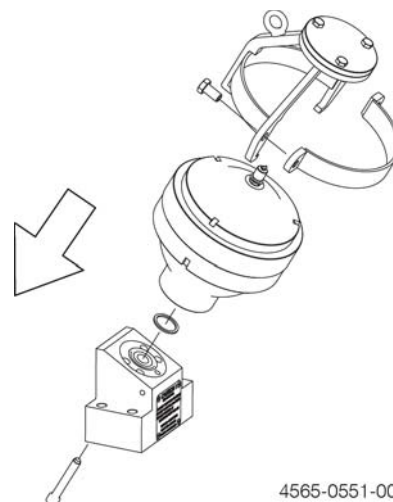
4565-0551-0001011

15. Flange and bracket

Mount a new O-ring on the accumulator flange.

Mount the accumulator on the accumulator flange.

Mount the lifting bracket on the accumulator.



4565-0551-0008031

NOTICE

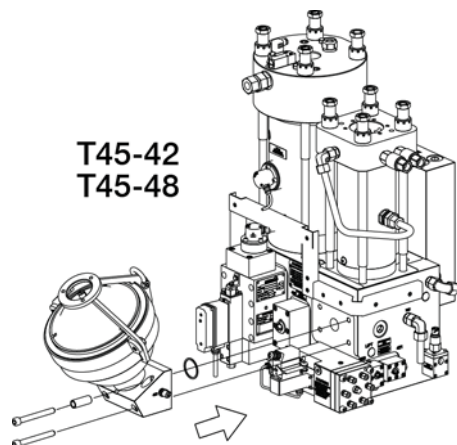
Great care must be taken to ensure that the area around the workplace is clean before and during assembly of the hydraulic system.

1. Mounting of accumulators on hydraulic cylinder unit

This can only be performed on a stopped engine with stopped hydraulic pumps.

Mount a new sealing ring on the accumulator.

Mount the accumulator assembly and a new second sealing ring on the hydraulic cylinder unit.



4565-0551-0013M01

NOTICE

Use Loctite ® 243 to secure the screws when mounting the flange and the accumulator.

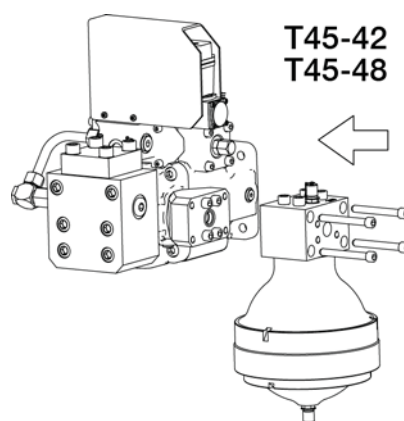
Close the high pressure outlet valve 421 and open the high pressure inlet valve 420.

Check accumulator nitrogen pressure.
See data T45-43.

2. Mounting of accumulators on hydraulic power supply unit

This can only to be performed on a stopped engine with stopped hydraulic pumps.

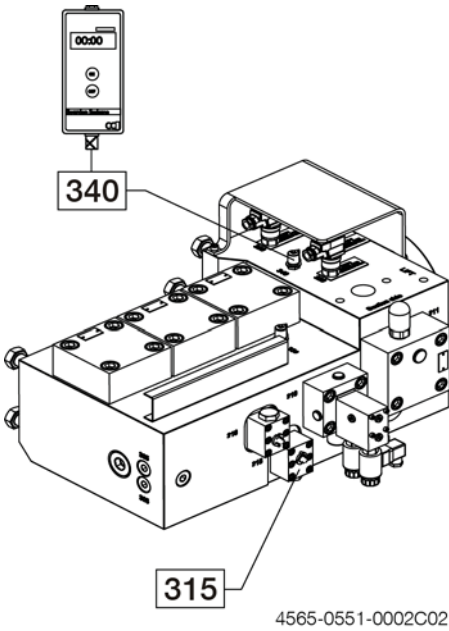
Mount the accumulators on the hydraulic pump valve block in the same way as on the HCU block.



4565-0551-0013M04

3. Finally

Close valve 315.



Safety
Precautions

*for detailed sketch
see 0545-0100*

○	Stop the Engine
○	Shut down hydraulic power supply



Data

Ref.	Description	Value	Unit
T45-33	FIVA Control valve	52	kg
T45-34	Screw, FIVA valve to Hydraulic Cylinder Unit	75	Nm

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

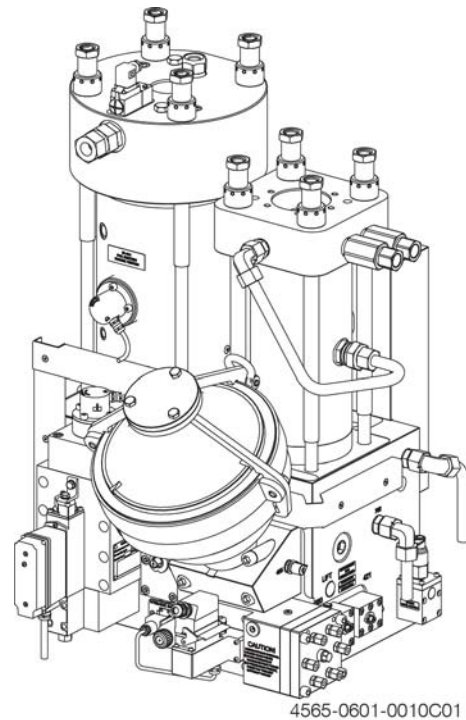
Plate	Item No.	Description
7670-0200	-	Torque spanners
7670-0300	-	Lifting tools, etc

1. FIVA

The function of the Fuel Injection and the Valve Activation Valve (FIVA) is continuously checked by the Engine Control System.

Malfunctions will be reported by the system to the MOP system and to the common alarm system.

Malfunctioning FIVA valves are to be overhauled by the supplier or by MAN Diesel & Turbo.



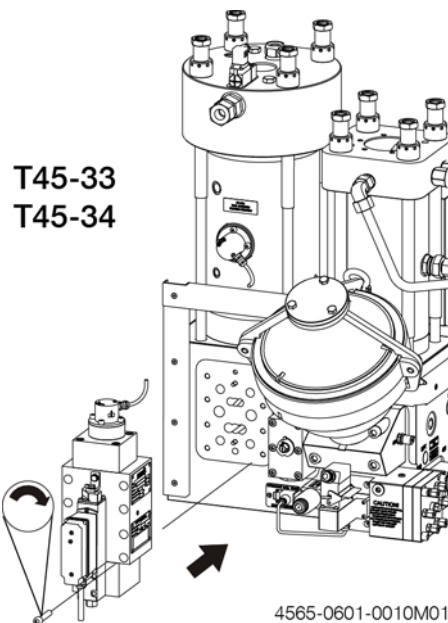
NOTICE

Great care must be taken to ensure that the area around the workplace is clean before and during any dismantling of the hydraulic system.

1. Mount the valve

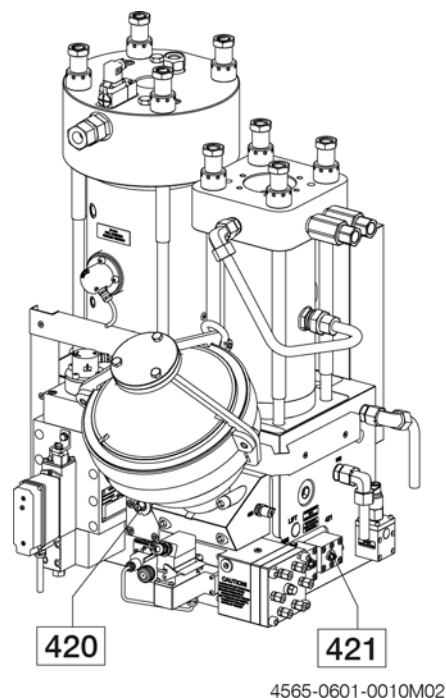
Mount new square section sealing rings in the control valve.

Mount the control valve on the two guide pins and tighten the eight screws.



2. Pressurise the HCU

Close the high pressure outlet valve 421 and open the high pressure inlet valve 420.



3. Electrical connections

Connect the electrical connections.

Safety**Precautions**

For detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Engage turning gear
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

**Data**

Ref.	Description	Value	Unit
T45-05	Electrical Motor	265	kg

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

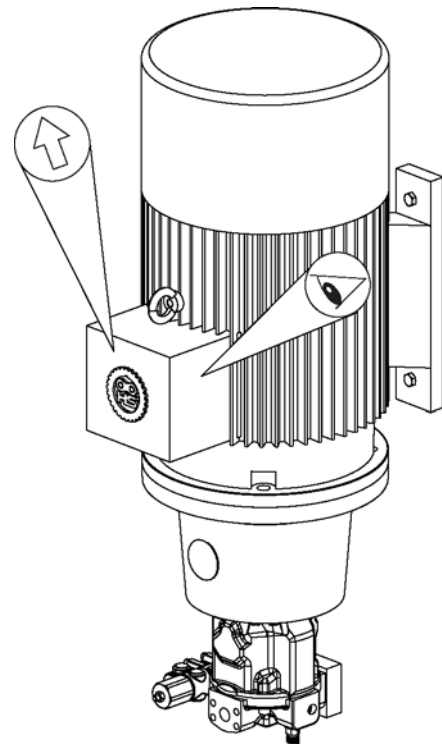
Plate	Item No.	Description
7670-0300	-	Lifting tools, etc

Hydraulic Pumps

1. Disconnect electrical breaker

Disconnect the electrical breaker to the electric pump in question.

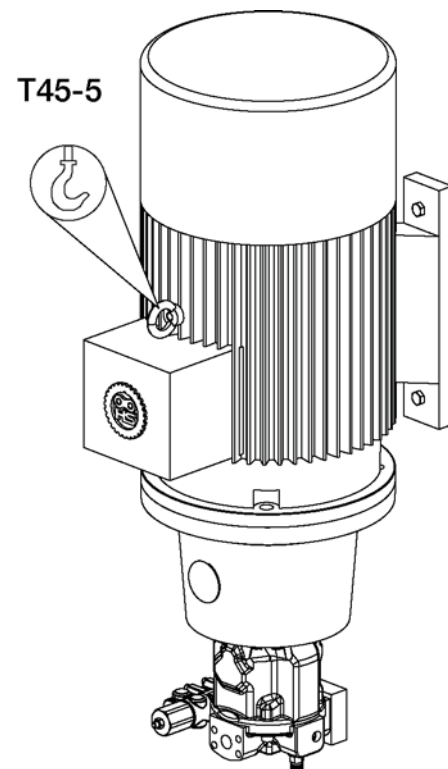
Take note of the correct wiring and disconnect the electrical connection on the electric pump.



4565-1001-0005D01

2. Arrange lifting equipment

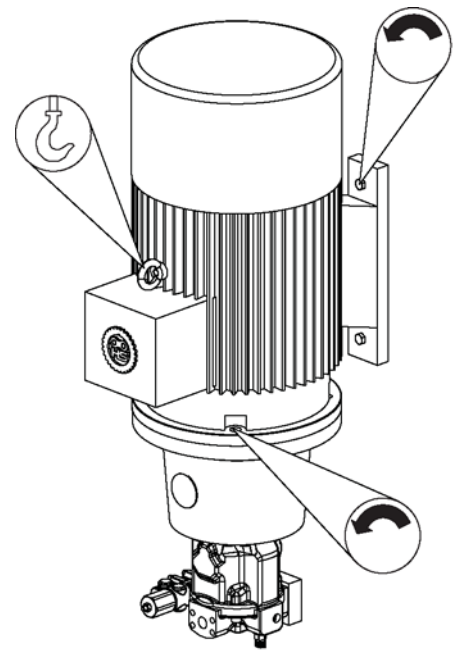
Mount a tackle above the pump and mount lifting slings to the eyebolts and support on the electric motor.



T45-5

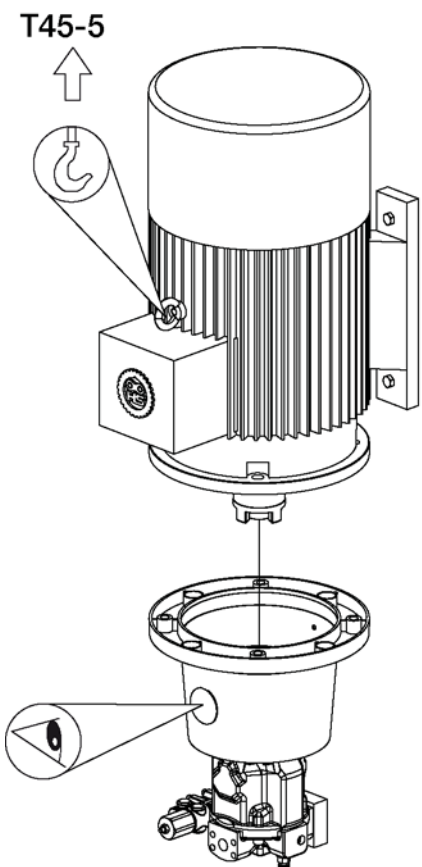
4565-1001-0005D02

3. Dismount the electric motor
Dismount the screws connecting the motor to the flange. Remove the inspection cover on the flange.



4565-1001-0005D03

4. Remove the electric motor
Lift the electric motor away. Look through the inspection hole to ensure that the flexible coupling separates without damage.

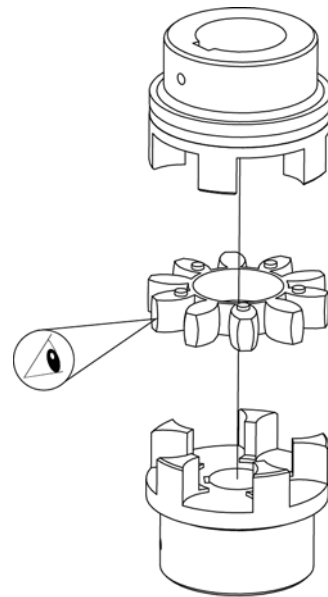


4565-1001-0005D04

1. Inspect the claw coupling

Inspect and clean the parts of the flexible claw coupling. If the middle part show considerable wear or missing teeth it must be renewed.

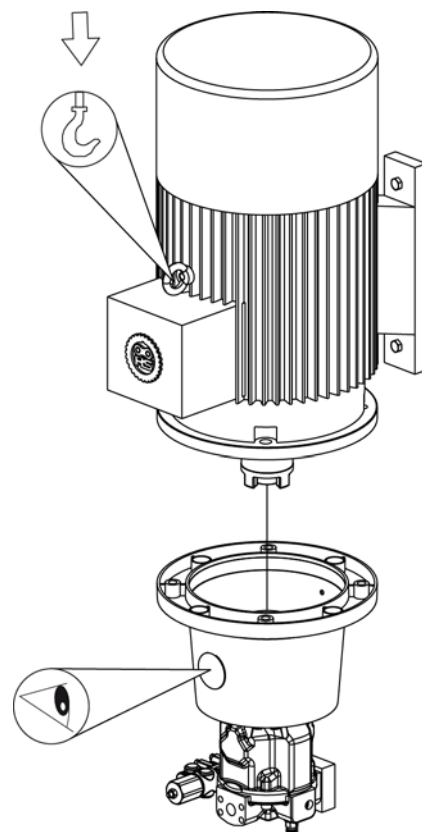
Mount the middle part in the claw coupling hub on the pump axle.



4565-1001-0002M01

2. Lower the electric motor into place

Use the tackle to lower the electric motor into place. Use the inspection hole to ensure that the claw coupling is assembled correctly.

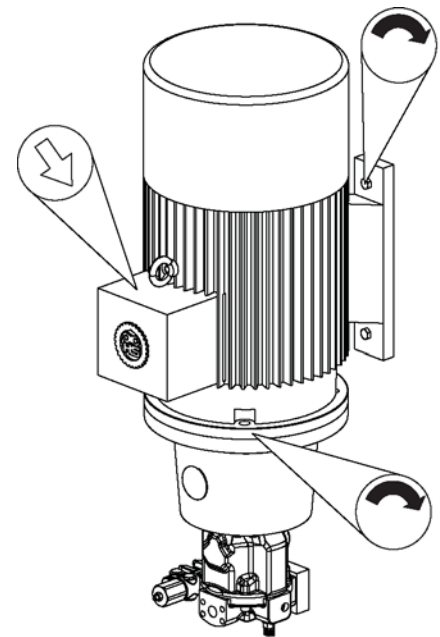


4565-1001-0005M02

3. Mount screws

Mount and tighten the screws on the flange.

Reconnect the electrical wiring and breaker.

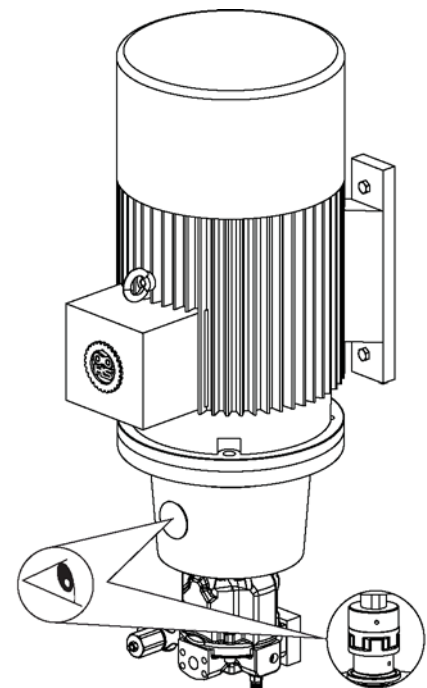


4565-1001-0005M03

4. Check for correct operation

Run the pump for a few seconds while observing for misalignment and unwanted noise. Check through the inspection hole that the coupling is undamaged.

Fit the inspection cover into place.



4565-1001-0005M04

Safety**Precautions**

*for detailed sketch
see 0545-0100*

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off safety air supply - Not ME Engines
☐	Shut off control air supply
☐	Shut off air supply to exhaust valve - Only when stopped lubricating oil pumps
☐	Engage turning gear
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

Data

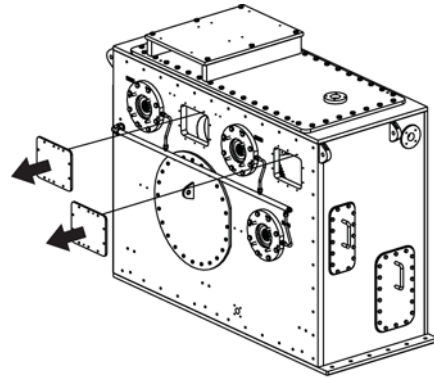
Ref.	Description	Value	Unit
-	Table is empty on purpose. No Data needed.	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

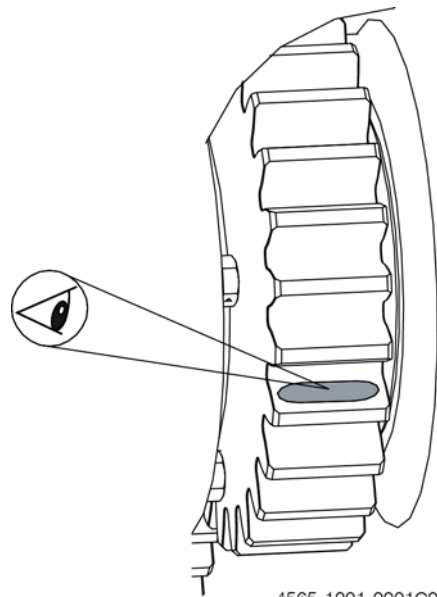
Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.

1. The cover on the exhaust and rear side Remove the cover on the exhaust and rear side of the chain drive.



4565-1201-0008C01

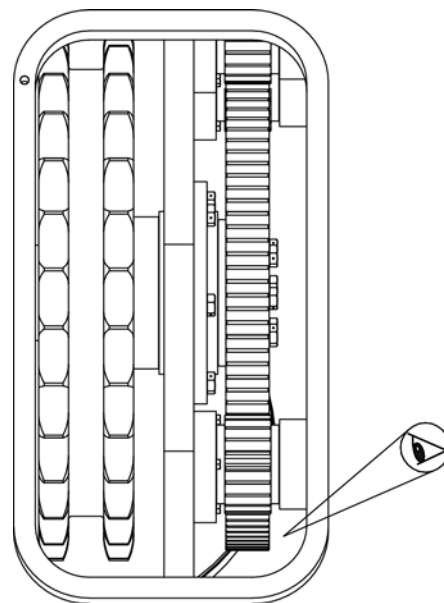
2. The contact face of the gear wheel tooth Check that there are no signs of abnormal wear on the contact faces of the gear wheel teeth.



4565-1201-0001C02

3. No abnormal particles below the bearings

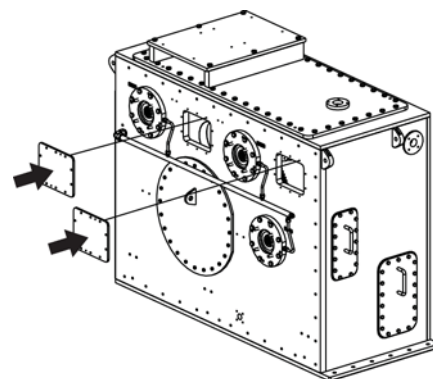
Check that there are no particles of bearing material on the horizontal surfaces below the bearings.



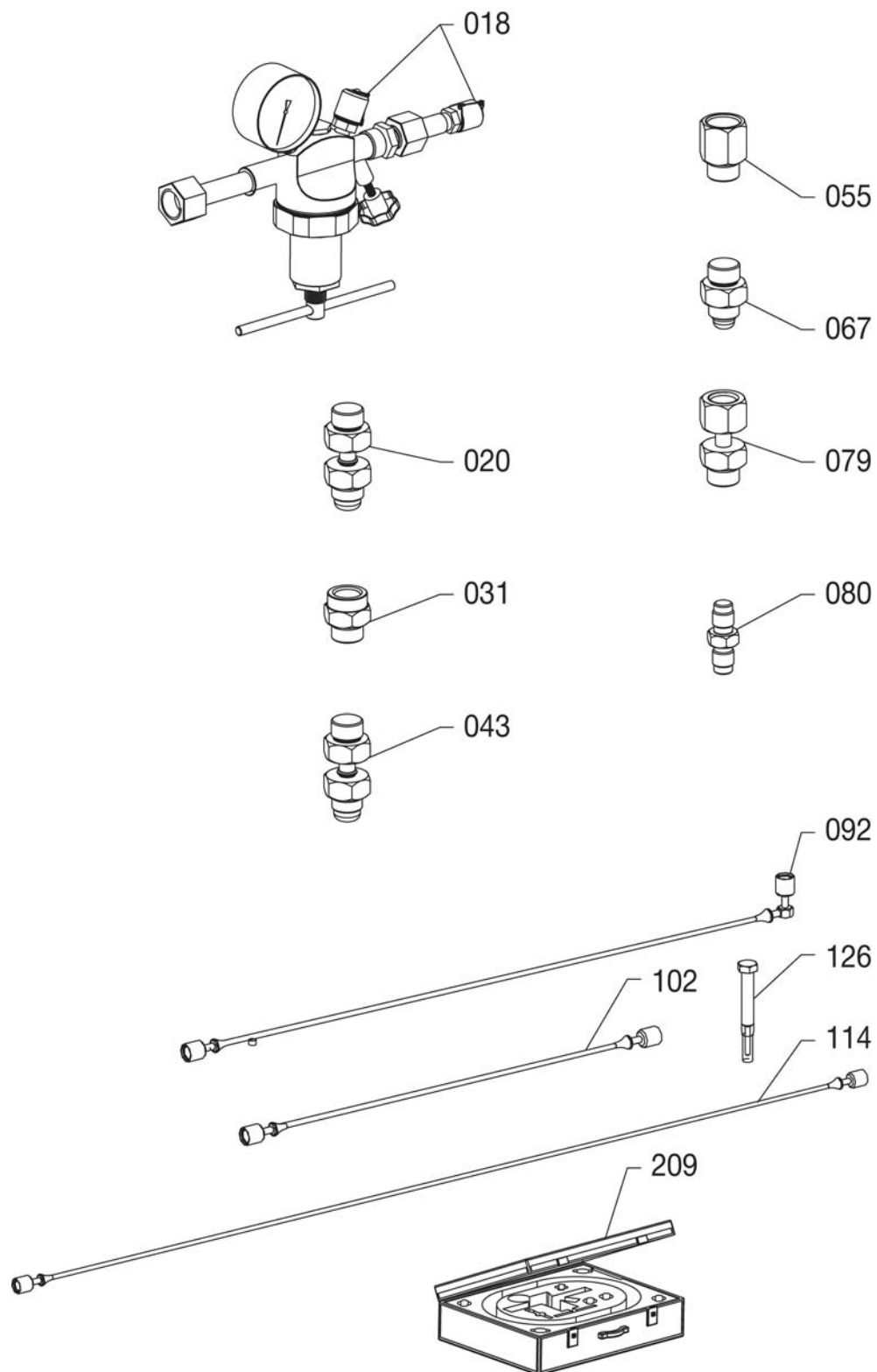
4565-1201-0001C03

4. Remount covers

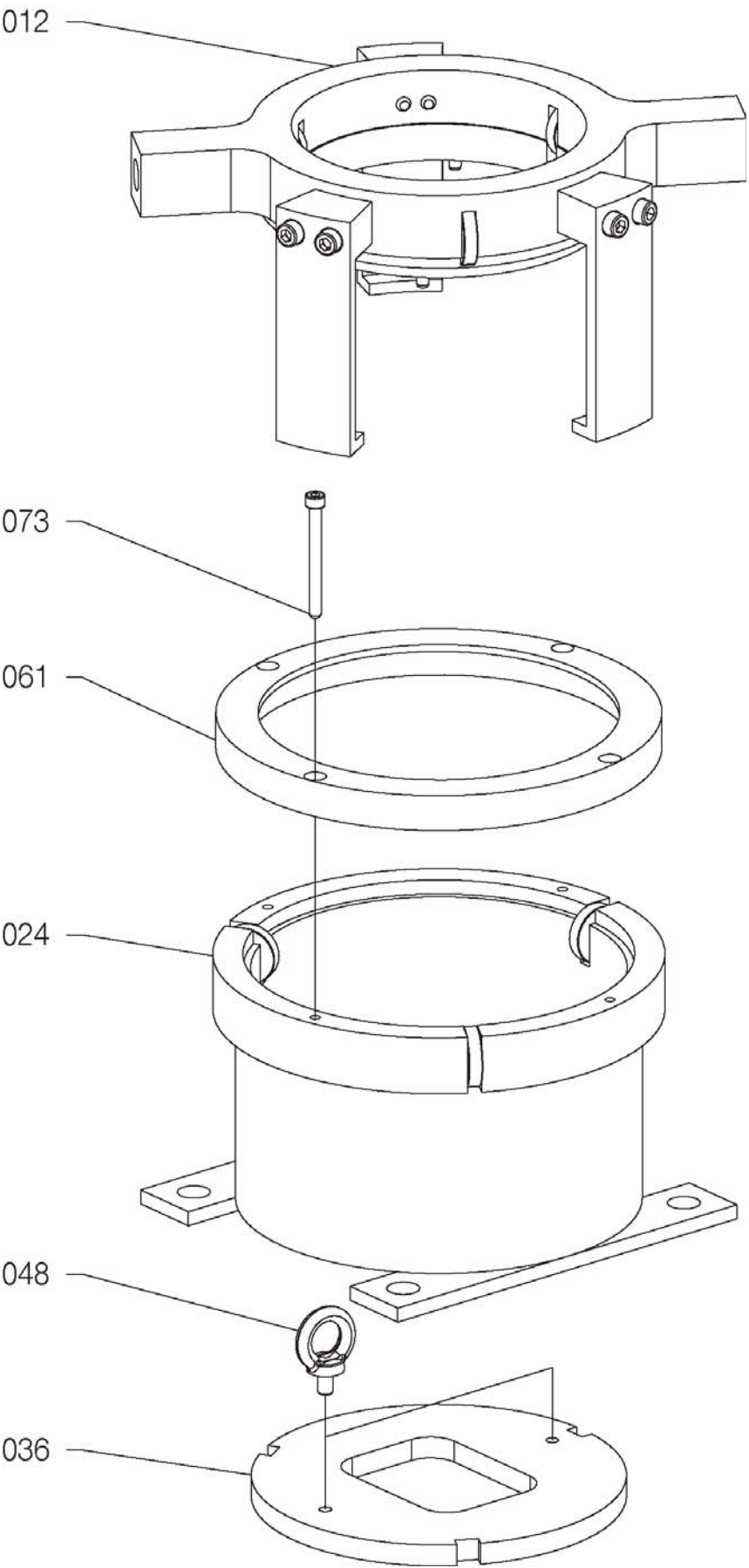
Mount the cover on the exhaust and rear side of the chain drive.



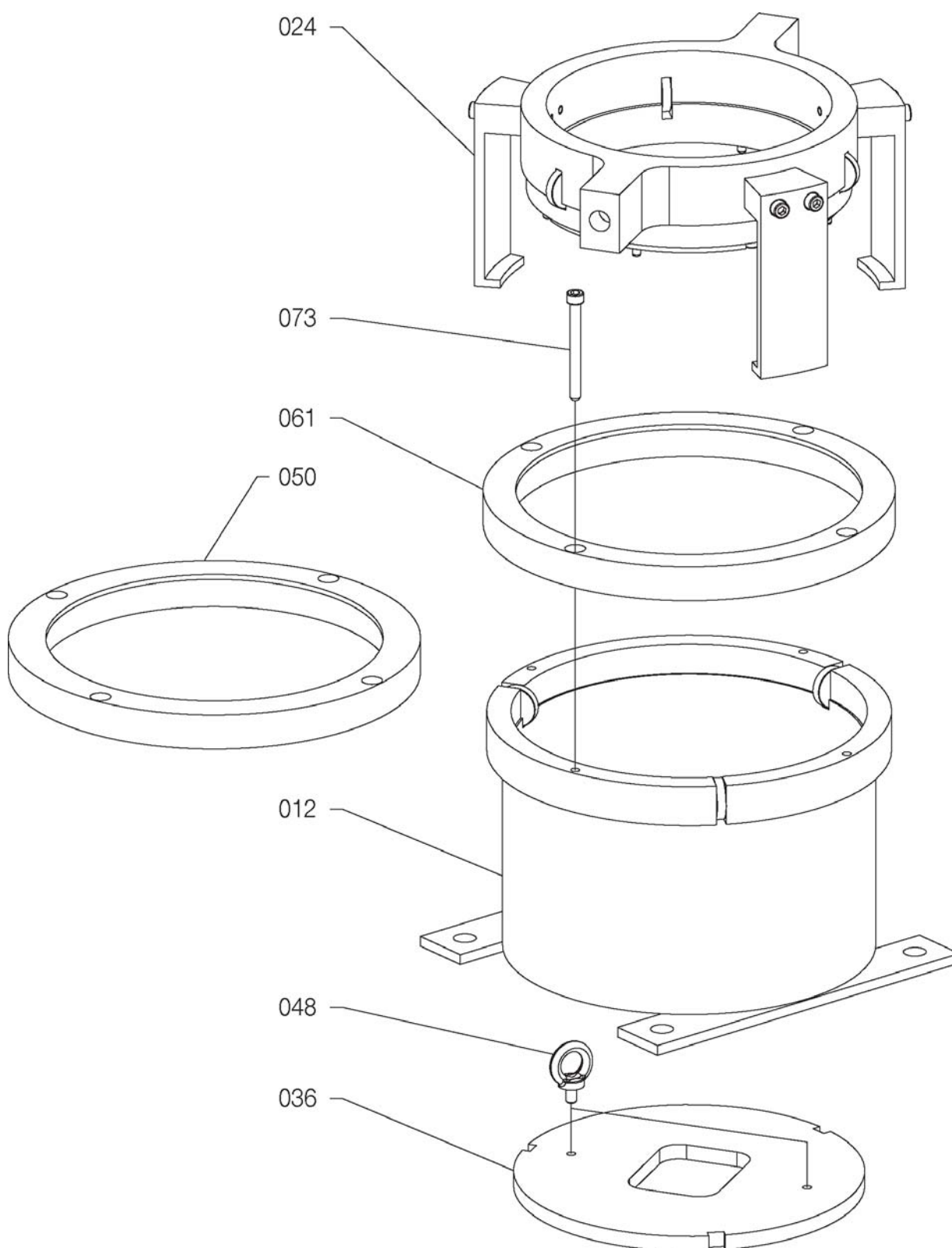
4565-1201-0008C04



Item No.	Qty	Item Designation
018	-	Reducing valve
020	-	Adaptor
031	-	Adaptor
043	-	Adaptor
055	-	Adaptor
067	-	Adaptor
079	-	Adaptor
080	-	Adaptor
092	-	Quick coupling, minimess
102	-	Quick coupling, minimess
114	-	Quick coupling, minimess
126	-	Screw
209	-	Tool box complete



Item No.	Qty	Item designation
012	-	Hook wrench
024	-	Pin wrench, special
036	-	Plate
048	-	Eye bolt
061	-	Ring for Hanmi + Hydro LeDuc accumulator
073	-	Screw

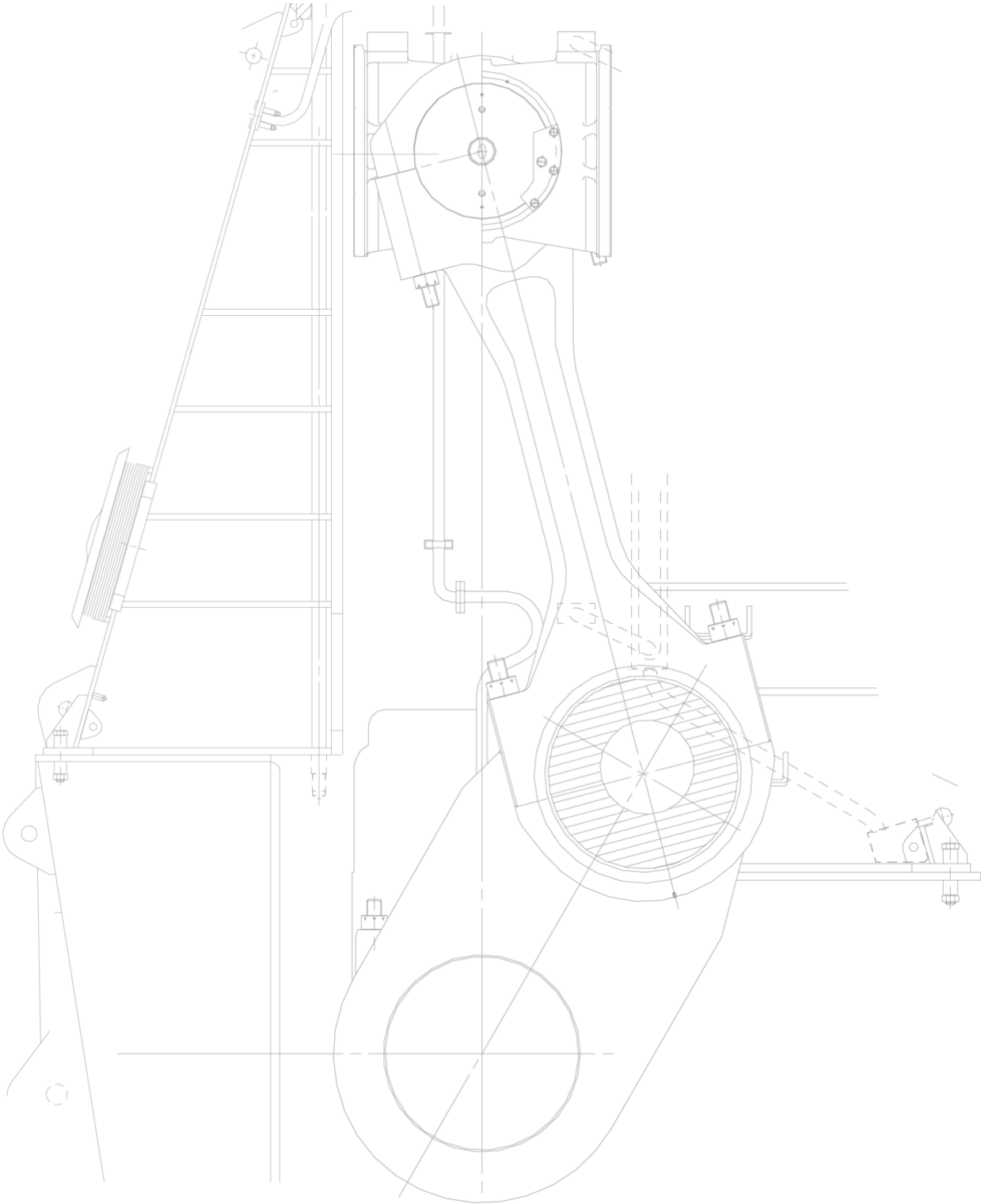


Item No.	Qty	Item designation
012	-	Pin wrench, special
024	-	Hook wrench
036	-	Plate
048	-	Eye bolt
050	-	Ring for Daeshin accumulator
061	-	Ring for Hydro LeDuc accumulator
073	-	Screw



Work Card

Multi Purpose Controller, Data	4765-1900-0001
Multi Purpose Controller	4765-1901-0002
Multi Purpose Controller	4765-1901-0004



**Safety
Precautions**

*for detailed sketch
see 0545-0100*

	Stop the Engine
---	-----------------



Data

Ref.	Description	Value	Unit
-	Table is empty on purpose. No Data needed.	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

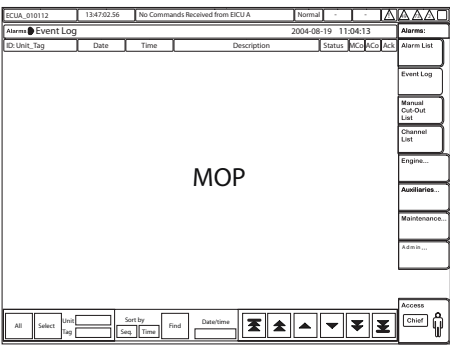
Tools

Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.

Multi Purpose Controller

Multi Purpose Controllers are used in CCU, ACU, ECU and EICU panels. Checking of the MPC is continuously performed by the MOP units.

See description in Chapter 6645 for a detailed view of the MOP panel screens.



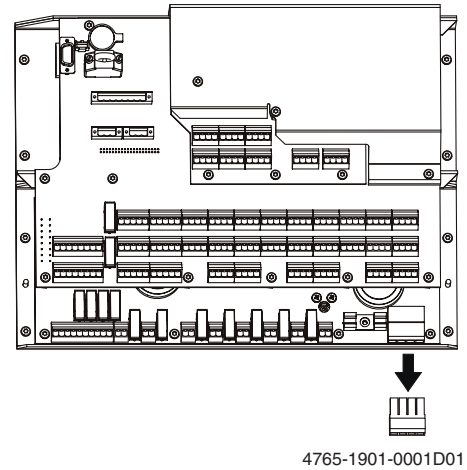
4765-1901-0001C01

Dismantling of MPC board

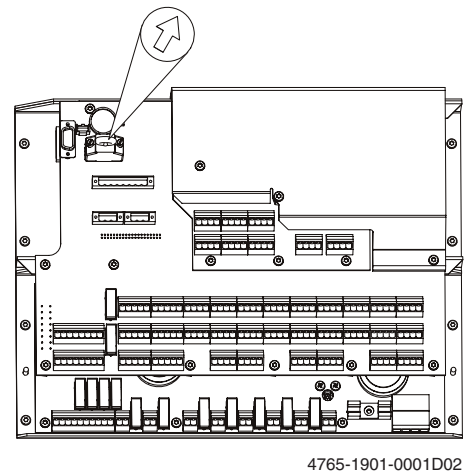
Static electricity may harm the MPC. When changing battery or doing other maintenance on the MPC it is important to level the electric potential between hand and frame. This is done immediately before any work on the MPC and MPC cabinet by simply touching any piece of non coated metal of the cabinet.

Power connector

Disconnect the power connector.

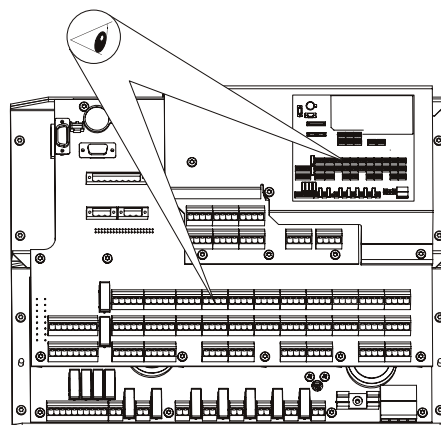
**ID-key**

Disconnect the ID-key.



MPC board

Check placement of connectors according to the table shown on the metal plate on the MPC board. If necessary, note down connector placement.



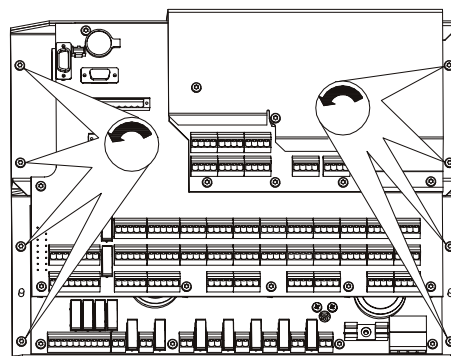
4765-1901-0001D03

Multi Purpose Controller • Dismantling**Connectors**

Disconnect all connectors on the MPC board.

Remove the MPC board

Unscrew the MPC board and remove it from the panel.



4765-1901-0001D05

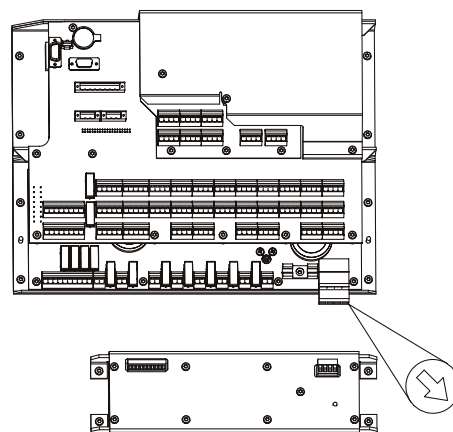
Dismantling of amplifier

In the CCU and ACU panels amplifiers are mounted below the MPC board.

**Work Card
4765-1901-0002**

Power connector

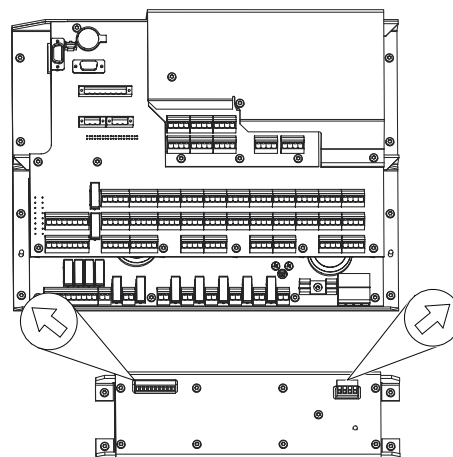
Unplug the power connector from the bottom of the MPC board.



4765-1901-0001D06

Amplifier

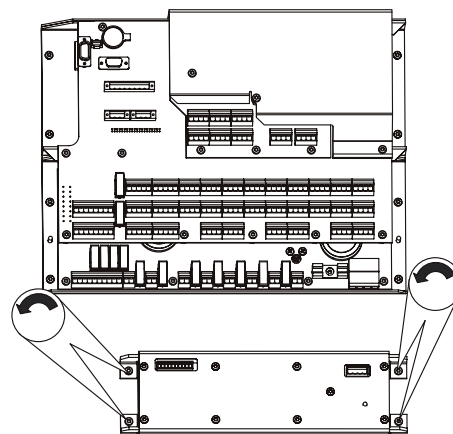
Unplug the two connectors on the amplifier.



4765-1901-0001D07

Amplifier

Unscrew the amplifier and remove it from the panel.



4765-1901-0001D08

Mounting the MPC board



WARNING

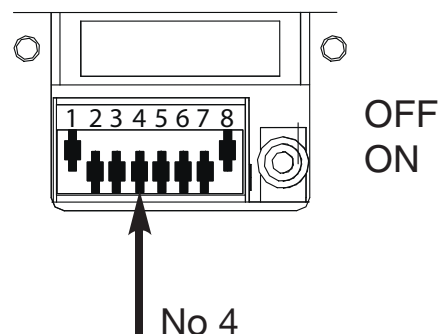
If a spare MPC board has been used previously on another engine it is necessary to force the MPC to update software from the MOP panel.

This is done in the following way: Set the yellow dip switch No. 4 on the side of the replacement MPC to OFF.

Mount the MPC as described.

Power on the MPC and let the MPC finish downloading.

When the MPC LED flashes 2 red and 3 green (APPLOAD_DIP see appendix), set the yellow dip switch No. 4 to ON.



4765-1901-0001M01



NOTE

Do not mount an MPC board unless the backup battery is installed.

Changing the battery of the Multi-Purpose Controller (MPC) may cause a reset and restart of the MPC.

Therefore, only change the battery while:



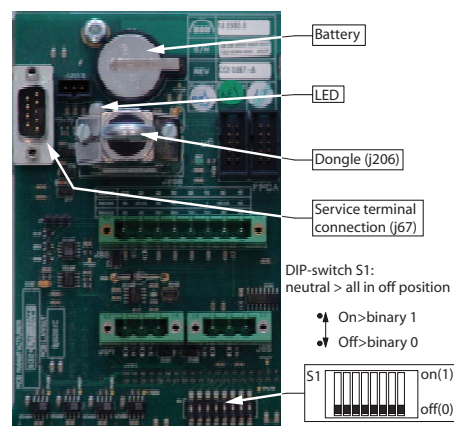
WARNING

- the ship is in harbour with engine stopped, or
- when sailing in unrestricted areas, where a restart of an MPC does not imply any risk for the ship or the engine.

The battery only serves as back-up supply for the built-in clock of the MPC, and a low battery level for several days until entering port is of no consequence to the safe operation of the engine.

Backup battery

Check that the back-up battery is mounted and that the DIP switch S1 is in neutral position. This means all switches are in the »off« position. This is also known as binary »0«.



4765-1901-0001M02

DIP switches

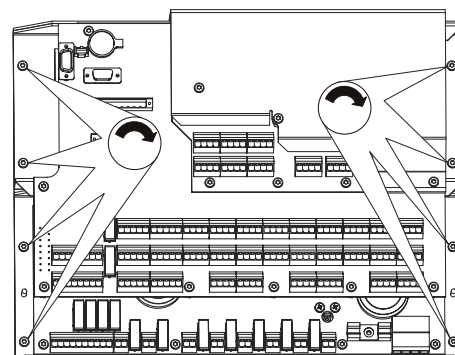
Check that the coloured DIP switches 1 and 8 on the side of the MPC board are set to the »off« position.



4765-1901-0001M03

MPC board

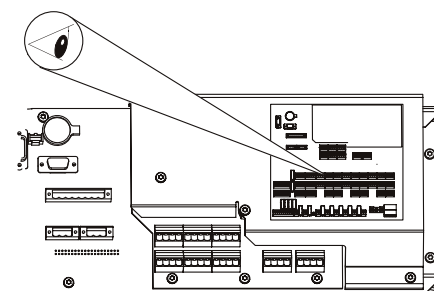
Mount the MPC board in the panel.



4765-1901-0001M04

Connectors

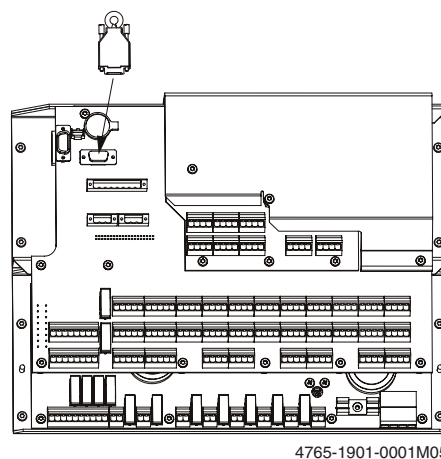
Mount the connectors according to the table shown on the metal plate on the MPC board.



4765-1901-0001M12

ID-key

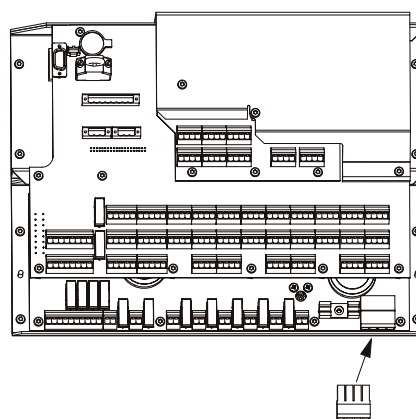
Mount the ID-key.



4765-1901-0001M05

Power connector

Mount the power connector.

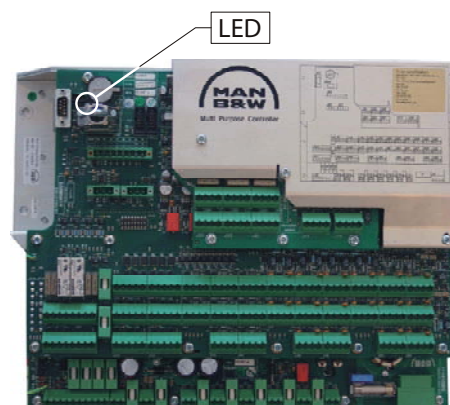


4765-1901-0001M06

Start-up process

During the start-up process, the LED will flash and the MPC board will reboot several times.

During start-up, the MPC verifies if the ID-key is connected. It reads the ID number and checks if the key ID is in the correct format and has a valid range, it reads the DIP-switch S1 value and verifies if it is 0 (Off). A new MPC board will download software and settings from the MOP panel during this process.



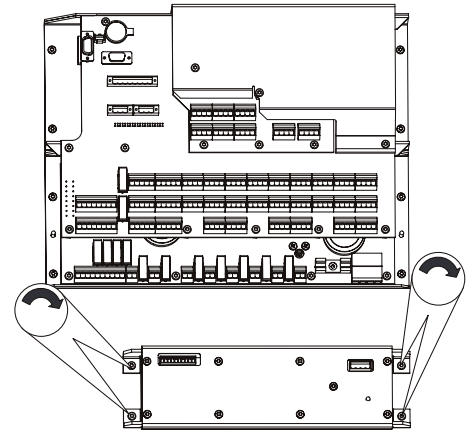
4765-1901-0001M07

The program completes the ID-key verification and is now ready to continue the boot sequence. Any deviations will send an error message via the LED. The start-up time of a new MPC board may vary but will take about 15 minutes.

When the LED shows green, the MPC board is running normally. The MPC LED indications are shown on the appendix in this procedure.

Amplifier

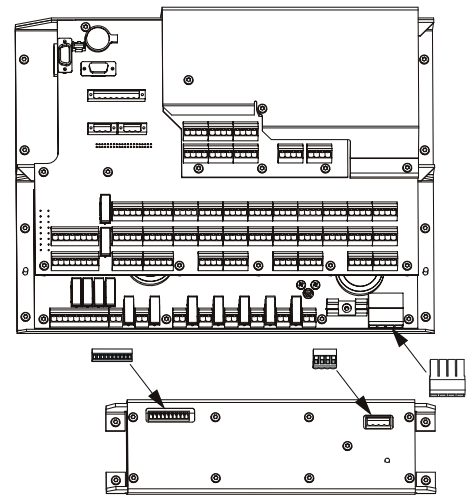
Mount the amplifier using the two screws.



4765-1901-0001M08

Connections

Connect the two connectors on the amplifier and the power connectors on the MPC board.



4765-1901-0001M09

The MPC LED flashes different sequences according to the process performed.

Some of these indications are for normal use and some are for service personnel use.

All of the LED indication sequences are shown in the diagram below.

This is to facilitate communication with MAN Diesel A/S service personnel if needed.

MPC LED Indication

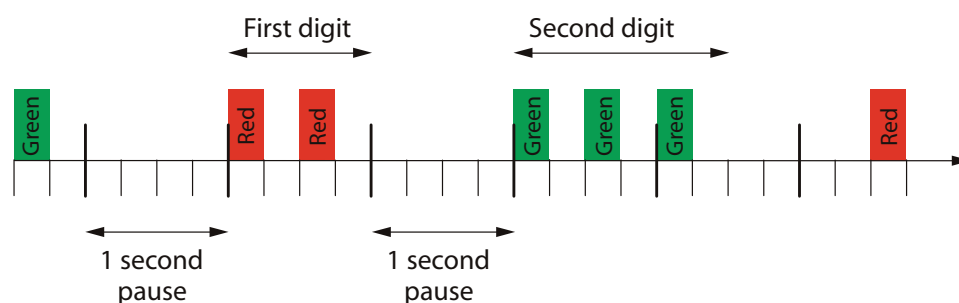
Description

The first part of the document describes the syntax of the LED indication and assigns a short description to each of the used indications. The second part presents a more detailed description of the different indications.

Syntax

The MPC LED may be issuing indications by either emitting constant light or by flashing. The LED indications are uniquely identified by the colour that the MPC LED emits.

A flashing LED indication consists of two pulse trains separated in time by a 1-second pause. Each of these pulse trains represents an integer. All pulses are set against a yellow background. The first pulse train will alternate between the yellow background and a red foreground, while the second will use green as foreground.



4765-1901-0001M10

For identification of the indication the user must therefore note the number of red and green pulses. The first digit is the number of red pulses and the second digit is the number of green pulses. In the illustration above, the indication code would thus be (2,3).

Indications

Constant

Colour	Short name	Short description
Red	ERROR	Either early initialization or fatal error
Orange	INIT	Initialization, no parameters available or non-normal node mode
Green	NORMAL	Application up and running

Flashing

Digits		Short name	Short description
Red	Green		
1	1	CTRL_PRG	Onboard control programming in progress
2	1	APPLOAD_SCAN	Application download in progress - scanning for server
2	2	APPLOAD_DOWNLOAD	Application download in progress - downloading program
2	3	APPLOAD_DIP	Application download completed - reset yellow DIP switch set to ON
3	1	BOOTLOAD_SCAN	Bootloader download in progress - scanning for server
3	2	BOOTLOAD_DOWNLOAD	Bootloader download in progress - downloading program
4	1	DONGLE_VERIFY	Checking node ID-key
4	2	DONGLE_ERROR	ID-key error - missing, broken or not programmed
4	3	DONGLE_DIP	Node ID DIP switch not correctly reset - reset it to 0x00

4765-1901-0001M11

Detailed description of LED indications

ERROR (Red)	This code is used primarily for indicating if the MPC has experienced a fatal error. However, the MPC will also use this indication during early initialisation. Therefore, the user should only take this code as an indication of error if it persists more than 10 seconds.
INIT (Orange)	Generally, this code is used for indicating initialisation, but the MPC may also use this indication to signal one of the following conditions: No parameters: No valid parameters are available to the application software. Configuration or test mode: The MPC is in a non-normal node mode. Generally, if the INIT code is shown longer than 10 seconds this would indicate one of the latter conditions.
NORMAL (Green)	Application is up and running.
CTRL_PGM (1,1)	One of the on-board micro controllers is being programmed. This is a part of the MPC initialization process.
APPLOAD_SCAN (2,1)	The application software download program (bootloader) is trying to find a server from which it can download its application program. If this code persists it indicates either that no application program server is connected to the network or the network is broken.
APPLOAD_DOWNLOAD (2,2)	An application program is being downloaded.
APPLOAD_DIP (2,3)	The yellow DIP-switch on the MPC CPU board can be used for forcing download of new application software. To avoid looping it is therefore required that the yellow DIP-switch be reset on completion of such a forced download. Reset it to ON/down.
BOOTLOAD_SCAN (3,1)	This indication is analogous to the APPLOAD_SCAN indication except that this code indicates that there is not server available from which the MPC can download a new bootloader. This code should only be indicated if attempts are being made to update the bootloader using the special update program.
BOOTLOAD_DOWNLOAD (3,2)	A new bootloader program is being downloaded and programmed.
DONGLE_VERIFY (4,1)	The ID-key is being checked. This should only take a couple of seconds.

**DONGLE_ERROR
(4,2)**

A ID-key error has been identified. Either the ID-key is missing, broken or holds an invalid value. Try to reprogram it.

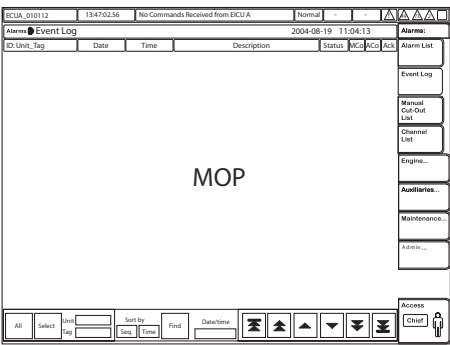
DONGLE_DIP (4,3)

The DIP-switch mounted on the CMI/O board is used for programming the ID-key. The programming process requires that this DIP-switch be reset before completing. This code is used for indicating this to the user. Reset the CMI/O board DIP switches to OFF/down.

Multi Purpose Controller

MPC-10 Controllers are used in the CCU panels. Checking of the MPC-10 is continuously performed by the MOP units.

See description in Chapter 6645 for a detailed view of the MOP panel screens.



4765-1901-0001C01

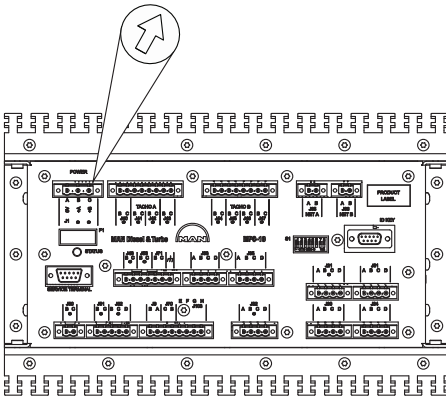
Dismantling of MPC board



Static electricity may harm the MPC-10. When changing battery or doing other maintenance on the MPC-10 controller it is important to level the electric potential between hand and frame. This is done immediately before any work on the MPC-10 and MPC-10 cabinet by simply touching any piece of non coated metal of the cabinet.

Power connector

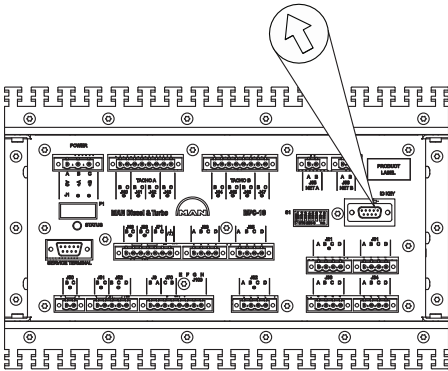
Disconnect the power connector.



4765-1901-0004D01

ID-key

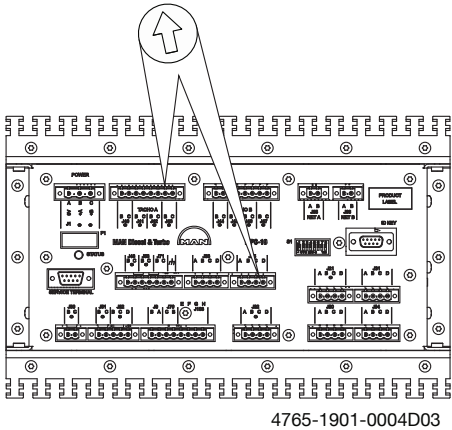
Disconnect the ID-key.



4765-1901-0004D02

Connectors

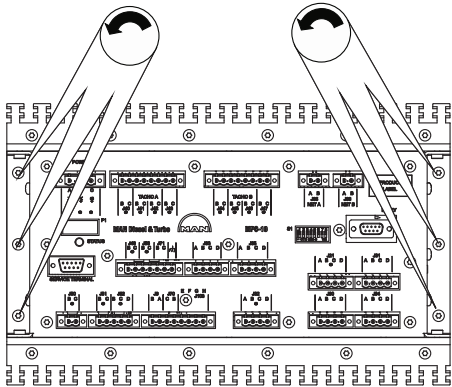
Disconnect all connectors from the MPC-10.



4765-1901-0004D03

Remove the MPC-10 controller

Unscrew the MPC-10 and remove it from the panel.



4765-1901-0004D04

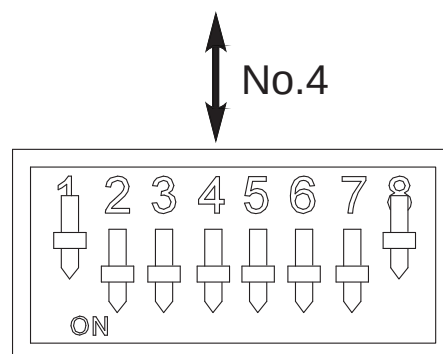
Mounting the MPC-10

If a spare MPC-10 unit has been used previously on another engine it is necessary to force the MPC-10 to update software from the MOP panel.

This is done in the following way: Set the dip switch no. 4 on the right side of the replacement MPC-10 to OFF.

Mount the MPC-10 as described. Power on the MPC-10 and let the MPC-10 finish downloading.

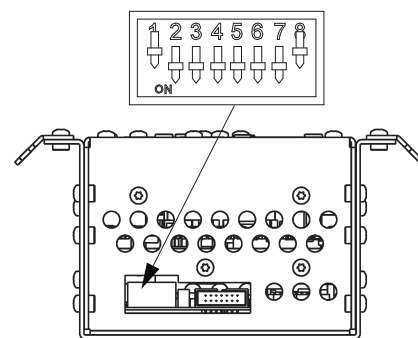
When the MPC LED flashes 2 red and 3 green (APPLOAD_DIP see appendix), set the dip switch no. 4 to ON.



4765-1901-0004M01

DIP switches

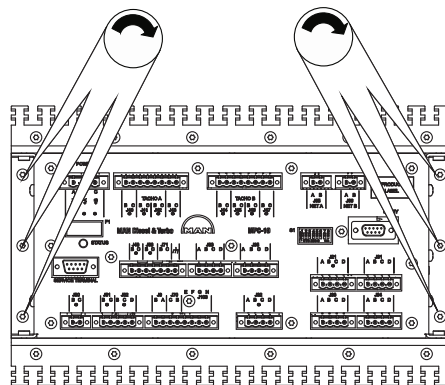
Check that the DIP switches no. 1 and 8 on the MPC-10 controller are set to the »off« position.



4765-1901-0004M02

MPC-10 controller

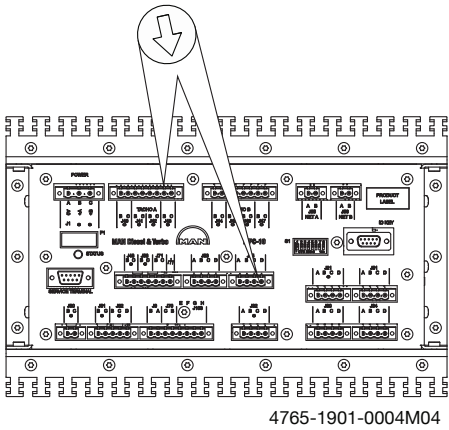
Mount the MPC-10 in the panel.



4765-1901-0004M03

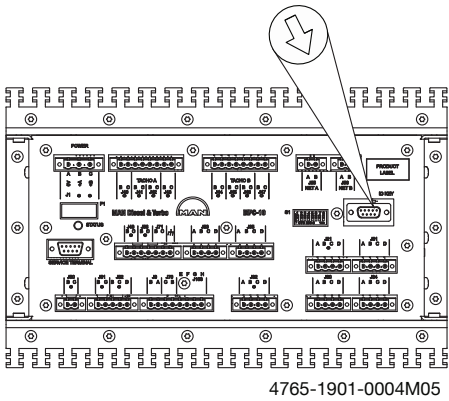
Connectors

Mount the connectors according to the numbering printed on the metal plate on the front of the MPC-10.



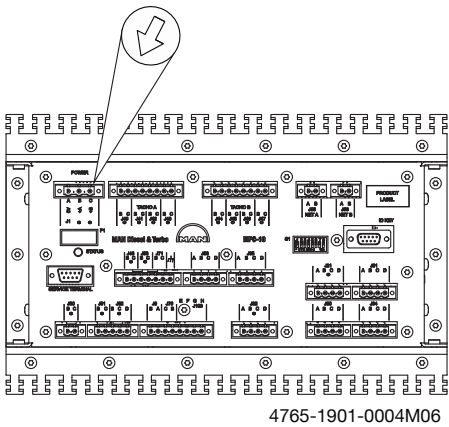
ID-key

Mount the ID-key.



Power connector

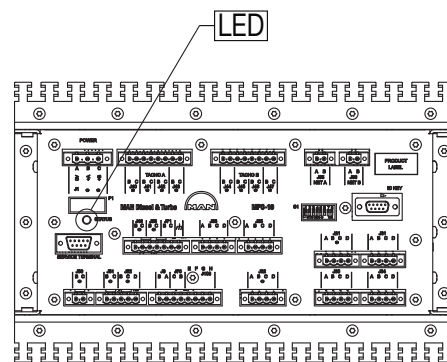
Mount the power connector.



Start-up process

During the start-up process, the LED will flash and the MPC-10 controller will reboot several times.

During start-up, the MPC-10 verifies if the ID-key is connected. It reads the ID number and checks if the key ID is in the correct format and has a valid range, it reads the DIP-switch S1 value and verifies if it is 0 (Off). A new MPC-10 controller will download software and settings from the MOP panel during this process.



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The program completes the ID-key verification and is now ready to continue the boot sequence. Any deviations will send an error message via the LED. The start-up time of a new MPC-10 board may vary but will take about 15 minutes.

When the LED shows green, the MPC-10 board is running normally. The MPC-10 LED indications are shown on the appendix in this procedure.

The MPC-10 LED flashes different sequences according to the process performed.

Some of these indications are for normal use and some are for service personnel use.

All of the LED indication sequences are shown in the diagram below.

This is to facilitate communication with MAN Diesel & Turbo service personnel if needed.

MPC-10 LED Indication

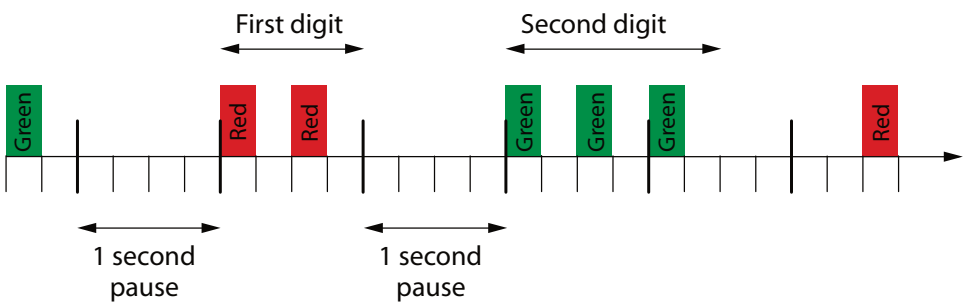
Description

The first part of the document describes the syntax of the LED indication and assigns a short description to each of the used indications. The second part presents a more detailed description of the different indications.

Content

The MPC-10 LED may be issuing indications by either emitting constant light or by flashing. The LED indications are uniquely identified by the colour that the MPC10 LED emits.

A flashing LED indication consists of two pulse trains separated in time by a 1-second pause. Each of these pulse trains represents an integer. All pulses are set against a yellow background. The first pulse train will alternate between the yellow background and a red foreground, while the second will use green as foreground.



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For identification of the indication the user must therefore note the number of red and green pulses. The first digit is the number of red pulses and the second digit is the number of green pulses. In the illustration above, the indication code would thus be (2,3).

Indications

Constant			
Colour	Short name	Short description	
Red	ERROR	Either early initialization or fatal error	
Orange	INIT	Initialization, no parameters available or non-normal node mode	
Green	NORMAL	Application up and running	

Flashing			
Digits		Short name	Short description
Red	Green		
1	1	CTRL_PRG	Onboard control programming in progress
2	1	APPLOAD_SCAN	Application download in progress - scanning for server
2	2	APPLOAD_DOWNLOAD	Application download in progress - downloading program
2	3	APPLOAD_DIP	Application download completed -reset yellow DIP switch set to ON
3	1	BOOTLOAD_SCAN	Bootloader download in progress - scanning for server
3	2	BOOTLOAD_DOWNLOAD	Bootloader download in progress - downloading program
4	1	DONGLE_VERIFY	Checking node ID-key
4	2	DONGLE_ERROR	ID-key error - missing, broken or not programmed
4	3	DONGLE_DIP	Node DIP switch S1 not correctly reset - set all switches to "OFF"
4	4	DONGLE_FORMAT	The ID-key needs to finalize the formatting process
4	5	DONGLE_DIP	ID Key EID number does not match MOP and/ or MPC

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Detailed description of LED indications

ERROR (Red)	This code is used primarily for indicating if the MPC10 has experienced a fatal error. However, the MPC-10 will also use this indication during early initialisation. Therefore, the user should only take this code as an indication of error if it persists more than 10 seconds.
INIT (Orange)	Generally, this code is used for indicating initialisation, but the MPC-10 may also use this indication to signal one of the following conditions: No parameters: No valid parameters are available to the application software. Configuration or test mode: The MPC-10 is in a non-normal node mode. Generally, if the INIT code is shown longer than 10 seconds this would indicate one of the latter conditions.
NORMAL (Green)	Application is up and running.
CTRL_PGM (1,1)	One of the on-board micro controllers is being programmed. This is a part of the MPC-10 initialization process.
APPLOAD_SCAN (2,1)	The application software download program (bootloader) is trying to find a server from which it can download its application program. If this code persists it indicates either that no application program server is connected to the network or the network is broken.
APPLOAD_DOWNLOAD (2,2)	An application program is being downloaded.
APPLOAD_DIP (2,3)	The yellow DIP-switch on the MPC-10 CPU controller can be used for forcing download of new application software. To avoid looping it is therefore required that the yellow DIP-switch be reset on completion of such a forced download. Reset it to ON/down.
BOOTLOAD_SCAN (3,1)	This indication is analogous to the APPLOAD_SCAN indication except that this code indicates that there is not server available from which the MPC-10 can download a new bootloader. This code should only be indicated if attempts are being made to update the bootloader using the special update program.
BOOTLOAD_DOWNLOAD (3,2)	A new bootloader program is being downloaded and programmed.
DONGLE_VERIFY (4,1)	The ID-key is being checked. This should only take a couple of seconds.

**DONGLE_ERROR
(4,2)**

An ID Key error has been identified. Either the ID Key is missing, broken or holds an invalid value. It may also indicate that a new ID Key is inserted.
Try to program the ID Key following the “Replacing an ID Key” procedure.

DONGLE_DIP (4,3)

The programming procedure requires that the DIP-switch S1 be reset before completing.
The operator must respond to this by setting all 8 switches on the DIP-switch S1 to “OFF” (Down).

**DONGLE_FORMAT
(4,4)**

The ID Key needs to finalize the formatting process. This situation may occur for different reasons; it might be that the ID key or MPC-10 have been replaced.

The operator must respond to this by setting the first (left) DIP-switch on S1 to “ON” (Up) in min. 2 sec.
Then put it back in “OFF” (Down).
This causes the final formatting of the ID key.

After this the MPC10 restarts.

**DONGLE_DIP_CON-
FLICT (4,2)**

ID Key EID number does not match MOP and/or MPC. This situation may occur when a new ID Key has been programmed and the old ID Key is inserted in the MPC-10.

The operator should insert the newly programmed ID Key and reset the MPC-10, or a new unused ID Key must be programmed following the “Replacing an ID Key” procedure.

**Replacing an ID
Key**

On the rare occasion, that an ID key fails, it can be replaced by a new one. The new key should be programmed as described in the following.

This key has to be formatted when the application use it for the first time and it will be reflected in a new parameter backup sent to the MOP. After that is done, the old key is no longer accepted.

Please go through the following steps:

- Power off the node.
- Remove the old ID Key.
- Set the DIP-switch S1 accordingly to table on page 11.
- Reconnect power to the node.
- Wait for the LED to indicate 4 red and 2 green blinks.
- Plug-in a new unused ID Key. Then the LED indicates 4 red and 3 green flashes.
- While the LED indicates 4 red and 3 green blinks, the operator must set all 8 switches on the DIP-switch S1 to “OFF” (Down).

Now the MPC-10 proceeds with application program download and final formatting.

The MPC-10 may start to download the application program while the LED indicates 2 red and 2 green flashes. This will take up to 5 minutes.

After this the MPC-10 restarts and stops for an operator dialog. The LED indicates this with 4 red and 4 green flashes.

- The operator must respond to this by setting the first (left) DIP-switch on S1 to "ON" (Up) in min. 2 sec.
- Then put it back in "OFF" (Down).

This causes the final formatting of the ID key.

After this the MPC-10 makes another restart before the application is executed.

Programming a

Blank ID Key

This use case concerns the initial use of an installation, or the case that the ID Key for some reasons has been replaced with a new and blank ID Key.

When the ID Key is blank, it means that the internal flash memory had the data values, as was left from the factory test of the ID Key itself.

The way to define the network address for a new ID key is using the DIP switch on the MPC-10 (all versions of BES and bootloader).

After this is done, the final formatting of the remaining fields in the ID key is done the first time an application program starts. User interaction is required to confirm this step.

Initializing a Blank

ID Key from DIP

Switch

The service terminal can optionally be used to observe what is happening in the MPC-10. The MOP is assumed to be running and connected to the MPC-10.

As this is the first set-up with a blank ID Key, the DIP-switch 1 must have the node address coded before power up (241 in this example) please see page 11 for correct network address.



NOTE

The ID Key must be unplugged before power up.

Please go through the following steps:

- At power up the LED indicates 4 red and 2 green blinks.
- Plug the blank ID Key in the current MPC10. Then the LED indicates 4 red and 3 green blinks.
- While the LED indicates 4 red and 3 green blinks, the operator must change the value in the DIP-switch to 0 in all bits. Then the LED indicates 2 red and 1 green blinks.

Now the MPC-10 proceeds with application program download and final formatting.

Software download and final formatting of ID

Hereafter the MPC-10 starts downloading the application program while the LED indicates 2 red and 2 green blinks.

After this the MPC-10 restarts and stops for an operator dialog. The LED indicates 4 red and 4 green blinks in this state

The operator must respond to this by setting bit 1 of DIP-switch 1 to 1, and keeping it there for at least 2 seconds.

This causes the final formatting of the ID Key

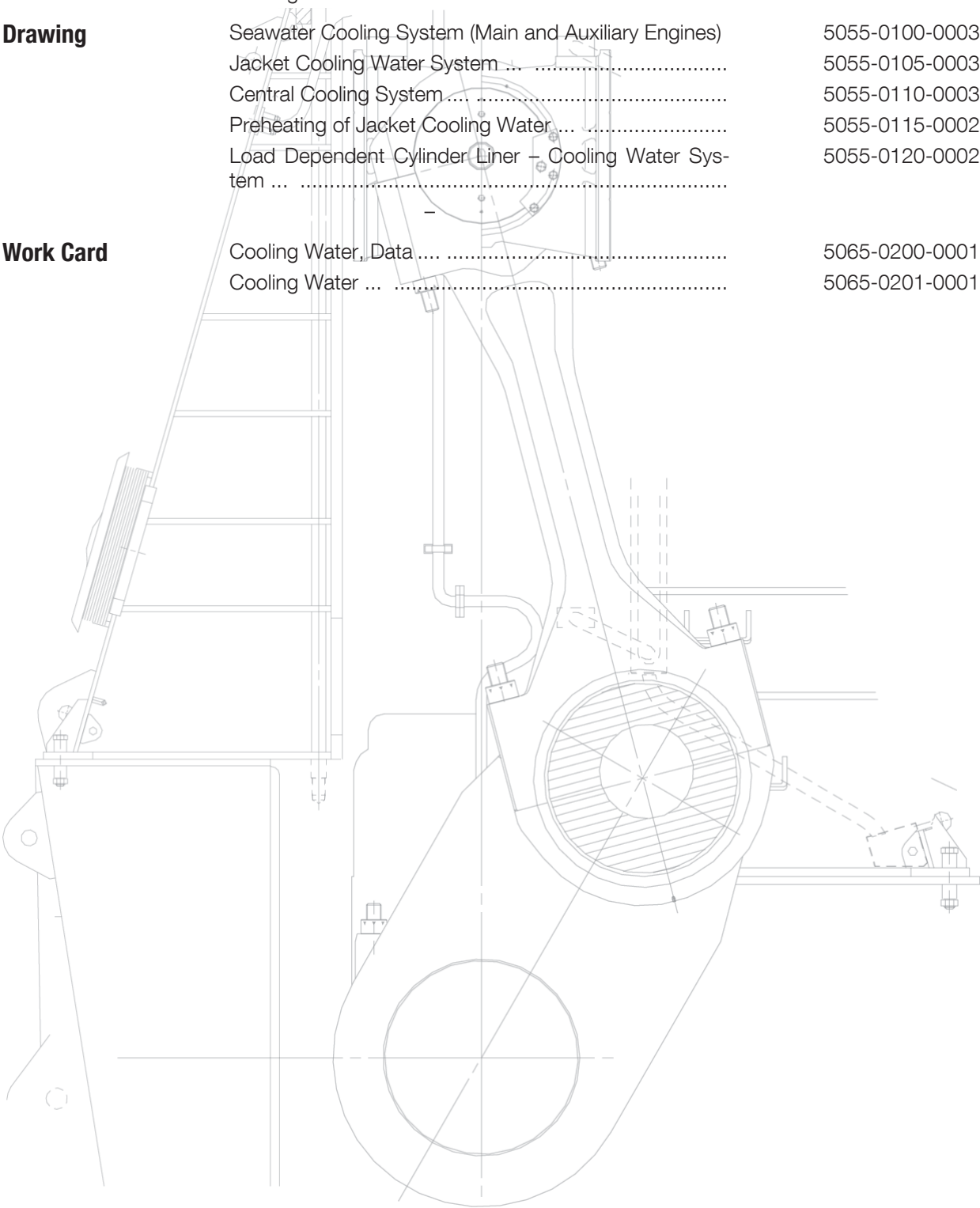
After this the MPC-10 makes another restart before the application is executed.

For correct settings of the DIP switch we refer to below table of network addresses:

	DIP switch bit No.	1	2	3	4	5	6	7	8
MPC	Network Address								
CCU1	240	Off	Off	Off	Off	On	On	On	On
CCU2	241	On	Off	Off	Off	On	On	On	On
CCU3	242	Off	On	Off	Off	On	On	On	On
CCU4	243	On	On	Off	Off	On	On	On	On
CCU5	244	Off	Off	On	Off	On	On	On	On
CCU6	245	On	Off	On	Off	On	On	On	On
CCU7	246	Off	On	On	Off	On	On	On	On
CCU8	247	On	On	On	Off	On	On	On	On
CCU9	248	Off	Off	Off	On	On	On	On	On
CCU10	249	On	Off	Off	On	On	On	On	On
CCU11	250	Off	On	Off	On	On	On	On	On
CCU12	251	On	On	Off	On	On	On	On	On
CCU13	252	Off	Off	On	On	On	On	On	On
CCU14	253	On	Off	On	On	On	On	On	On
CCU15	254	Off	On	On	On	On	On	On	On
CCU16	255	On	On	On	On	On	On	On	On

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Preface Chapter	Cooling Water	5040-0100-0001
Description	Cooling Water System	5045-0100-0005
	Cooling Water Treatment	5045-0200-0002
Drawing	Seawater Cooling System (Main and Auxiliary Engines)	5055-0100-0003
	Jacket Cooling Water System	5055-0105-0003
	Central Cooling System	5055-0110-0003
	Preheating of Jacket Cooling Water	5055-0115-0002
	Load Dependent Cylinder Liner – Cooling Water Sys- tem	5055-0120-0002
Work Card	Cooling Water, Data	5065-0200-0001
	Cooling Water	5065-0201-0001



Cooling Water System

This chapter contains informations on how to operate and maintain your cooling water system.

Please note that the pipe systems vary considerably from plant to plant.

1 General

Pipe systems vary considerably from plant to plant. The following schematic pipe diagrams are included here, for guidance, to illustrate the essential principles of the circuits and their correlation.

NOTICE

For a specific plant, the correct details must be found in the piping diagrams supplied by the shipyard.

2 Seawater Cooling System

Drawing 5055-0100

The seawater cooling system is a low temperature system. However, to be sure that the lubricating oil is kept at a viscosity level suitable for heat transfer, a recirculating arrangement controlled by the thermostatic valve, **item 3**, ensures that the inlet temperature of the cooling water does not fall below 10 °C.

2.1 Operation at Sea

Drawing 5055-0100

Seawater is drawn by the seawater pump, **item 2**, through two separate inlets or "sea chests", **item 1**, and pumped through the various coolers for both the main engine and the auxiliary engines.

The coolers incorporated in the system are the lubricating oil cooler, **item 6**, the scavenge air cooler(s), **item 7**, and a common jacket water cooler, **item 8**.

The air cooler(s) are supplied directly by the seawater pumps and are therefore cooled by the coldest water available in the system. This ensures the lowest possible scavenge air temperature, and thus optimum cooling is obtained with a view to the highest possible thermal efficiency of the engines.

Since the system is seawater cooled, all components are to be made of seawater resistant materials.

With both the main engine and one or more auxiliary engines in service, the seawater pump, **item 2**, supplies cooling water to all the coolers and, through non-return valve, **item 5**, to the auxiliary engines. The pump, **item 4**, is inactive.

2.2 Operation in Port

Drawing 5055-0100

During operation in port, when the main engine is stopped but one or more auxiliary engines are running, a small seawater pump, **item 4**, is started up, instead of the large pump, **item 2**. The seawater is led from the pump to the auxiliary engine(s), through the common jacket water cooler, **item 8** and is divided into two strings by the thermostatic valve **item 3**, either for recirculation or for discharge to the sea.

3 Jacket Cooling Water System

High engine load

See drawing 5055-0105.

The jacket cooling water system controls the temperature of the engines proper.

The jacket cooling water must be inhibited to protect the surfaces of the cooling system against corrosion, corrosion fatigue, cavitation and the formation of scale.
See description 5045-0200.

Low engine load

During low engine load the temperature in the cylinder becomes relatively low and this causes the sulphur from the fuel oil to condensate on the cylinder liner wall which will cause corrosion.

The purpose of the jacket cooling water systems mentioned below is to raise the temperature on the cylinder liner wall to prevent the condensation of the sulphur. Raising the temperature of the cylinder liner wall is done by raising the jacket cooling water temperature at low load. This will cause the cylinder liner wall to have a higher temperature and thus, the condensation of sulphur will be reduced.

In order to prevent cold corrosion in the cylinder liner, the following add-ons to the jacket cooling water system have been introduced on some engine types.

- Load Dependent Cylinder Liner (LDCL).
See this description item 3.3 and drawing 5055-0120.
- Load Dependent High Temperature (LDHT).
See this description item 3.4 and drawing 5055-0130.
- Jacket Cooling Water Bypass Basic (JBB).
See this description item 3.5 and drawing 5055-0140.

NOTICE

Jacket cooling water system variants

Only one or none of the above-mentioned three jacket cooling water system variants are present in the system.

3.1 Operation at Sea

See drawing 5055-0105

The jacket water pump, **item 1**, circulates hot cooling water through the main engine to the freshwater generator, **item 2**, and from there to the jacket water cooler, **item 3**. Here a thermostatically controlled 3-way valve, **item 4**, mixes cooled and uncooled water to maintain a constant outlet temperature from the main engine.

An integrated loop in the auxiliary engines ensures a constant temperature of 80 °C at the outlet of the auxiliary engines.

There is one common expansion tank, **item 6**, for the main engine and the auxiliary engines.

To prevent the accumulation of air in the jacket water system, a deaerating tank, **item 5**, is to be installed. An alarm device is inserted between the deaerating tank and the expansion tank, so that the operating crew can be warned if excess air or gas is released, as this signals a malfunction of engine components.

3.2 Operation in Port

See drawing 5055-0105 and 5055-0115

The main engine is preheated by utilising hot water from the auxiliary engine(s). Depending on the size of main engine and auxiliary engines, an extra preheater may be necessary. This preheating is activated by *closing valve A and opening valve B*.

Activating valves A and B will change the direction of flow, and the water will now be circulated by the auxiliary engine- driven pumps. From the auxiliary engines, the water flows through valve B directly to the main engine jacket outlet. When the water leaves the main engine, through the jacket inlet, it flows to the thermostatically controlled 3-way valve, **item 4**.

As the temperature sensor for the valve in this operating mode is measuring in a non-flow, low temperature piping, the valve will lead most of the cooling water to the jacket water cooler, **item 3**. The integrated loop in the auxiliary engines will ensure a constant temperature of 80 °C at the auxiliary engine outlet, the main engine will be preheated, and auxiliary engines on stand-by can also be preheated by operating valves **F3** and **F1**.

3.3 Load Dependent Cylinder Liner Cooling Water System (LDCL cooling water system)

The LDCL cooling water system is an add-on to the jacket cooling water system. The LDCL cooling water system is the part of the jacket cooling water system which controls the cooling water temperature in the cylinder liners, cylinder covers and exhaust valves.

See drawing 5055-0120.

3.3.1 Function

The purpose of the LDCL system is to increase the temperature of the jacket cooling water in order to limit problems with cold corrosion in the cylinder liners caused by sulphur in the fuel. The increase in temperature is achieved by re-circulating part of the cooling water. To ensure a high flow through the cylinder liners, the cooling water circulation in the liners is driven by a circulation pump (LDCL circulation pump). This LDCL circulation pump is operative during the load spectrum i.e. 2% → 100%. The LDCL circulation pump is controlled by the engine control system and operated on the MOP.

If the 'LDCL state' is in automatic mode, the LDCL circulation pump starts and stops automatically.

See description 6645-0250 'Process Information' and MOP screen - Engine > Process Information > LDCL.

The water in the circulation circuit is heated by absorbing energy from the cylinder liner. The temperature of the water in the circuit is controlled by a 3-way mixing valve which controls the amount of re-circulated water (being heated) and the amount of water which is being replaced with colder water. In this way the controller adjusts the temperature of the water until it reaches the set point.

See drawing 5055-0120. Fig. 1.

In case of failure in the system, the circulation pump will stop and the 3-way mixing valve will move to fail safe position which is fully open 3(B) – 1(AB). If, for whatever the reason, the mixing valve does not move to fail safe position, the valve can be manually opened by venting the control air, this is done by closing the pneumatic valve, which triggers: port "B" – "AB" fully open. In this position, the full flow of cooling water from the jacket cooling water pump is sent through the liners and the cooling water temperature will be controlled by the jacket cooling water system.

When the sub-telegraph command state is changed from Stand By to Finished With Engine the 3-way mixing valve will be set to a fixed position, e.g. 15% open. Subsequently a timer for the LDCL circulation pump and the 3-way mixing valve will be activated. When the time limit is reached (eg. 20 minutes), or the cooling water temperature increase through the liner has dropped to a certain limit, the 3-way mixing valve will open fully and the LDCL circulation pump will stop.

See also description 6645-0250 'Process Information' > "LDCL tab"

3.3.2 Control

The cooling water control unit (CWCU) measures inlet and outlet temperatures, inlet and outlet pressures for the LDCL circulation pump and receives the actual engine load from the ECS.

Based on the jacket cooling water outlet temperature and the engine load and (additionally on some engines) the engine speed and low sulphur signal, the 3-way mixing valve is moved to a position where the temperature of the circulating cooling water matches the inlet and outlet temperatures defined by the systems parameters.

See drawing 5055-0120. Fig. 2.

In addition, the CWCU will order an inlet temperature from the jacket cooling water system, which again is defined by the systems parameters (indicated in figure 2).

In case of a sensor failure or if the LDCL circulation pump starter cabinet is put in 'local control', an alarm will be raised, and the system in failure mode.

In case of LDCL system failure leading to LDCL system in-activity, the cylinder liners will potentially be exposed to increased Sulphur acid condensation and increased corrosive wear. It is therefore recommended to increase the (High BN) Feed Rate Factor by 0.05 in g/kWh immediately, or no later than two weeks after the LDCL system has been shut off, in order to compensate for the reduced liner running surface temperature when operating the engine without the LDCL system.

For more information and operation of the LDCL system, *see description 6645-0250 'Process Information'.*

3.4 Load Dependent High Temperature Cooling Water System (LDHT cooling water system)

The LDHT cooling water system is a add-on to the jacket cooling water system. The LDHT cooling water system is the part of the jacket cooling water system which controls the cooling water temperature in the entire engine.

See drawing 5055-0130.

3.4.1 Function

The LDHT cooling water system differs from the normal system by having a circulation circuit of cooling water over the engine. The circulation is driven by a circulation pump to ensure a high flow over the engine. The circulation circuit is cooled by removing hot water from the circuit and adding cold, corresponding to the heat release of the engine and the temperature set point in the control system.

The high temperature circulation is only operative up to e.g. 75% engine load. Operation point is engine dependent. At this point, the circulation pump is stopped and the 3-way mixing valve is moved to full open 3(B) – 1(AB) position. In this position, the full flow of cooling water from the ship is sent through the engine.

See drawing: 5055-0130. Fig. 1.

In case of failure in the system, the circulation pump will stop and the 3-way mixing valve will move to fail safe position which is full open 3(B) – 1(AB), and the cooling water temperature will be controlled by the ships cooling water supply.

3.4.2 Control

The cooling water control unit (CWCU) measures inlet and outlet temperatures, inlet and outlet pressures for the circulation pump and the actual engine load.

Based on these inputs, the 3-way mixing valve is moved to a position where the temperature of the circulating cooling water matches the inlet and outlet temperatures defined by the systems parameters.

See drawing 5055-0120. Fig. 2.

In addition, the CWCU will order an inlet temperature from the ships cooling water system, which again is defined by the systems parameters (indicated in figure 2).

In case of a sensor failure or if the circulation pump starter cabinet is put in local control, an alarm will be raised, and the system returns to fail safe state.

3.4.3 User interface

The stand-alone implementation of the LDHT cooling water control has a single common alarm output for the ships alarm system and a local status indication.

The status indication consists of 3 lamps and 2 buttons:

-  Alarm:
A red light indicates an active alarm. The circulation pump is stopped and the high temperature circulation is inoperative. Action required to find and correct the problem.
-  Un-acknowledged alarm:
An alarm has occurred but the alarm condition is no longer present. Action required to acknowledge the alarm by pressing the blue button to re-activate the system.
-  System OK:
No alarms, and the system is operative.
-  Acknowledge button (on or inside the cabinet):
After an alarm condition has been rectified, the button must be pressed to re-activate the system.
-  Lamp test button.



Please note that acknowledging an un-acknowledged alarm will start the circulation pump if no other alarms are active!

3.5 Jacket Cooling Water Bypass Basic (JBB)

In order to prevent cold corrosion in the cylinder liner, "Jacket Cooling Water Bypass Basic" (JBB) has been introduced a retrofit solution on engine designs already in service.
See drawing 5055-0140.

3.5.1 Function

In the JBB-system, two bypass pipes connect the liner inlet pipe with the cooling water connections between the liner cooling jacket and the cylinder cover cooling jacket. With this connection, 75% of the cooling water flow is bypassed from the liner cooling jacket. In the outlet of the liner cooling jacket, orifices are placed to control the water flow through the liner jacket.
See drawing 5055-0140. Fig. 1.

The bypass is designed to increase the liner wall temperature by 10-20°C in the top ring at TDC position to reduce cold corrosion. The temperature increase, compared to the standard cooling layout, will mostly be towards the top of the liner and less downwards. Below the liner cooling jacket, the liner temperature will be as in the standard configuration. The fixed orifice bypass (JBB) is designed to provide sufficient cooling even at 100% load.
See drawing 5055-0140. Fig. 2.

The JBB will bring the cylinder components out of the cold corrosion danger zone for a wide range of engine loads.

4 Central Cooling System

See drawing 5055-0110

The central cooling system is an alternative to the seawater cooling system. It is based on the same design principles with regard to cooler locations, flow control and preheating, but has a central cooler and an additional set of pumps.

Maintenance work is minimised by the use of a central cooler, as this is the only component that is in direct contact with seawater. All other parts of the system use inhibited freshwater in accordance with MAN Diesel & Turbo specifications
See description 5045-0200.

The low and high temperature systems are directly connected to gain the advantage of preheating the main and auxiliary engines during standstill.

As all fresh cooling water is inhibited and common for the central cooling system, only one common expansion tank, **item 10**, is necessary for deaeration of both the low and high temperature cooling systems. This tank accommodates the difference in water volume caused by changes in the temperature.

To prevent the accumulation of air in the cooling water system, a deaerating tank, **item 11**, is located below the expansion tank. An alarm device is inserted between

the deaerating tank and the expansion tank so that the operating crew can be warned if excess air or gas is released, as this signals a malfunction of engine components.

4.1 Operation at Sea

See drawing 5055-0110

The seawater cooling pump, **item 1**, pumps seawater from the sea chests through the central cooler, **item 2**, and overboard. Alternatively, some shipyards use a pumpless scoop system. On the freshwater side, the central cooling water pump, **item 3**, circulates the low-temperature fresh water, in a cooling circuit, directly through the lubricating oil coolers, **item 4**, of the main engine, the auxiliary engines and the scavenge air coolers, **item 5**.

The jacket water cooling system for the auxiliary engines is equipped with engine-driven pumps and a by-pass system integrated in the low-temperature system.

The main engine jacket system has an independent pump circuit with a jacket water pump, **item 6**, circulating the cooling water through the main engine to the fresh water generator, **item 7**, and the jacket water cooler, **item 8**.

A thermostatically controlled 3-way valve, **item 9**, at the jacket cooler outlet mixes cooled and uncooled water to maintain an outlet water temperature of 88-92 °C from the main engine.

4.2 Operation in Port

See drawing 5055-0110

During operation in port, when the main engine is stopped but one or more auxiliary engines are running, valves A are closed and valves B are open. A small central water pump, **item 3**, will circulate the necessary flow of water for the air cooler, the lubricating oil cooler, and the jacket cooler of the auxiliary engines. The auxiliary engine-driven pumps and the previously mentioned integrated loop ensure a satisfactory jacket cooling water temperature at the auxiliary engine outlet.

The main engine and the stopped auxiliary engines are preheated as described for the jacket water system, *item 3.2 and drawing 5055-0105*.

5 Preheating during Standstill

Preheat the engine in accordance with *See description 6645-0170*.

Preheat by means of:

- A built-in preheater, *see also drawing 5055-0115*.
The capacity of the preheater pump should correspond to about 10% of the capacity of the jacket water main pump.
The pressure drop across the preheater should be approx. 0.2 bar.
The preheater pump and the main pump should be electrically interlocked to avoid the risk of simultaneous operation.
- Cooling water from the auxiliary engines, *see item 3.2, 'Operation in Port'*

6 Jacket Water Cooling Failure

It is assumed that the temperature rise is not caused by defective measuring equipment or thermostatic valve. These components should be checked regularly to ensure correct functioning.

If the cooling water temperature, for a single cylinder or for the entire engine, rises to **93-100°C**, follow this procedure:

Open the test cocks on the cylinder outlets.

Is the water coming out?	
YES	▪ Close the test cocks.
	▪ Re-establish the cooling water supply at once, or stop the engine for troubleshooting.
NO	<i>The cooling space is not completely filled with water. This results in local overheating, and hence the formation of steam.</i>
	▪ Close the test cocks.
	▪ Stop the engine.
	▪ Close the outlet valve on the overheated cylinder.
	▪ Open the indicator cocks.
	▪ Keep the auxiliary blowers and lub. oil pumps running.
	▪ Turn the piston of the cylinder concerned to BDC to slowly cool down the overheated area via the air flow through the cylinder and indicator cock.
	▪ Leave the engine to cool. This prevents extra shock heat stresses in cylinder liner, cover and exhaust valve housing, if the water should return too suddenly.
	▪ After 15 minutes, open the outlet valves a little so that the water can rise slowly in the cooling jackets. Check the level at the test cocks.
	▪ Find and remedy the cause of the cooling failure.
	▪ Check for proper inclination of the freshwater outlet pipe, and for proper deaeration from the forward end of the engine.
	▪ Make a scavenge port inspection to ensure that no internal leakage has occurred. <i>See also description 2245-0100.</i>
	Note: Slow-turn the engine with open indicator cocks before starting the engine.

1 Reducing Service Difficulties

To reduce service difficulties to a minimum, we strongly recommend:

- effective protection against corrosion of the cooling water system by adding a chemical **corrosion inhibitor**. *See Item 1.2.*
- using the correct **cooling water quality**. *See Item 1.3.*
- effective **venting** of the system. *See Item 1.4.*
- Checking the system and water during service. *See Item 2.*
- Using the correct cleaning and inhibiting procedure. *See Items 3 and 4.*

1.1 Types of Damage

If the above-mentioned precautions are not taken, the following types of damage may occur:

- **corrosion**, which removes material from the attacked surface by a chemical process.
- **corrosion fatigue**, which may develop into cracks because of simultaneous corrosion and dynamic stresses.
- **cavitation**, which removes material because of local steam formation and subsequent condensation in the cooling water, due to high water velocity or vibrations.
- **scale formation**, which reduces the heat transfer, mostly due to lime deposits.

Corrosion and cavitation may reduce the lifetime and safety factors of the parts concerned. Deposits will impair the heat transfer and may result in thermal overload of the components to be cooled.

1.2 Corrosion Inhibitors

Various types of inhibitors are available but, generally, only nitrite-borate based inhibitors are recommended.

A number of products marketed by major companies are specified in the table on Page 10. The relevant dosages are also mentioned, and we recommend that these directions are strictly observed.

Cooling water treatment using inhibiting oils is not recommended, as such treatment involves the risk of uncontrolled deposits being formed on exposed surfaces, and furthermore represents an environmental problem.

NOTICE

The legislation for disposal of waste water, incl. cooling water, prohibits the use of chromate for cooling water treatment. Chromate inhibitors must not be used in plants connected to a freshwater generator.

1.3 Cooling Water Quality

It is important to use the correct cooling water quality. We recommend to use deionized or distilled water (for example produced in the freshwater generator) as cooling water.

This prevents, to a wide extent, the formation of lime stone on cylinder liners and in cylinder covers, which would impair the heat transfer, and result in unacceptably high material temperatures.

Before use, check that the following values are not exceeded:

- Hardness: max. 10° dH (=10 ppm CaO)
- pH: 6.5-8.0 (at 20°C)
- Chloride: 50 ppm (50 mg/litre)
- Sulphate: 50 ppm (50 mg/litre)
- Silicate: 25 ppm (25 mg/litre)

Check that there is no content of:

- Sulphide
- Chlorine
- Ammonia

NOTICE

Softening of the water does not reduce its sulphate and chloride contents.

If deionized or distilled water cannot be obtained, normal drinking water can be used in exceptional cases.

Rain water, etc. **must not** be used, as it can be heavily contaminated.

1.4 Venting

The system is fitted with a deaerating tank with alarm and with venting pipes which lead to the expansion tank. *See description 5045-0100.*

2 Checking the System and Water during Service

We recommend to keep a record of all tests, to follow the condition and trend of the cooling water.

Check the cooling water system and the water at the intervals given below:

2.1 Regularly

Whenever practical, check the cooling water system for sludge or deposits. *See also Item 2.5, 'Every Four-Five Years and after Long Time Out of Operation'.*

Check at the cooling pipes, cooling bores, at the top of the cylinder and cover and exhaust valve bottom piece.

Sludge and deposits can be due to:

- contaminated cooling water system,
- zinc galvanized coatings in the cooling water system.
Experience has shown that zinc galvanized coatings in the freshwater cooling system are often very susceptible to corrosion, which results in heavy sludge formation, even if the cooling system is correctly inhibited.

In addition, the initial descaling with acid will, to a great extent, remove any galvanized coating. Therefore, generally, we advise against the use of galvanized piping in the freshwater cooling system.

2.2 Once a Week

Take a water sample from the circulating system during running.
i.e. not from the expansion tank or the pipes leading to the tank.

Check the condition of the cooling water.
Test kits are normally available from the inhibitor supplier.

Check:

- *The concentration of inhibitor must not* fall below the value recommended by the supplier, as this will increase the risk of corrosion.
When the supplier specifies a concentration range, we recommend to maintain the concentration in the upper end.
- *pH-value* should be within 8.5-10 at 20°C.
A decrease of the pH-value (or an increase of the sulphate content, if measured) can indicate exhaust gas contamination (leakage).
pH can be increased by adding inhibitor, however, if large quantities are necessary, we recommend to change the water.
- Chloride content should not exceed 50 ppm (mg/litre).

In exceptional cases, a maximum of 100 ppm can be accepted, however, the upper limit specified by the inhibitor supplier must be adhered to. An increase of the chlorine content can indicate salt water ingress. Trace and repair any leakages at the first opportunity.

NOTICE

If out-of-specification results are found, repeat the tests more frequently.

2.3 Every Third Month

Take a water sample from the system during running, as described in Item 2.2, 'Once a week'.

Send the sample for laboratory analysis, in particular to ascertain the content of:

- inhibitor
- sulphate
- iron
- total salinity.

2.4 Once a Year

Empty, flush and refill the cooling water system. Add the inhibitor.
See also Item 4.5, 'Adding the Inhibitor', further on.

2.5 Every Four-Five Years and after Long Time Out of Operation

Based on the regular checks, see Item 2.1, clean the cooling water system for oil-sludge, rust and lime. Refill and add the inhibitor.
See Items 3 and 4 further on.

2.6 Water Losses and Overhauling

Replace evaporated cooling water with non-inhibited water.

Replace water from leakages with inhibited water.

After overhauling, e.g. of individual cylinders, add a new portion of inhibitor immediately after completing the job.

Check the inhibitor concentration any time a substantial amount of cooling water is changed or added.

3 Cleaning and Inhibiting

3.1 General

Carry out cleaning before inhibiting the cooling water system for the first time. This ensures uniform inhibitor protection of the surfaces and improves the heat transfer.

During service, carry out cleaning and inhibiting every 4-5 years and after long time out of operation, *see also Item 2.5*. Cleaning comprises degreasing to remove oil sludge and descaling to remove rust and lime deposits.

3.2 Cleaning Agents

Special ready-mixed cleaning agents can be obtained from companies specialising in cooling water treatment, and from the supplier of inhibitors. *See item 5.1.*

These companies offer treatment, assistance and cooling water analysis. We point out that the directions given by the supplier should always be closely followed.

The cleaning agents **must not** be able to damage packings, seals, etc. It must also be ensured that the cleaning agents are compatible with all parts of the cooling system to avoid any damage.

The cleaning agents should not be directly admixed, but should be dissolved in water and then added to the cooling water system.

For **degreasing**, agents emulsified in water, as well as slightly alkaline agents, can be used.

NOTICE

Ready-mixed agents which involve the risk of fire obviously must not be used

For **descaling**, agents based on amino-sulphonic acid, citric acid and tartaric acid are especially recommended.

NOTICE

Use only inhibited acidic cleaning agents

These acids are usually obtainable as solid substances, which are easily soluble in water, and do not emit poisonous vapours.

3.3 Inhibitors

See Item 1.2, 'Corrosion Inhibitors', earlier in this Chapter.

4 Cleaning and Inhibiting Procedure

4.1 General

NOTICE

The engine must be at a standstill during the cleaning procedure to avoid overheating during draining.

Normally, cleaning can be carried out without any dismantling of the engine.

Since cleaning can cause leaks to become apparent (in poorly assembled joints or partly defective gaskets), inspection should be carried out during the cleaning process.

4.2 Degreasing

NOTICE

Be careful. Use protective spectacles and gloves.

4.2.1 Prepare for degreasing

Does the cooling water contain inhibitor?	
YES	Drain the system. Fill up with clean tap water. Follow the procedure below.
NO	Follow the procedure below.

Heat the water to 60°C and circulate it continuously.
Drain to lowest water level in the expansion tank sight glass.

4.2.2 Add the degreasing agent

Add the degreasing agent, preferably at the suction side of the running jacket water pump.
Use the amount of agent specified by the supplier.



Drain again to the lowest level in the expansion tank if the cooling water system is filled-up, before all agent is applied.

4.2.3 Circulate the solution

Circulate the agent for the period specified by the supplier.
Check and repair any leaks.

4.2.4 Drain and flush the system

Drain the system completely.
This will also flush out any oil or grease settled in the expansion tank.

Fill up with clean tap water.
Circulate the water for two hours.
Drain the system completely.
Proceed to the descaling procedure, *see Item 4.3, 'Descaling'*.

4.3 Descaling

On completing the degreasing procedure, *see Item 4.2, 'Degreasing'*, apply this descaling procedure.

NOTICE

Be careful. Use protective spectacles and gloves.

To avoid polluting the discharge water with acid, it is recommended, if possible, to collect all the drained water that contains acid in a tank where it can be neutralised, for example by means of soda, before being disposed.

4.3.1 Prepare for descaling

Fill up with clean tap water.
Heat the water to a maximum of 70°C, and circulate it continuously.

NOTICE

Some ready-mixed cleaning agents are specified to be used at a lower temperature. This maximum temperature must be adhered to.

4.3.2 Add the acid solution

Dissolve the necessary dosage of acid compound in a clean iron drum, half filled with hot water. Stir vigorously, e.g. using a steam hose.
For engines that were treated before the sea trials, the lowest dosage recommended by the supplier will normally be sufficient.

For untreated engines, a higher dosage - depending on the condition of the cooling system - will normally be necessary.

The solubility of acids in water is often limited. This can necessitate descaling in two stages, with a new solution and clean water. Normally, the supplier specifies the maximum solubility.

Fill the drum completely with hot water while continuing to stir. Slowly add the acid compound at the suction side of the jacket water cooling pump.

Drain some water from the system, if necessary.

4.3.3 Circulate the acid solution

Keep the temperature of the water at the prescribed preheating temperature, and circulate it constantly.

The duration of the treatment will depend on the degree of fouling.

Normally, for engines that were treated before the sea trials, the shortest time recommended by the supplier will be sufficient.

For untreated engines, a longer time must be reckoned with.

Check every hour, for example with pH-paper, that the acid has not been neutralised.

A number of descaling preparations contain colour indicators which show the state of the solution.

If the acid content is exhausted, a new admixture dosage can be added, in which case the weakest recommended concentration should be used.

4.3.4 Neutralise any acid residues

After completing the descaling, drain the system and flush with water.
The flushing is necessary to remove any debris that may have formed during the cleaning.

Continue the flushing until the water is neutral (pH approx. 7).
Acid residues can be neutralised with clean tap water containing 10 kg soda per ton of water. As an alternative to soda, sodium carbonate or sodium phosphate can be used in the same concentration.

Circulate the mixture for 30 minutes.

Drain and flush the system.

Continue to flush until the water is neutral (pH approx. 7).

NOTICE

*Check the acid content of the system oil directly after the descaling, and again 24 hours later.
See description 3045-0130*

4.4 Filling up with Water

To prevent the formation of rust on the cleaned surfaces, fill up with water immediately after the cleaning.

Fill up, with deionizer or distilled water, to the lowest level in the expansion tank.
See also Item 1.3, 'Cooling Water Quality'.

4.5 Adding the Inhibitor

On account of the lack of hardness, the deionized or distilled water is relatively corrosive.

Add the corrosion inhibitor immediately after filling up.

Weigh out the quantity of inhibitors specified by the supplier. *See item 5.1.*

We recommend to use the maximum amount specified by the makers.

Dissolve the inhibitor in hot deionized or distilled water, using a *clean* iron drum.

Add the solution at the suction side of the running jacket water cooling pump or at another place where flow is ensured.

A liquid inhibitor may be entered directly into the system by equipment supplied by the maker. Follow the maker's instructions.

Fill up to *normal*/water level, using deionized or distilled water.

Circulate the cooling water for not less than 24 hours. This ensures the forming of a stable protection of the cooling surfaces.

Check the cooling water with a test kit (available from the inhibitor supplier) to ensure that an adequate inhibitor concentration has been obtained.
See also Item 2.2, 'Once a Week', 'Check: Inhibition concentration'.

5 Central Cooling System, Cleaning and Inhibiting

It is important for the proper functioning of this system to remove existing deposits of lime, rust and/or oil sludge in order to minimise the risk of blocking the coolers, and to ensure a good heat transfer. Subsequent inhibiting shall, of course, be carried out.

For central cooling water systems, which are arranged with separate high and low temperature freshwater circuits, the careful, regular checks which are necessary for the jacket cooling water (= high temperature freshwater circuit) are not necessary for the low temperature freshwater circuit.

5.1 Nitrite-borate Corrosion Inhibitors for Fresh Cooling Water Treatment

Company	Name of Inhibitor	Delivery Form	Maker's min. Recommended Dosage (*)
Castrol Ltd. Swindon Wiltshire, England	Castrol Solvex WT4 Castrol Solvex WT2	Powder Liquid	3 kg / 1.000 l 20 l / 1.000 l
Drew Ameriod Marine Boonton, N.J./USA	DEWT NC Liquidewt Maxiguard	Powder Liquid Liquid	3,2 kg / 1.000 l 8 l / 1.000 l 16 l / 1.000 l
Nalfloc Ltd. Northwich, Cheshire, England	NALFLEET 9-121 NALFLEET 9-108	Powder Powder Liquid	2,5 kg / 1.000 l 2,2 kg / 1.000 l 5 l / 1.000 l
Rohm & Haas (ex Duolite) Paris, France	RD11 DIAPROSIM RD25 DIA PROSIM	Powder Liquid	3 kg / 1.000 l 50 l / 1.000 l
Vecom Maassluis, Holland	CWT Diesel QC2	Liquid	12 l / 1.000 l
Wilhelmsen Ships Service AS Lysaker, Norway	Unitor Dieselguard NB Unitor Rocor NB Liquid	Powder Liquid	2 kg / 1.000 l 9 l / 1.000 l

Generally we recommend 2000-2500 ppm Nitrite.

(*) Initial dosage may be larger.

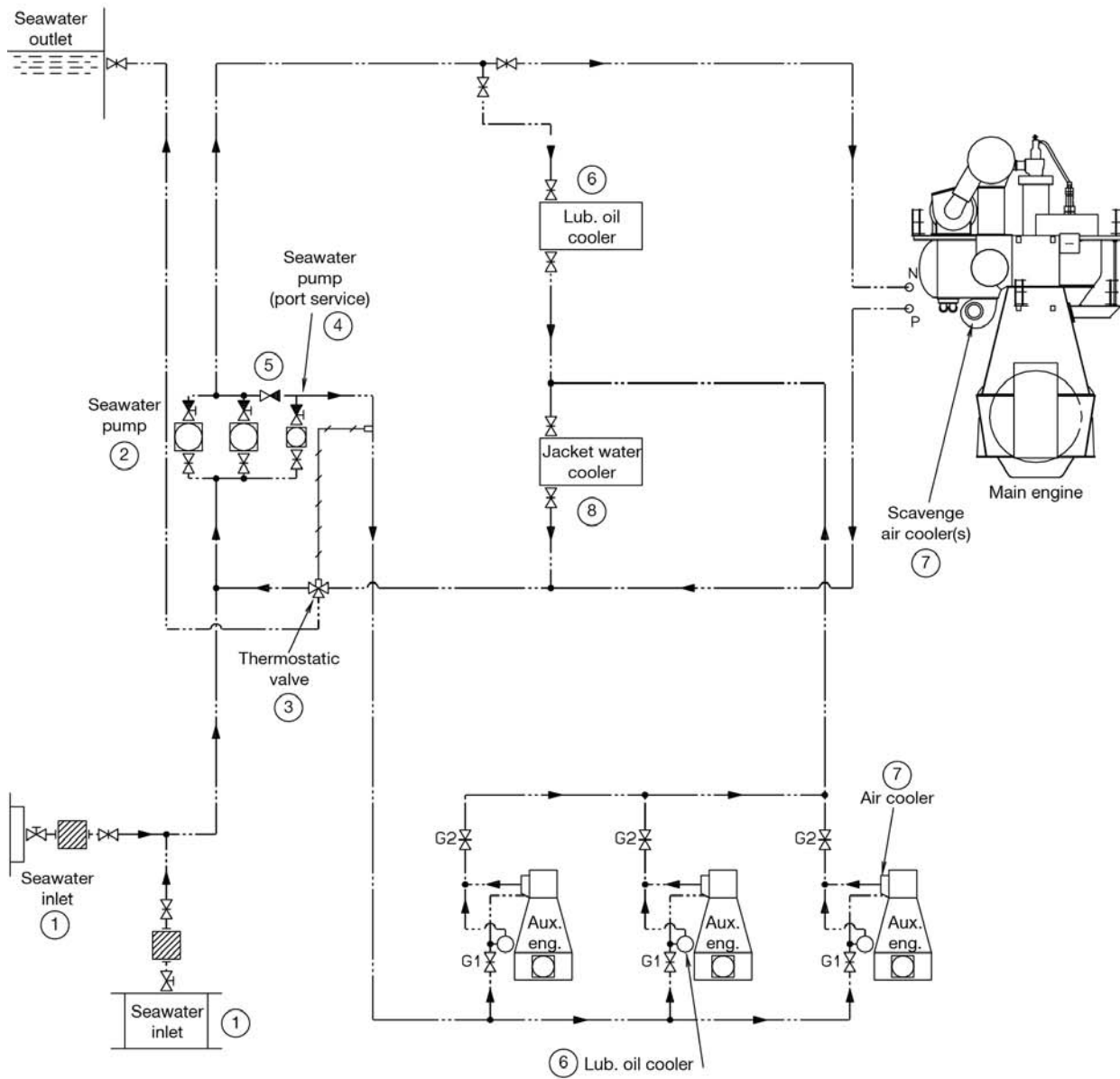
5.2 Non Nitrite-borate Corrosion Inhibitors for Fresh Cooling Water Treatment

Company	Name of Inhibitor	Delivery Form	Maker's min. Recommended Dosage (*)
Chevron, Houston USA	Havoline XLI Havoline XLC	Liquid Liquid	50 l / 1.000 l 350 l / 1.000 l
Wilhelmsen Ships Service AS Lysaker, Norway	Unitor Cooltreat AL	Liquid	50 l / 1.000 l

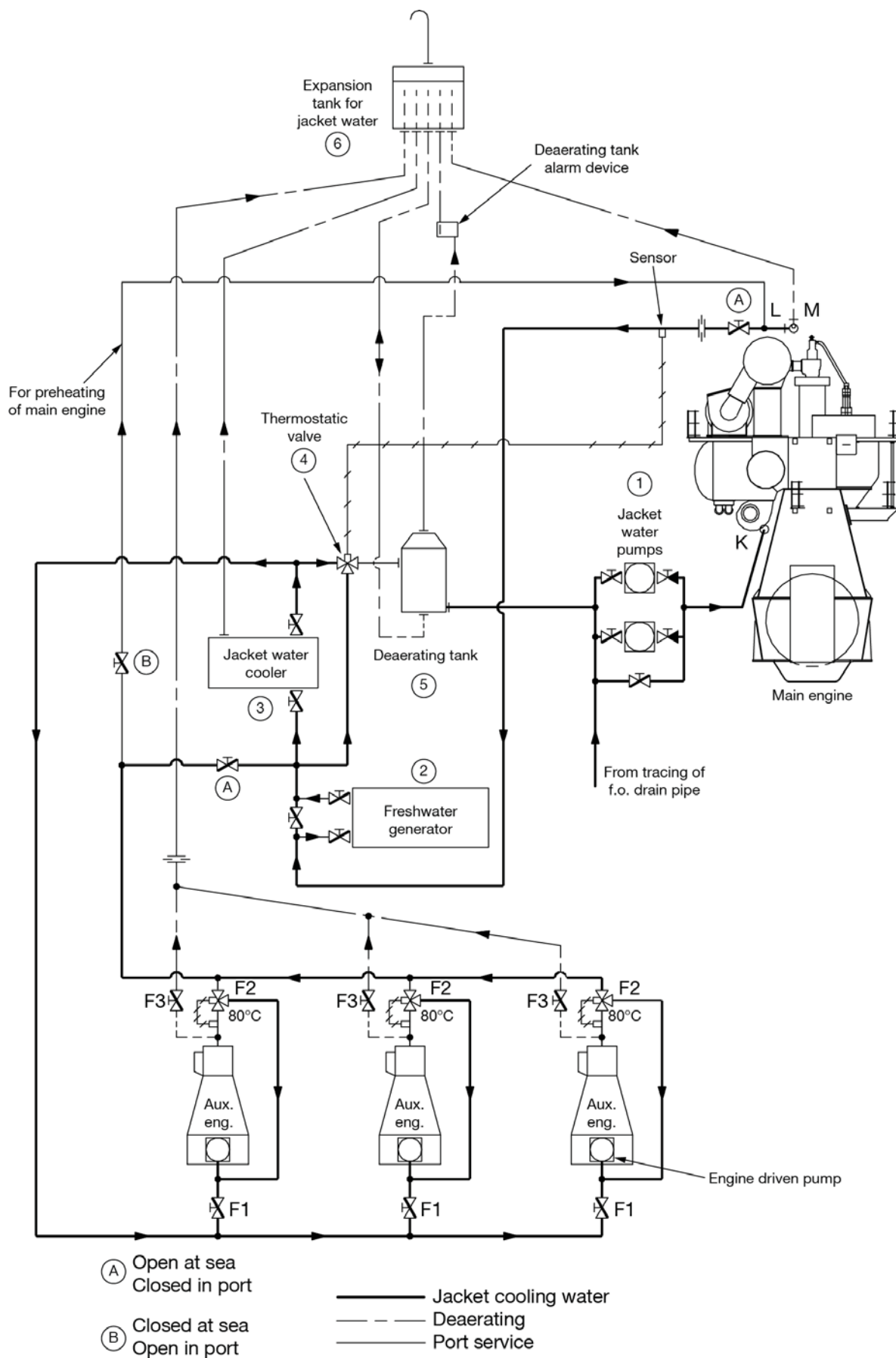
(*) Initial dosage may be larger.

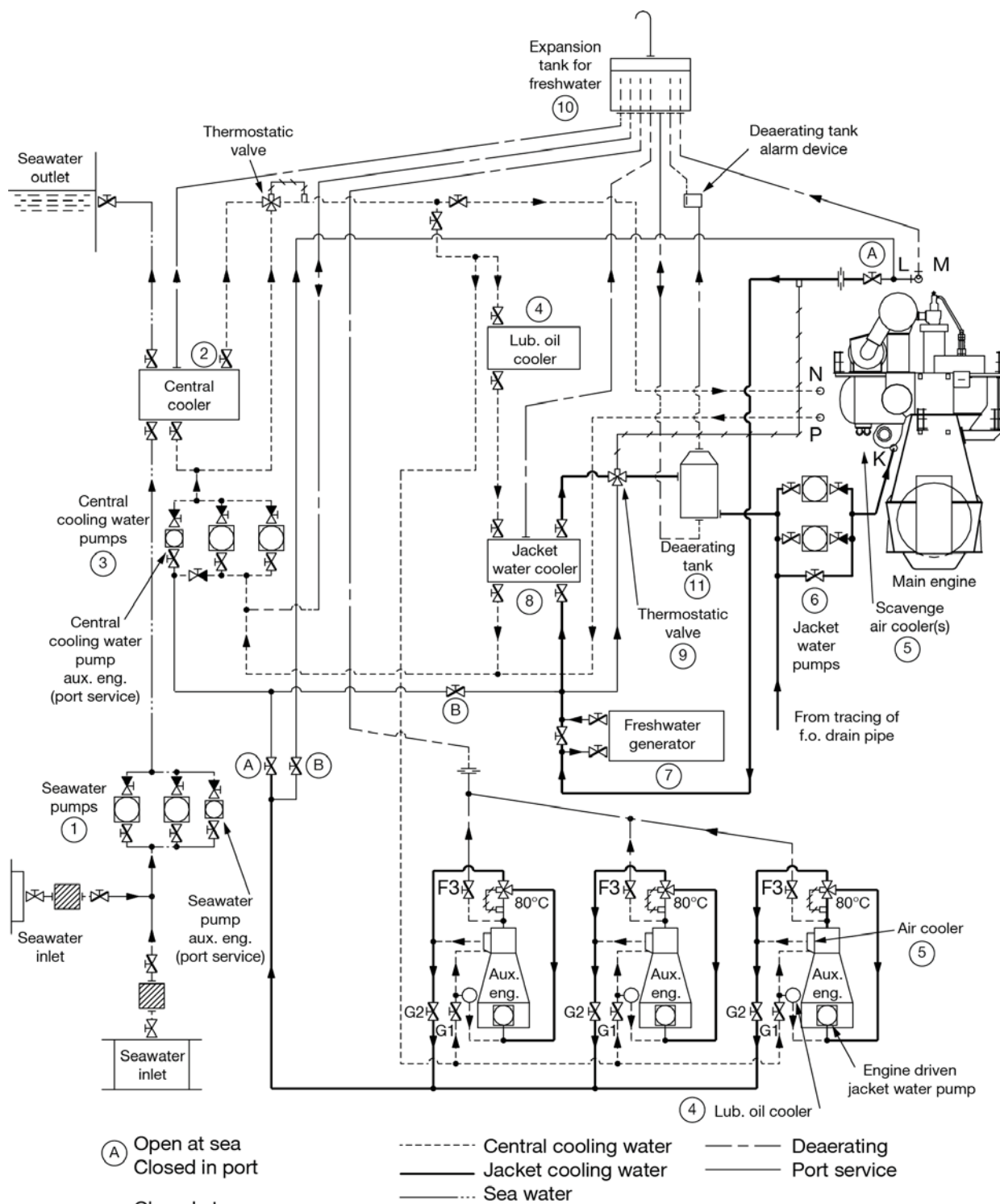
These lists are for guidance only and must not be considered complete. We undertake no responsibility for difficulties that might be caused by these or other water inhibitors/chemicals.

Suitable cleaners can normally also be supplied by these firms.

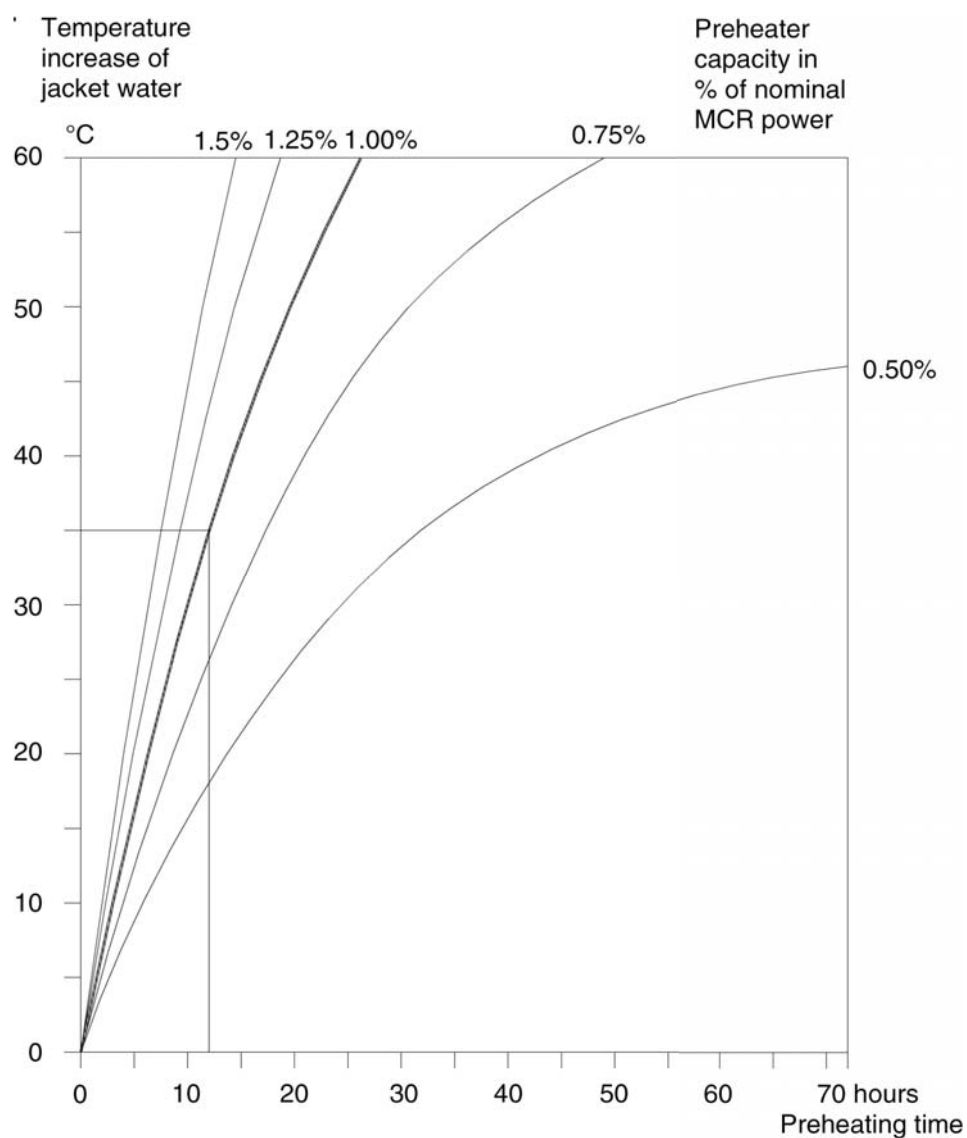


Seawater Cooling System (Main and Auxiliary Engines)





Preheating of Jacket Cooling Water



If the cooling water is heated by means of a preheater installed in the freshwater system, the curves above can be used.

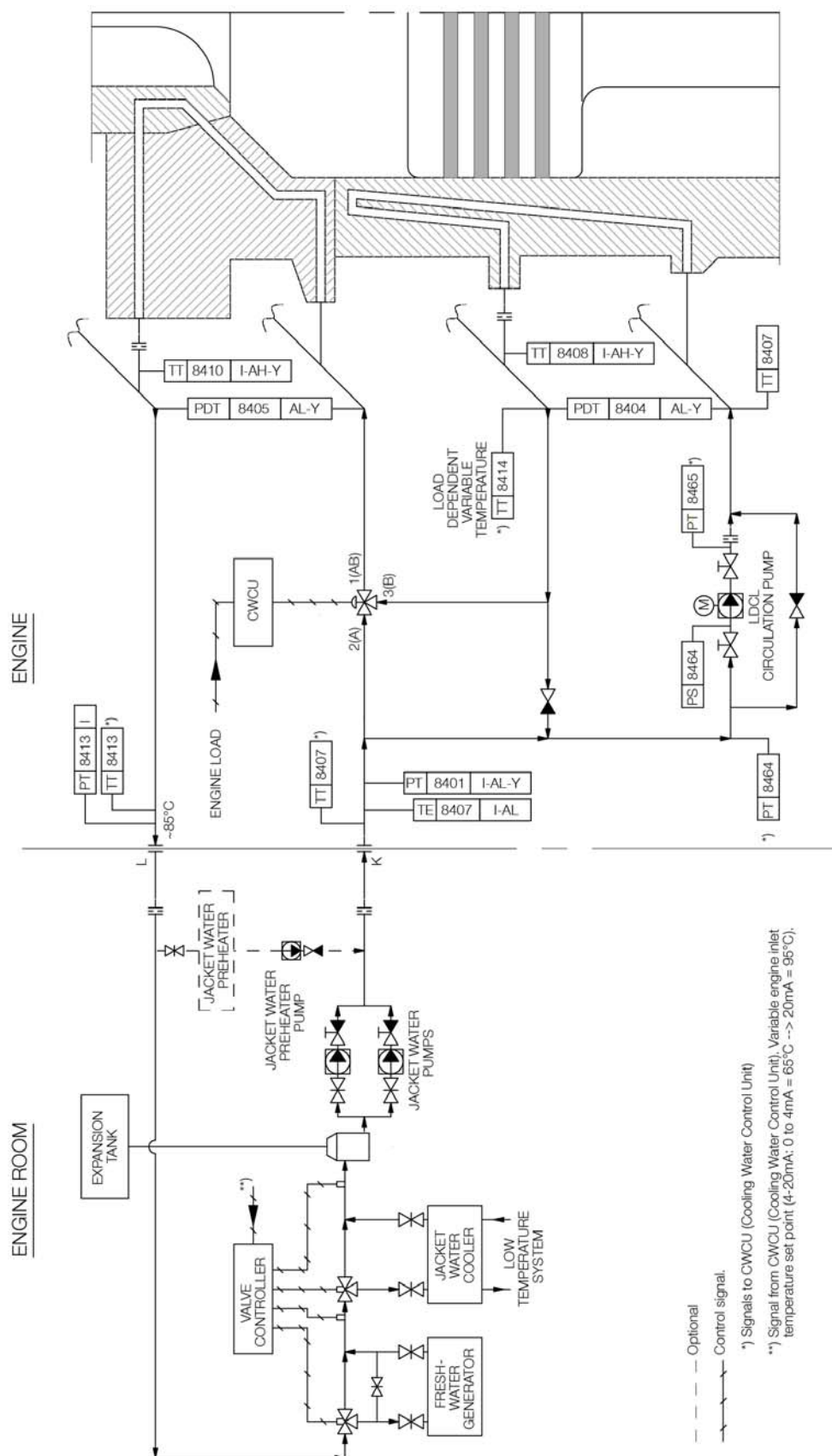
The curves are drawn on the basis that, at the start of preheating, the engine and engine-room temperatures are equal.

Example:

A freshwater preheater, with a heating capacity equal to 1% of nominal MCR engine shaft, output, is able to heat the engine 35°C (from 15°C to 50°C) in the course of 12 hours.

Cooling water preheating during standstill is described in *description 6645-0170*.

Schematic outline of the LDCL Cooling water system - Figure 1

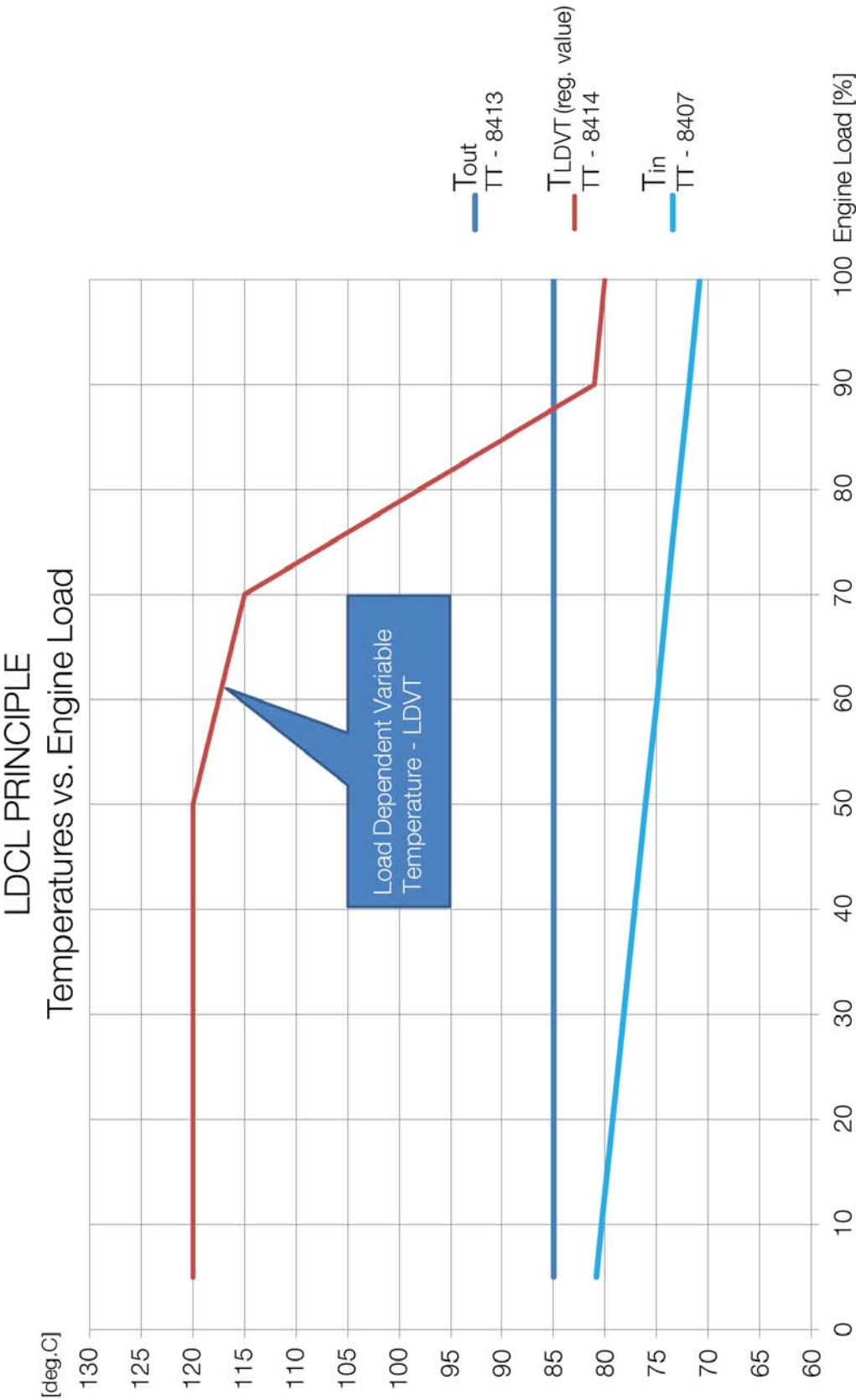


Load Dependent Cylinder Liner - Cooling Water System

Drawing

5055-0120-0002

LDCL Principle - Temperature VS Engine Load - Figure 2



Safety**Precautions**

for detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off safety air supply - Not ME Engines
☐	Shut off control air supply
☐	Shut off air supply to exhaust valve - Only when stopped lubricating oil pumps
☐	Engage turning gear
☐	Shut off cooling water
☐	Shut off fuel oil
☐	Stop lubricating oil supply
☐	Lock the turbocharger rotors

Data

Ref.	Description	Value	Unit
T47-03	Inhibitor concentration (see inhibitor makers specification)	-	ppm
T47-04	pH - value at 20°C	8.5 - 10	pH
T47-05	Maximum chloride content	50	ppm

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.

1. Once a week
- Cooling water is to be checked for concentration of inhibitor, PH-value and chloride content once a week.

2. Water samples
- In addition to the on board surveillance of the cooling water condition.
See description 5045-0200.

Water samples must be sent ashore for analysis every third month.

The samples should be taken while the engine is running, and from a test cock on a main fresh water pipe through which the water is circulating.



3065-0151-0001C02

3. Once a year
- Empty, flush and refill the cooling water system once a year. Add the inhibitor.

Preface Chapter

Drawing

Work Card

Tool Plate

Exhaust Gas and Scavenge Air System	5440-0100-0001
Scavenge Air Drain Pipes	5455-0100-0001
Scavenge Air Spaces, Fire Extinguishing Systems	5455-0105-0001
Dry Cleaning of Turbocharger – Turbine side	5455-0110-0004
Wet Cleaning of Turbocharger – Turbine side	5455-0115-0002
Air Cooler Cleaning System – Option	5455-0120-0001
Scavenge Air Cooler Element, Data	5465-0100-0006
Scavenge Air Cooler Element	5465-0101-0016
Water Mist Catcher, Data	5465-0200-0004
Water Mist Catcher	5465-0201-0003
Scavenge Air Non-Return Valve, Data	5465-0400-0001
Scavenge Air Non-Return Valve	5465-0401-0002
Auxiliary Blower	5465-0500-0003
Auxiliary Blower	5465-0501-0005
Scavenge Air Safety Valve, Data	5465-0600-0001
Scavenge Air Safety Valve	5465-0601-0001
Turbocharger Cleaning, Data	5465-0700-0001
Turbocharger Cleaning	5465-0701-0002
Turbocharger Cut Out, Data	5465-0710-0001
Turbocharger Cut Out	5465-0711-0001
Exhaust Gas Bypass Valve, Data	5465-0810-0005
Exhaust Gas Bypass Valve	5465-0811-0003
Scavenge Air Cooler Tools	5470-0110-0001
Scavenge Air Cooler Tools	5470-0110-0004
Scavenge Air Cooler Lifting Tools	5470-0120-0001

Air System

The engine is supplied with scavenge air from one or more turbochargers, depending on the engine type and layout.

The engine exhaust gas drives the turbine wheel of the turbocharger and, through a common shaft, the turbine wheel drives the compressor wheel.

The compressor draws air from the engine room, through the air filters. From the compressor outlet, the air passes through the charging air pipe to the charging air cooler where the air is cooled down.

The charging air pipe, with compensator, is insulated.

The air cooler incorporates a water mist catcher, which is designed to separate condensate from the air.

When the air has passed the water mist catcher, it is pressed into the scavenge air receiver through non-return valves. The non-return valves open by pressure from the turbocharger.

From the scavenge air receiver, the air flows to the cylinder through the scavenge air ports when the piston is in the bottom position. When the exhaust valves open, the exhaust gas is pressed into a common exhaust gas receiver, from where the gas drives the turbine of the turbocharger with an even and steady pressure

Charging Air Cooler

The charging air cooler insert is of the block type. It is mounted in a housing which is welded up of steel plates.

The cooler housing is provided with inspection covers.

The cooler is designed with an air reversing chamber which incorporates a water mist catcher. The water mist catcher is built up of a number of lamellas which separate the condensation water from the scavenge air during the passage of the airflow.

The separated water is collected in the bottom of the cooler housing from which it is moved by a drain system.

**CAUTION**

Check the drain

It is important to check that the drain functions correctly, as otherwise water droplets may enter the cylinders.

See description 6345-0320.

An alarm device for high water level in the drain system is installed.

Non-Return Valves

It is of the utmost importance that the non-return valves of the auxiliary blowers always function correctly and move easily. This can be checked either by moving the valves manually in connection with the regular scavenge port inspections, or via locally placed inspection covers.

The non-return valves protect the blowers and engine during:

- Start-up of the auxiliary blowers.
- Running with auxiliary blowers.

Starting the auxiliary blowers:

1. Owing to the relatively high starting current, the blowers start in sequence, with 6-10 seconds in between.

The non-return valve of the blower that has not yet started must be in the closed position to prevent the blower from rotating backwards. Otherwise, there is a risk that the electric motor will burn out when it starts.

2. If an auxiliary blower fails to start, the non-return valve must be in the closed position. Otherwise, the operating blower will not be able to draw fresh air in through the turbocharger and air cooler. This is due to differences in the air flow resistance.

Running with auxiliary blowers:

If an auxiliary blower fails during running, the non-return valve must close to ensure the continued supply of fresh air to the engine.

See "Starting the auxiliary blowers", Item 2, above.

Auxiliary Blowers

The engine is provided with two or more auxiliary blowers. The suction sides are connected to the space after the water mist catcher. The discharge sides are connected to the scavenge air receiver. Separate non-return valves are installed at the suction side or discharge side of the auxiliary blowers, in order to prevent reversed air flow.

See also item, "Non-return valves", above.

El. panels for auxiliary blower

See special instructions supplied by the engine builder.

Running with auxiliary blowers

During the starting of the engine, and when the engine is running at low load, the turbocharger is not able to supply enough air. In these cases a pressure switch automatically starts the auxiliary blowers.

When the auxiliary blowers are operating, they draw air from the engine room through the turbochargers air filter and compressor side.



If the auxiliary blowers do not start during low-load running (because of faults, or because the switch for the blowers is not in “AUTO” position), unburned fuel oil may accumulate on top of the pistons. This situation involves the risk of a scavenge air box fire.

In order to avoid such a fire:

- Obtain permission to stop the engine
- Stop the engine
- Remove any unburned fuel oil from the top of the pistons
- Re-establish the supply of scavenge air
- Start the engine

NOTICE

The switch for the auxiliary blowers should be in “AUTO” position during all modes of engine control, i.e.:

- Remote control
- Control from engine side control console.

The non-return valves fitted after the water mist catcher are now closed as a result of partial vacuum and gravitation acting on the valve flaps.

There will be a lack of air supply if the non-return valves do not close.

Scavenge Air Receiver

The scavenge air receiver is a container having a large volume. The receiver is bolted on to the cylinder frame, or alternatively integrated into the cylinder frame, if welded.

See chapter 10.

Scavenge air is collected in the receiver after the air has passed through the cooler, the water mist catcher and the non-return valves.

The receiver and the cylinder frame communicate through large openings.

The scavenge air receiver is provided with manhole covers and a safety valve.

**Safety Valve,
Scavenge Air Receiver**

The scavenge air receiver is fitted with a safety valve which is set to open should the pressure in the scavenge air receiver exceed a value somewhat higher than the normal scavenge air pressure of the engine.

In some cases it may be necessary to open the valve manually,
see description 6645-0310.

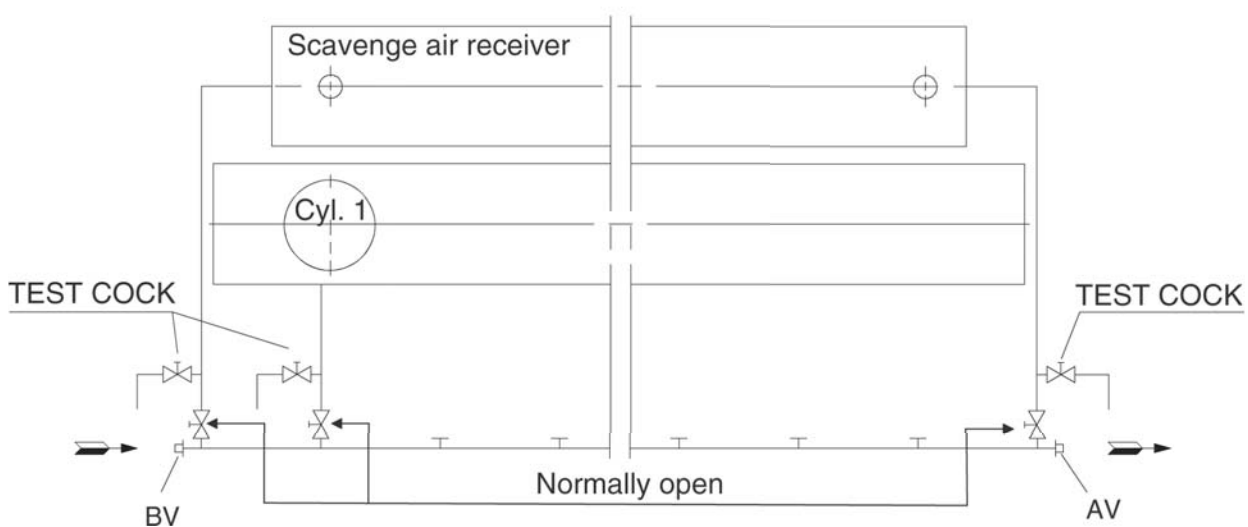
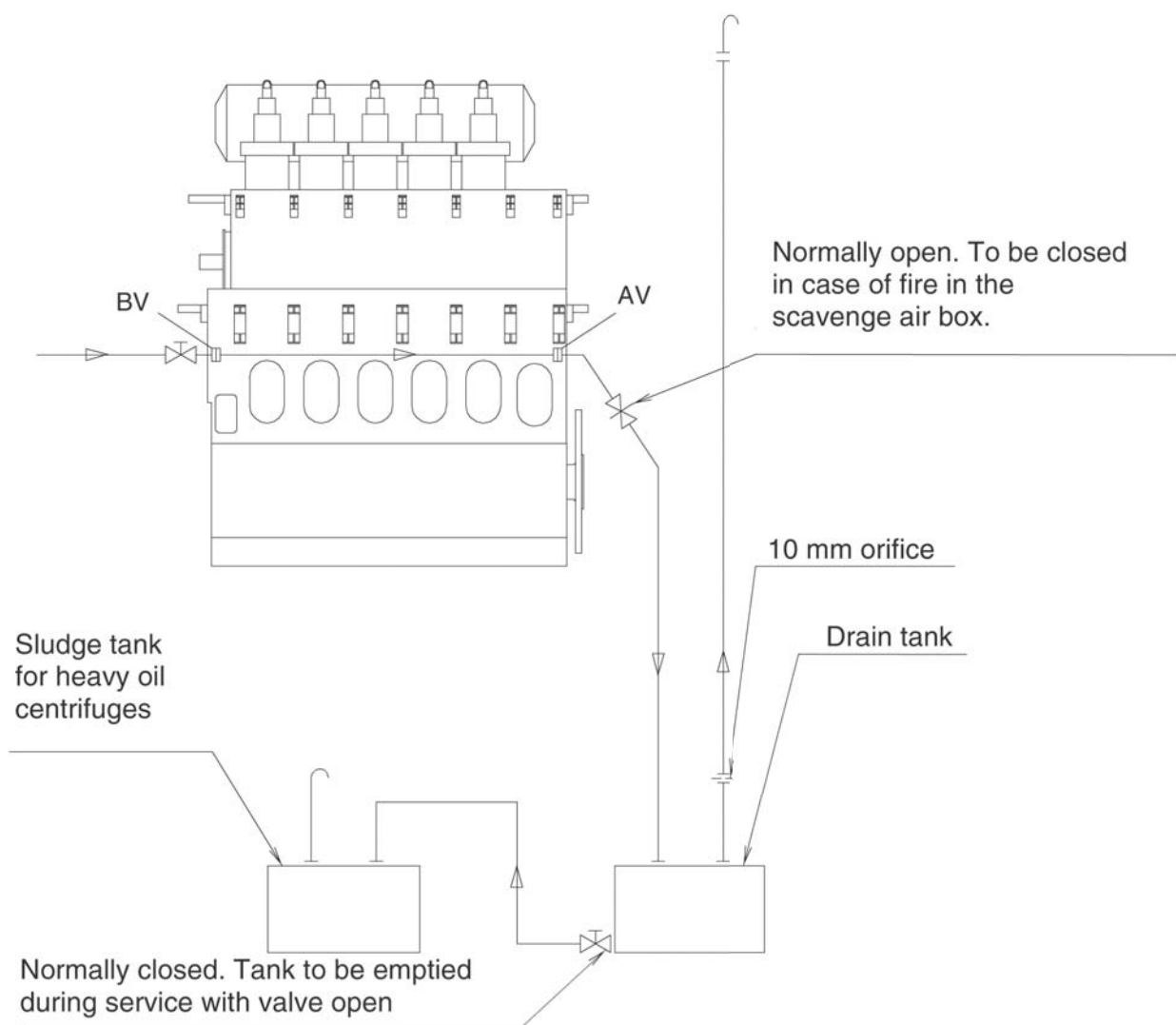
Exhaust Gas Receiver

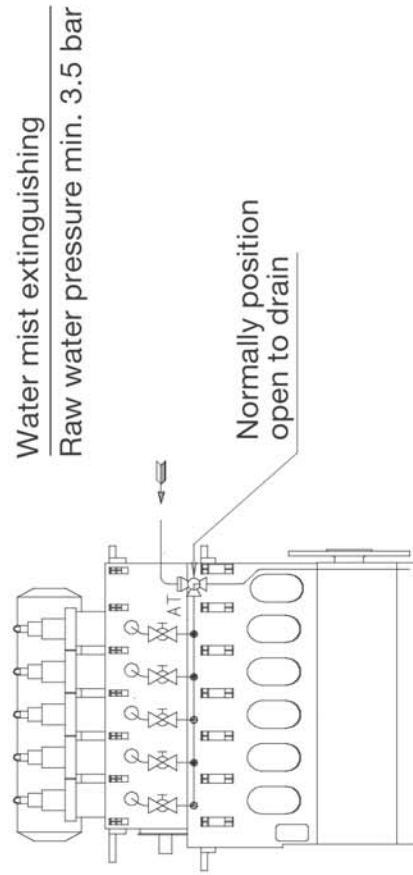
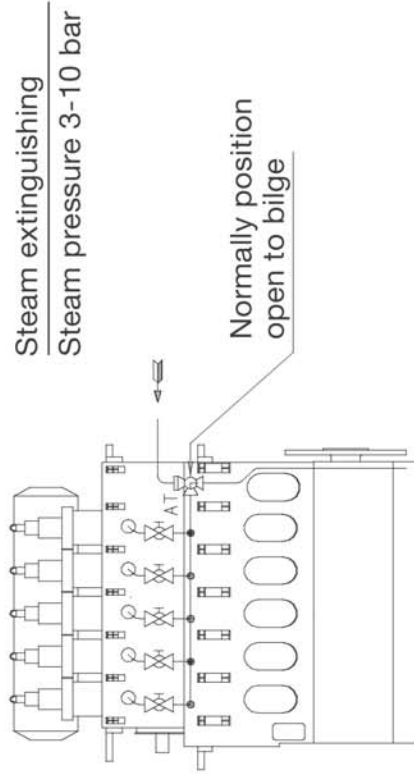
From the exhaust valves, the exhaust gas is led to the exhaust gas receiver where the pulsatory pressure from the individual exhaust valves is equalized and led to the turbocharger at a constant pressure.

The exhaust gas receiver is fastened to the seating by flexible supports. Compensators are inserted between the receiver and the exhaust valves, and between the receiver and the turbocharger.

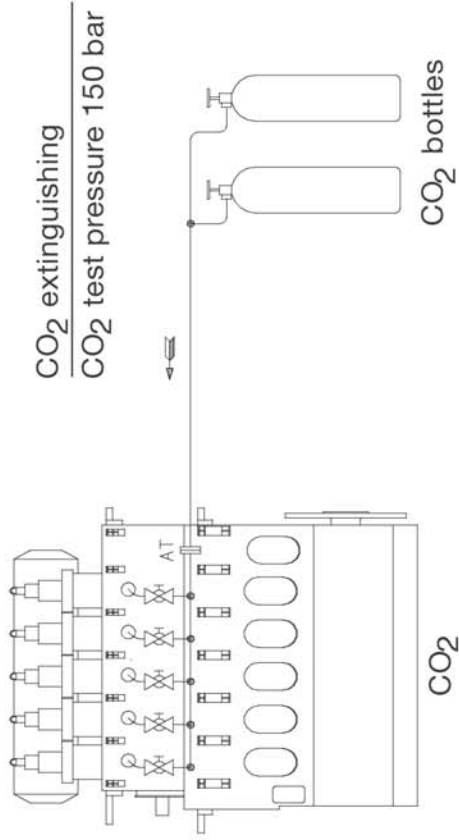
Inside the exhaust gas receiver, a protective grating is mounted before the turbocharger.

The exhaust gas receiver and the exhaust pipe are insulated.





To prevent the fire from spreading to the next cylinder(s), the ball-valve of the neighbouring cylinder(s) should be opened in the event of fire in one cylinder



At least two bottles ought to be installed. In most cases, one bottle should be sufficient to extinguish fire in three cylinders, while two or more bottles would be required to extinguish fire in all cylinders

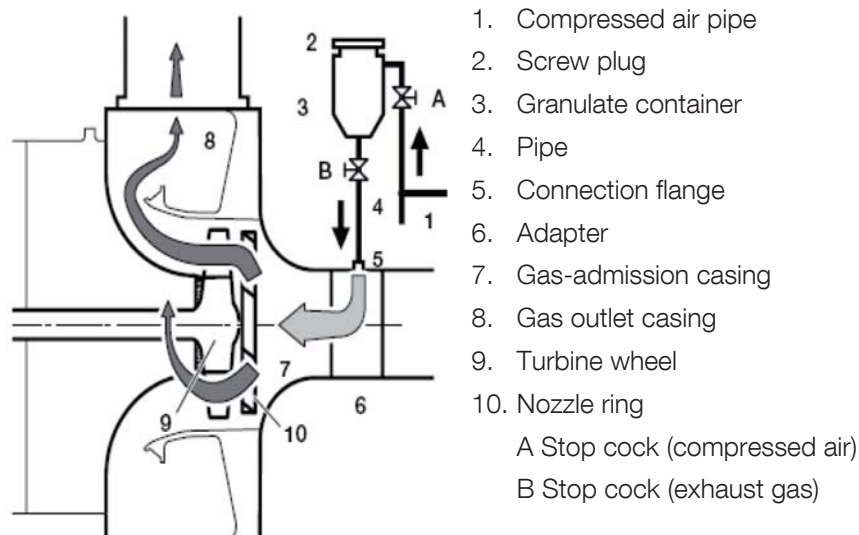
Turbine side

Dry cleaning is carried out under high engine load (50% - 100%).

For ABB turbo chargers the engine load is (25% - 85%)

See makers instruction.

It is recommended to perform the cleaning with granules every one to two days.



Dry wash operation:

1. Open valve A and B, in order to vent the granulate container for possible deposits or condensate.
2. Close valve A and B. Fill the container with the specified amount of granules and shut the container tight.
3. Slowly open valve A. Then open valve B to blow the granulate into the turbine.
4. After 1 to 2 minutes, close valves B and A.

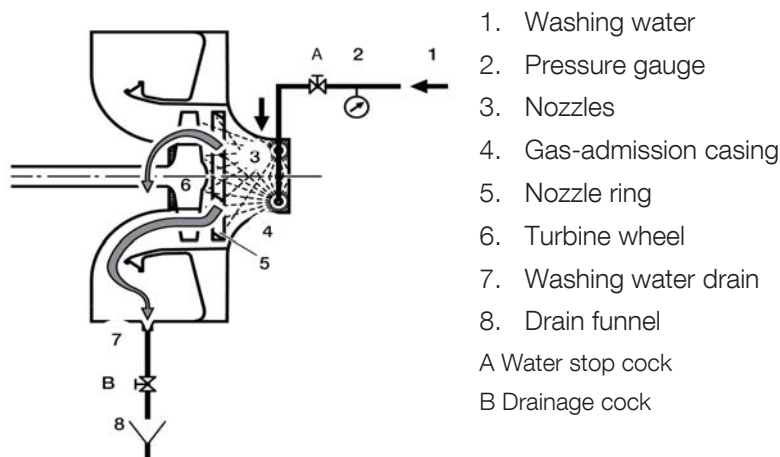
T/C type	Amount [liter]	T/C type	Amount [liter]	T/C type	Amount [liter]
TCR 10	0.2	TCA 99	3.0	MET 66	2.6
TCR 12	0.2	TPL 61	0.5	MET 71	3.0
TCR 14	0.3	TPL 65	0.6	MET 83	3.5
TCR 16	0.3	TPL 69	0.9	MET 90	3.5
TCR 18	0.4	TPL 73	1.2	A165-L	1.0
TCR 20	0.4	TPL 77	1.5	A170-L	1.5
TCR 22	0.5	TPL 80	2.0	A175-L	2.0
TCA 33	0.5	TPL 85	3.0	A180-L	2.5
TCA 44	0.5	TPL 91	3.5	A185-L	3.0
TCA 55	1.0	MET 33	0.4	A190-L	3.5
TCA 66	1.5	MET 42	0.7		
TCA 77	2.0	MET 53	1.6		
TCA 88	2.5	MET 60	2.1		

Turbine side

Wet cleaning of the turbine is carried out during operation at reduced engine load in order to avoid overstressing of the turbine blades (thermal shock)

A general recommendation is to perform cleaning every 250 operating hours.

Type	TCR 22	TCR 33	TCR 44	TCA 55	TCA 66	TCA 77	TCA 88	TCA 99
Exh. gas temperature before Turbine [°C]	≤ 320	≤ 320	≤ 320	≤ 320	≤ 320	≤ 320	≤ 320	≤ 320
Turbocharger Speed [rpm]	≤ 12 000	≤ 15 500	≤ 13 000	≤ 11 000	≤ 9 500	≤ 8 000	≤ 7 000	≤ 5 500

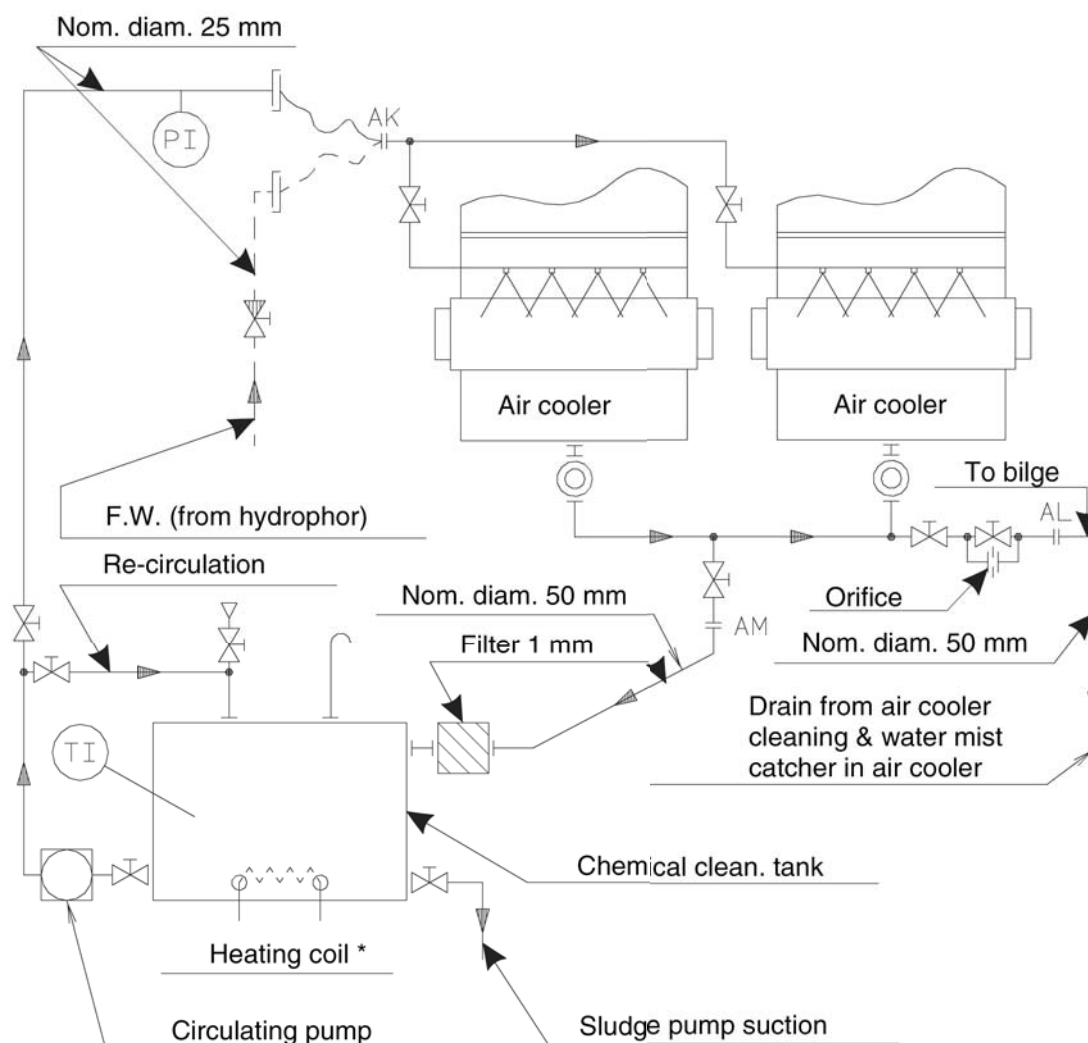


- Use fresh water without any chemical additives.
- The washing duration is 10 to 20 minutes (until clean water comes out of the dirt-water outlet openings).

The wash water flows through the stop cock with a water pressure of 2-3 bar into the gas-admission casing. The washing nozzles spray the water in front of the turbine. The droplets of the washing water bounce against the nozzle ring and the turbine where they wear off contamination.

The washing water collects in the gas-outlet casing and runs through the washing water outlet and the drainage cock. The washing water is conducted via a funnel to a sediment tank and collected there.

The funnel enables the visual inspection of the washing water. The cleaning procedure is completed once the washing water remains clean.



* Capacity for heating coils according to requirement from supplier of the chemical

Safety Precautions

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Shut off cooling water



Data

Ref.	Description	Value	Unit
T54-04	Air cooler element, complete with covers, up to	2650	kg
T54-06	Reversing chamber	350	kg
T54-07	Water inlet/outlet cover	350	kg

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
5470-0110	-	Scavenge air cooler tools
5470-0120	-	Scavenge air cooler lifting tools
7670-0300	-	Lifting tools, etc
7670-0310	013	Travelling Trolley

1. Pressure and temperature

For the day-to-day checking of the scavenge air cooler, measure the drop in pressure and temperature of the scavenge air across the cooler while the engine is running.

Compare these measurements with the testbed data.

For further evaluation of the measurements, see description 6345-0320.

An increase in the air pressure drop across the scavenge air cooler indicates fouling on the air side of the cooler.

A decrease in the air temperature drop across the scavenge air cooler indicates fouling of the water side of the cooler.

If the measurements indicate fouling of the water side of the air cooler element, the element must be overhauled/cleaned.

See overhaul procedure.

2. Access to the air cooler element

Remove the inspection hole covers on the air cooler.

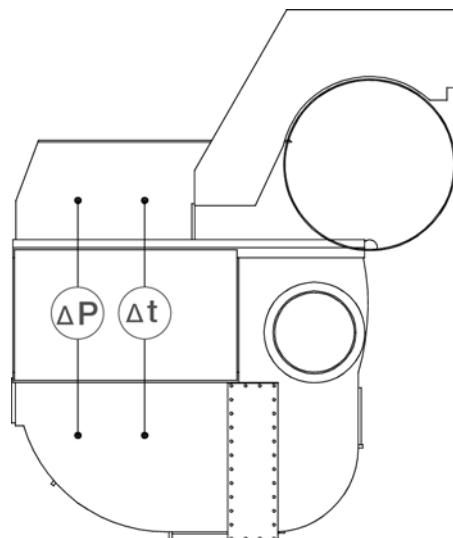
3. Visual inspection

Visually inspect the air cooler elements through the openings.

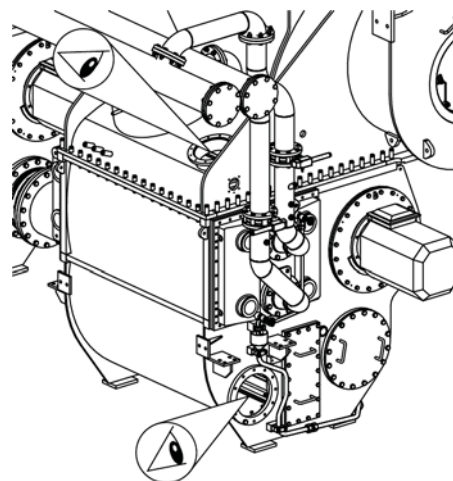
For further information, see description 6645-0100.

If the air side of an element is fouled, clean the element using the spray pipe arrangement mounted above the air cooler element.

See overhaul procedure.



5465-0101-0003C01



5465-0101-0016C03

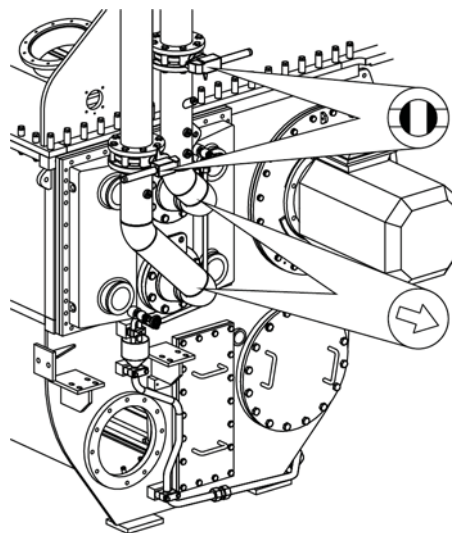
The cooler element normally does not need to be dismantled for inspection purposes.

NOTICE

During dismantling, take care not to damage the cooler element.

1. Cooling water

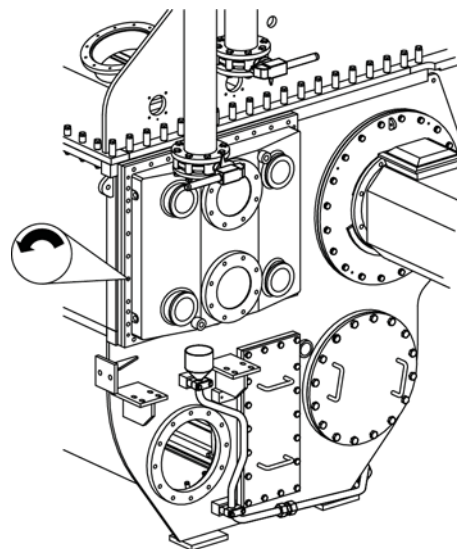
Close the cooling water inlet and outlet valves. Open the drain cocks to drain off the cooling water and dismantle the drain pipes.



5465-0101-0016D01

2. Inlet cover

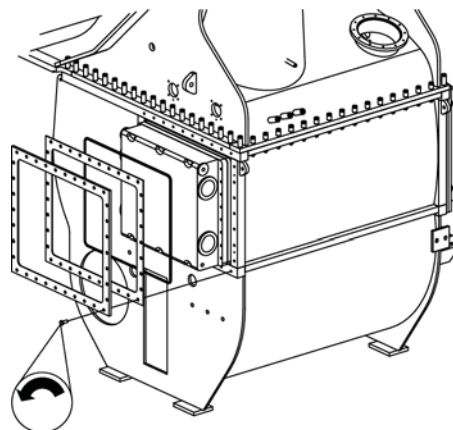
Unscrew the bolts which fasten the water inlet and outlet flanges to the inlet cover, and the inlet cover to the cooler housing. Disconnect the pipes.



5465-0101-0016D02

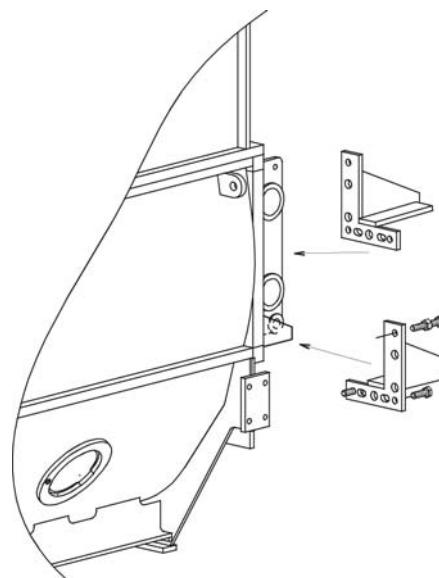
3. Sealing flanges end cover Remove the sealing flanges around the end cover.

Discard the O-ring.



5465-0101-0016D03

4. Guide rails Mount the pair of guide rails on the cooler housing below the end cover.

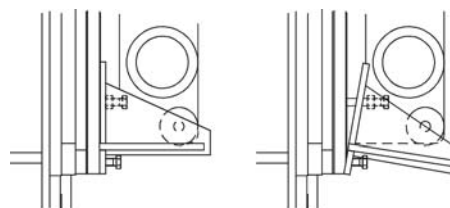


5465-0101-0003D04

5. Loosen cooler element

When mounting the guide rails, hold them up against the wheels of the cooler element and mount the lowermost bolts without tightening them. Mount and tighten the uppermost bolts.

Finally, tighten the lowermost bolts and the thrust nuts on the uppermost bolts simultaneously. This results in loosening and lifting the cooler element.



5465-0101-0003D05

6. Freeing the cooler element

Assemble the lifting bracket to the inlet cover.

Mount a travelling trolley on the beam above the inlet cover.



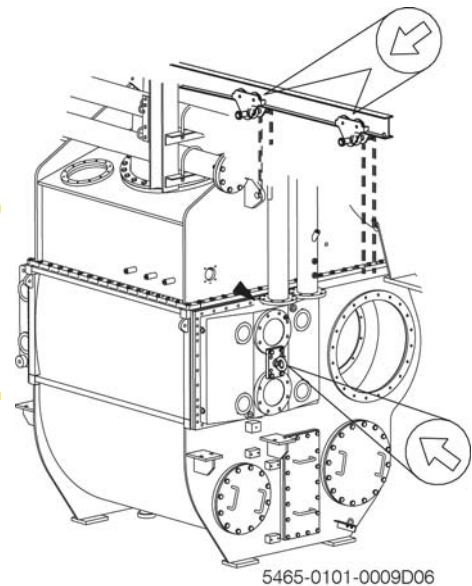
WARNING

Safe working load (SWL)

Always use lifting gear with sufficient SWL.

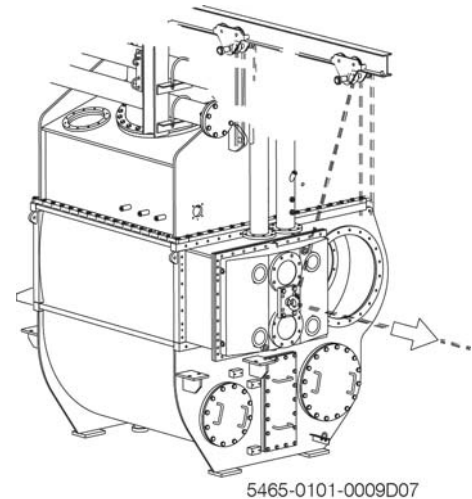
See data.

Install a tackle between the travelling trolley and the lifting bracket. Use the tackle to lift the air cooler element approx. 1-2 mm.



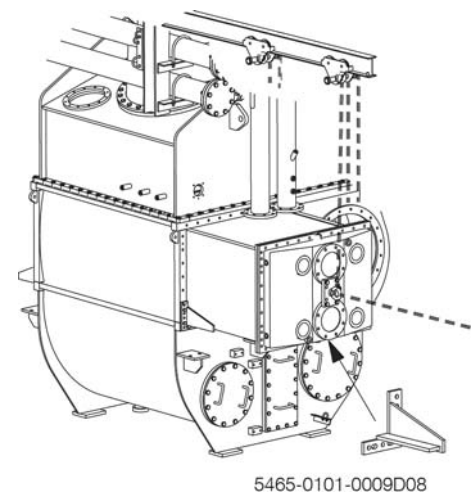
7. Loosening and lifting the cooler element

Mount a second tackle on the lifting bracket, and use it to pull out the air cooler element approx. half a metre.



8. Second set of guide rails

Mount the second set of guide rails to the frame around the air cooler element.



9. Lifting the cooler element out of the housing

Pull out the air cooler element until the front end cover of the air cooler element is clear of the air cooler housing.



WARNING

Keep clear of the cooler element during the lift.

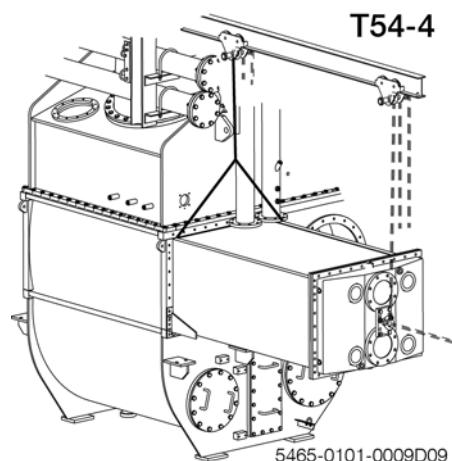
Assemble a second travelling trolley to the beam above the air cooler.

Mount a tackle between the second travelling trolley and the lifting holes in the upper corners of the front end cover of the air cooler element.

Using the tackles, lift the air cooler element away and land it on a couple of wooden planks.

NOTICE

Depending on the engine and the engine room installation, it may be necessary to remove some pipes and floor plates.



Air Cooler Element • Dismantling

Work Card

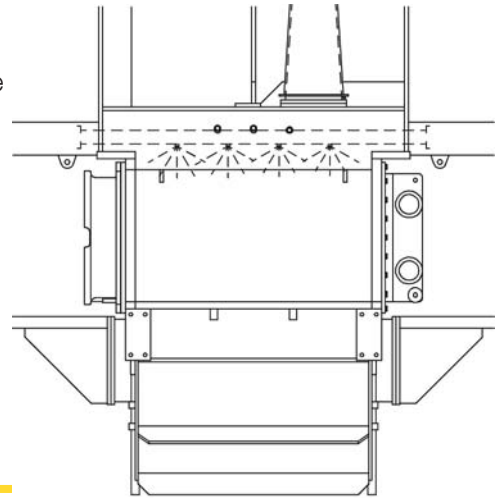
5465-0101-0016

1. **Cleaning the air side** The air side of the cooler is cleaned by injecting a chemical fluid through the spray pipe arrangement mounted in the air chamber above the cooler element.

It is recommended to use one of the following cleaning fluids, or a similar product.

Product 1: ACC 9, produced by Drew Chemical Corp., New York, USA

Product 2: 80B, produced by Vecom Int., Maassluis, Holland



5465-0101-0003001

NOTICE

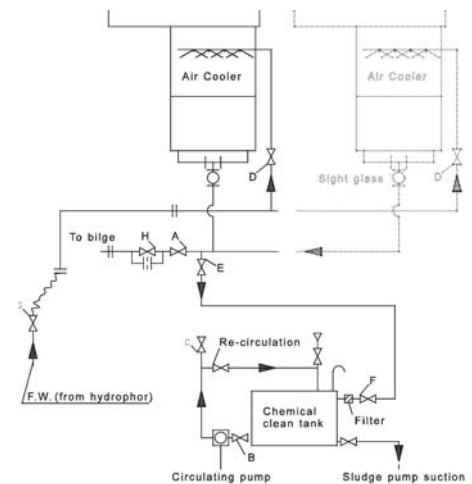
Do not start cleaning until the engine has been at a standstill for about 30 minutes. Do not disconnect the compressed air supply to the exhaust valve.

2. **Cleaning instructions** Follow the detailed cleaning instructions displayed at the cleaning pipe on the engine. To ensure satisfactory spraying of the cleaning fluid, the circulating pump pressure must be at least 0.7 bar.

Continue the cleaning process for at least 30 minutes. The time required depends on the frequency with which cleaning is carried out and on the chemical product used.

After cleaning, flush the cooler with clean water until the water appearing in the sight glasses is clean and pure.

Inspect the element either by removing the cover on top of the cooler or by dismantling the charging air pipe.

Cleaning condition

- 1) Chemical cleaning
Open: B, C, D, E, F
Close: A, G, H
Start the pump

Water flushing

- 2) Open: A, D, G, H
Close: B, C, E, F

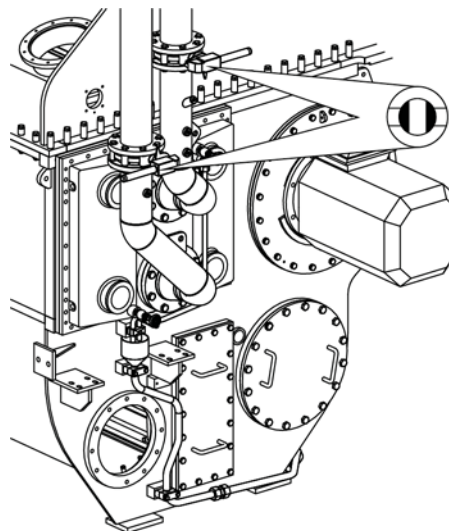
Normal running condition

- 3) Open: A
Close: B, C, D, E, F, G, H
Close the inspection covers on the scavenge air receiver

5465-0101-0003002

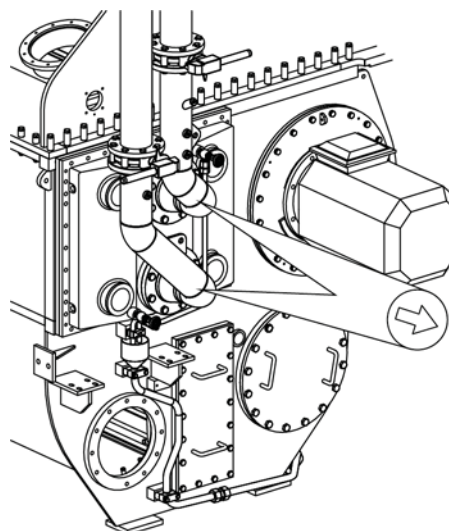
Cleaning the water side: The following dismounting and dismantling procedure is to be followed if it is desired to clean the water side of the cooler insert.

1. **Cooling water pipes** Close the cooling water inlet and outlet valves. Drain off the water from the cooler.



5465-0101-0016O06

2. **Cooling water pipes dismantling** Dismount the cooling water inlet and outlet pipes from the inlet cover.



5465-0101-0016O07

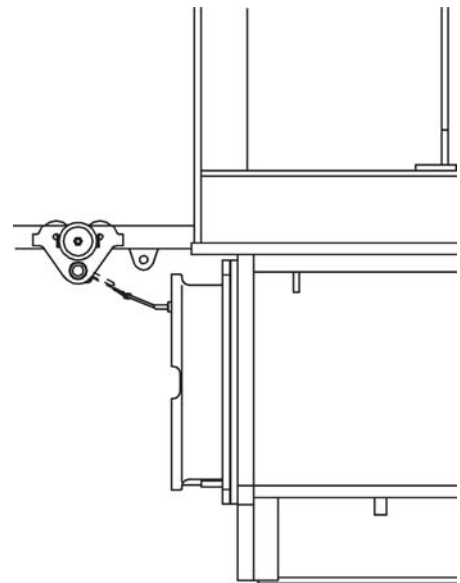
3. Lifting tools

Screw two eye bolts into the upper flange of the inlet cover.

Mount a lifting wire rope between the eye bolts.

Mount a travelling trolley on the beam above the inlet cover.

Mount a tackle between the travelling trolley and the lifting wire rope. Tighten up the tackle.



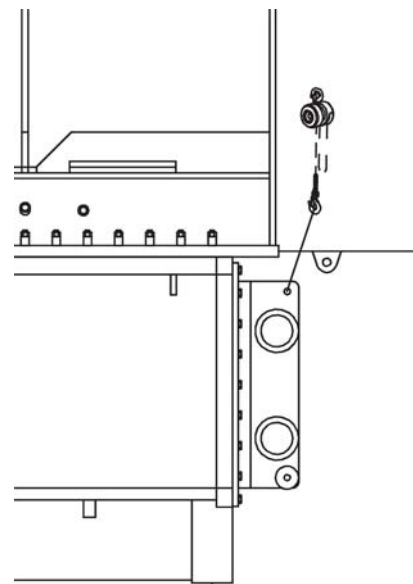
5465-0101-0003O08

4. Tighten up

Mount a shackle in each of the two lifting eyes on the end cover.

Mount two tackles above the end of the air cooler.

Hook the tackles on to the shackles and tighten up.

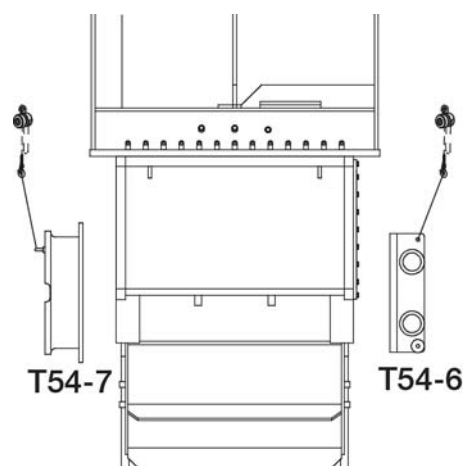


5465-0101-0003O09

5. Dismantling the end covers

Unbolt the inlet and end covers.

Lower both covers and land them on a couple of wooden planks. Discard the gaskets.



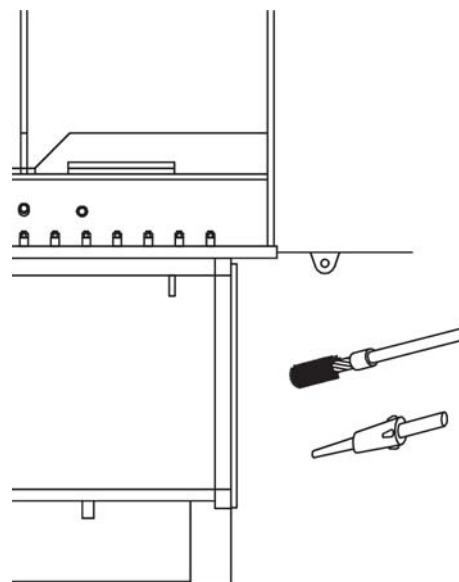
5465-0101-0003O10

6. Cleaning the tubes

Clean the inside of the tubes, using the cleaning brush (supplied by the cooler element manufacturer) mounted on a drilling machine. In the event of leakages between cooling tube and tube plate, the tubes are rolled with the tube expander (also supplied by the cooler element manufacturer).

Clean the front-end and aft-end covers inside with a stiff brush and then rinsed with fresh water.

Replace the anti-corrosion blocks, if necessary.



5465-0101-0003O11

NOTICE

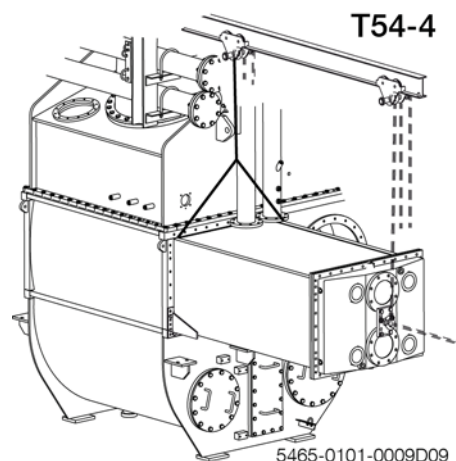
If damaged, the coating inside the covers is to be repaired with the original coating or a similar product.

When cleaning is complete, mount the covers in the reverse order to dismantling.

1. Landing the cooler element

Lift the air cooler element and land the end of the element on the guide rails mounted on the inlet end of the air cooler housing.

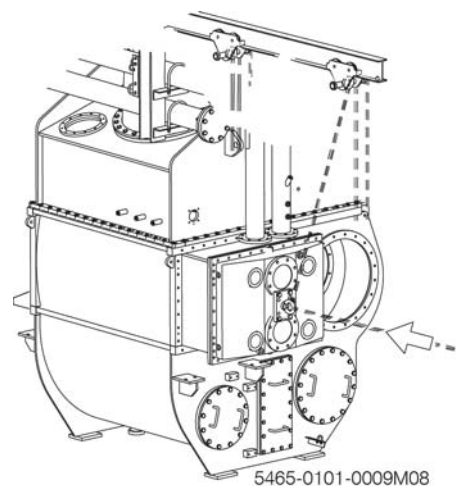
Remove the tackle from the end of the cooler element.



2. Guide rails

Push the air cooler element inwards approx. one metre.

Remove the guide rails from the air cooler housing.



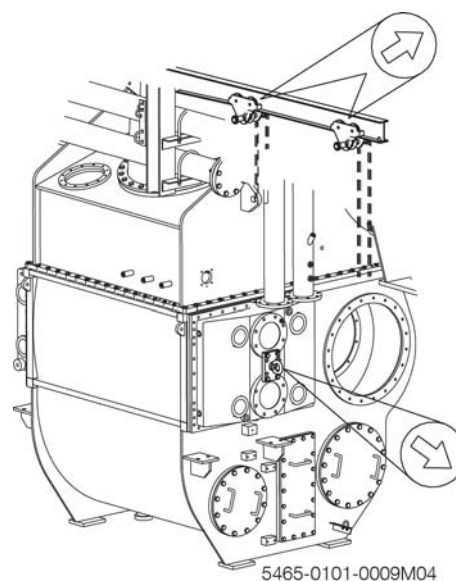
3. Assemble the element

Push the cooler element into the housing and mount the bolts holding the inlet cover.

Remove the lifting bracket..

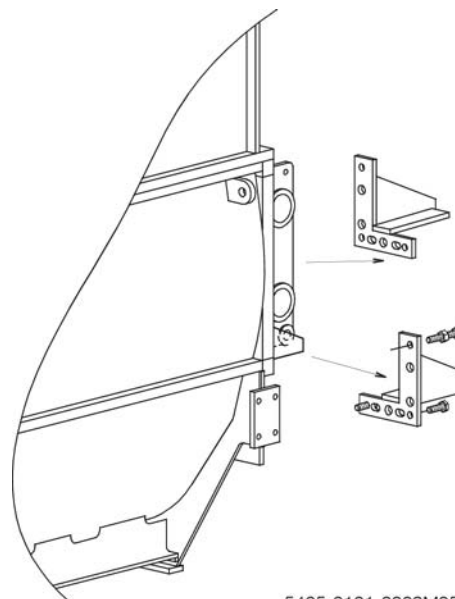
NOTICE

Before pushing the air cooler element fully in, make sure that the sealing flanges and a new O-ring are in position, hanging on the cooling water pipes.



4. Guide rails

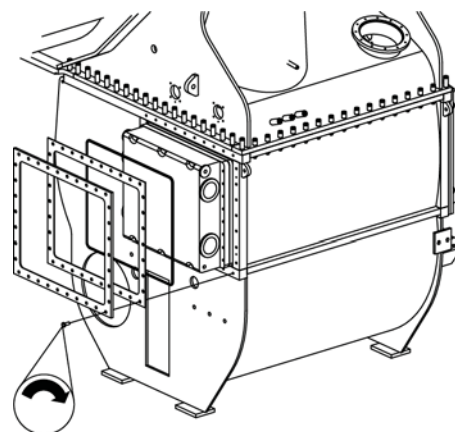
Remove the second pair of guide rails on the end of the cooler housing.



5465-0101-0003M05

5. End cover sealing plate

Assemble the sealing plate, a new O-ring and the frame around the end cover.



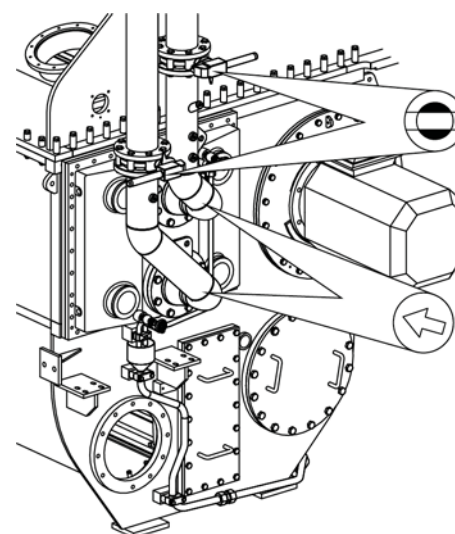
5465-0101-0016M05

6. Cooling water pipes

Insert new gaskets between the inlet cover and the flanges of the cooling water pipes.

Mount and tighten the bolts which fasten the cooling water inlet and outlet pipes to the inlet cover.

Connect the drain pipes, and open the cooling water inlet and outlet valves.



5465-0101-0016M06

NOTICE

Remember to vent trapped air from the air cooler element.

Safety**Precautions**

*for detailed sketch
see 0545-0100*

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Shut off cooling water

Data

Ref.	Description	Value	Unit
T54-11	Water mist catcher	100-200	kg

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
7670-0300	-	Lifting tools, etc

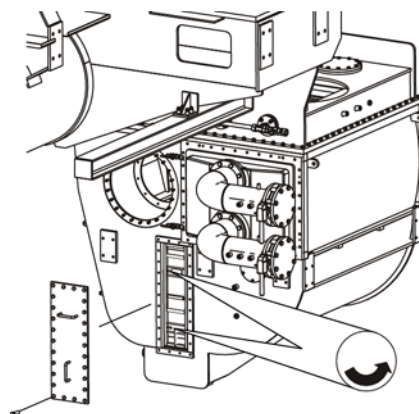


Normally it is not necessary to remove the water mist catcher from the scavenge air cooler housing. If, however, the water mist catcher has been fouled or damaged, it must be dismantled for cleaning or repair.

1. Rectangular covers Dismantle the rectangular covers from both the front and aft ends of the scavenge air cooler housing. Then loosen the screws at both ends of the water mist catcher.

NOTICE

Note the position of the water mist catcher. During mounting, the water mist catcher must be re-mounted in the same position.



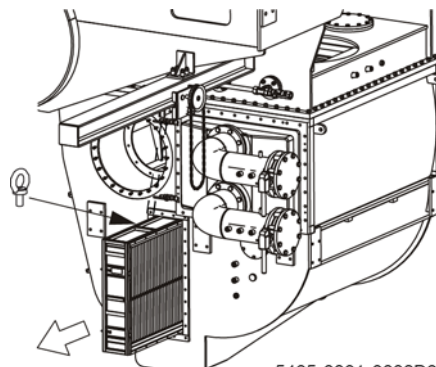
5465-0201-0003D01

2. Mount an eye bolt Pull or push the water mist catcher halfway out and mount an eye bolt in the top of the water mist catcher.

Hook a tackle on to the eye bolt and lift the water mist catcher away. Land it on a couple of wooden planks.

NOTICE

Take care not to damage the water mist catcher during the lift.

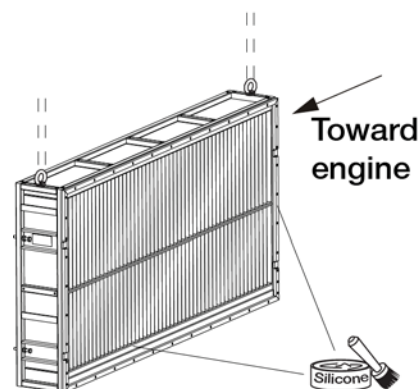


5465-0201-0003D02

3. Water mist catcher cleaning Clean the water mist catcher with the same cleaning fluid as used for the scavenge air cooler element.

1. Silicone paste

Apply a thin layer of silicone paste to the frame of the water mist catcher on the side which will face away from the engine when the water mist catcher is mounted (the side opposite to the screws).



5465-0201-0003M01

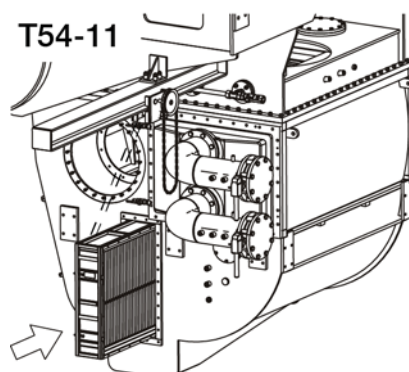
2. Mount the water mist catcher

Slide the water mist catcher into the scavenge air cooler housing.

NOTICE

Make sure to mount the water mist catcher correctly. The screws of the water mist catcher must face the exhaust side of the engine.

When the water mist catcher is half-way in, remove the tackle and the eye bolt, and push the water mist catcher fully into the scavenge air cooler housing.

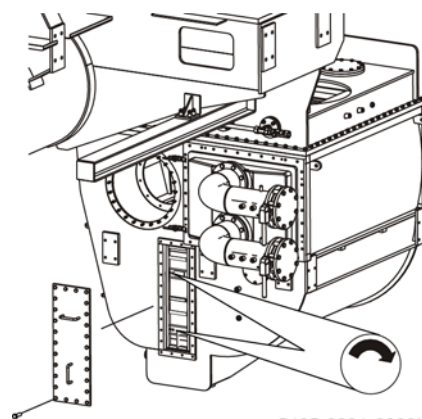


5465-0201-0003M02

3. Tightening of screws

Tighten the screws at both ends of the water mist catcher.

Apply a thin layer of silicone paste on the frame and mount the rectangular covers on the front and aft ends of the scavenge air cooler housing.



5465-0201-0003M03

Safety**Precautions**

for detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off safety air supply - Not ME Engines
☐	Shut off control air supply
☐	Shut off air supply to exhaust valve - Only when stopped lubricating oil pumps

**Data**

Ref.	Description	Value	Unit
-	Table is empty on purpose. No Data needed.	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.

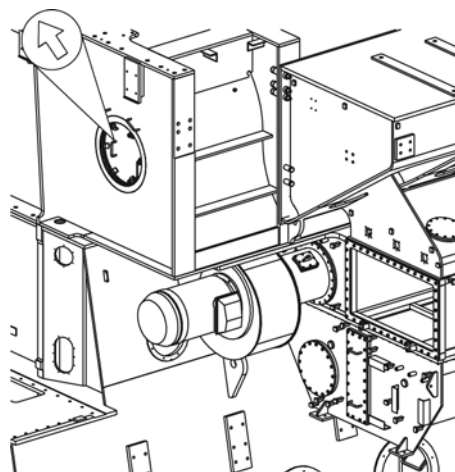
1. Access to the non-return valve

This procedure treats the non-return valve.

The non-return valves are accessed via the scavenge air receiver through the round access hatch.

NOTICE

Access to the scavenge air receiver must not be attempted until the air in the receiver is clean. The access hatch to the scavenge air receiver must be blocked in the open position during work in the receiver.

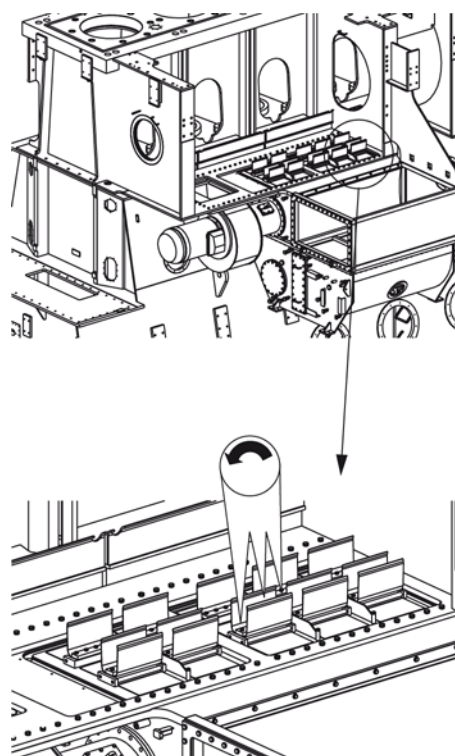


5465-0401-0002001

2. Remove the valve

Inside the scavenge air cooler housing, remove the middle and the two outermost screws of the valve that is to be overhauled.

Remove the valve from the engine.

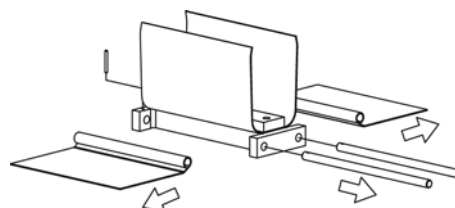


5465-0401-0002002

3. Dismantling

Remove the spring pin from the valve shaft and knock the valve shaft out of the valve flap.

Clean the valve shaft and the slide bearings inside the valve flaps. Lubricate the valve shaft and the slide bearings with molybdenum disulphide (MoS_2).

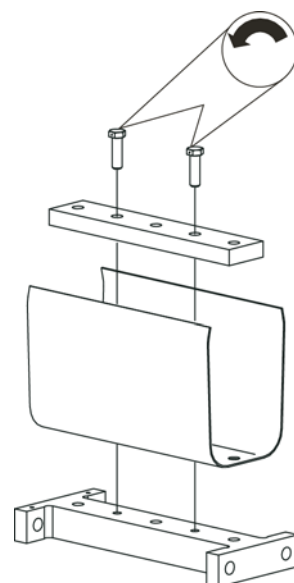


5465-0401-0002003

4. Further dismantling For further dismantling, remove the two screws which hold the supports and the clamp together as an assembly.

After the overhaul, it must be possible to move the valve flap by the light touch of a finger.

Assemble the valve and re-mount it in the scavenge air cooler housing.



5465-0401-0002004

Safety**Precautions**

for detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off safety air supply - Not ME Engines
☐	Shut off control air supply
☐	Engage turning gear

**Data**

Ref.	Description	Value	Unit
T54-21	Electric motor, impeller and motorplate	360	kg

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
7670-0300	-	Lifting tools, etc

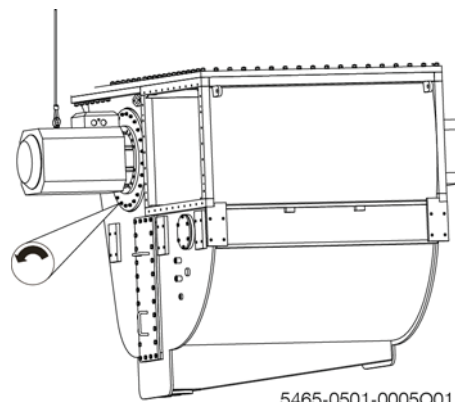


When cleaning and inspecting the auxiliary blower, take out the electric motor and the blower wheel as one whole assembly.

1. **Blower motor** Disengage the cable connections to the blower motor.

Attach a wire rope with shackle to the eye bolt mounted on the blower flange, and hook on the tackle suspended from mountings on the gallery bracket.

Remove the bolts in the blower wheel flange, and pull the electric motor with flange and blower wheel out of the end cover, using the tackle.



5465-0501-0005O01

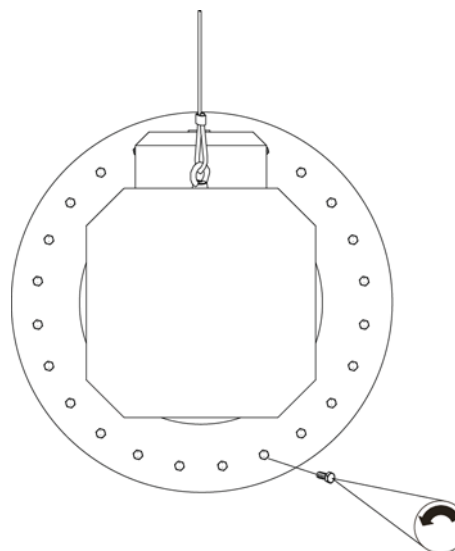
2. **Inspection** Inspect and clean the blower wheel as well as the blower housing.

3. **Blower assembly** If the whole blower assembly is to be removed, the inspection covers on the scavenge air receiver are to be removed first.

NOTICE

Make sure that the air in the receiver is clean before making the access.

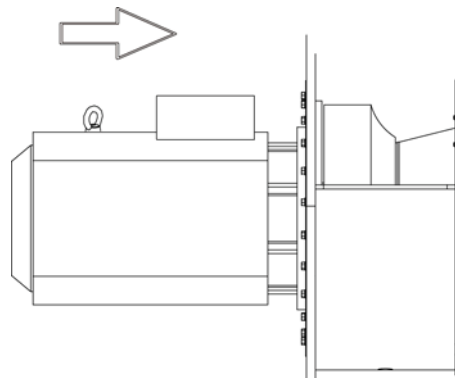
Remove all bolts holding the motor flange. The complete blower can now be pulled free of the suction pipe by means of the tackle. While pulling out the blower assembly, make sure that the blower housing disengages from the air pipe without deforming it.



5465-0501-0005O03

4. **Remounting** When mounting the end cover with the complete blower, the parts are to be guided into place with care.

For overhaul of blower wheel and bearings, see blower manufacturer's instructions.



5465-0501-0005O04

Safety**Precautions**

*for detailed sketch
see 0545-0100*

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Engage turning gear
☐	Lock the turbocharger rotors

Data

Ref.	Description	Value	Unit
-	Table is empty on purpose. No Data needed.	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.



NOTICE

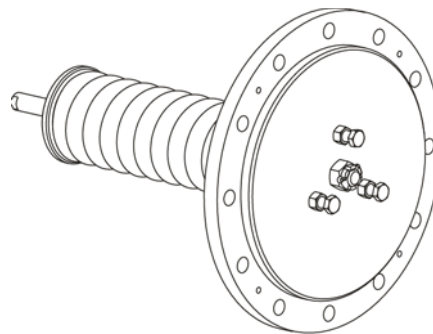
The scavenge air receiver safety valve is calibrated at the factory and does not require any adjustment.

1. Checking the
scavenge air receiver
safety valve

Check the scavenge air receiver safety valve by loosening the counter nut and turn the forced opening screw to open the valve approx. 10 mm.

Use a piece of cloth to wipe out any dirt from the O-ring packing and close the valve again. Tighten the counter nut.

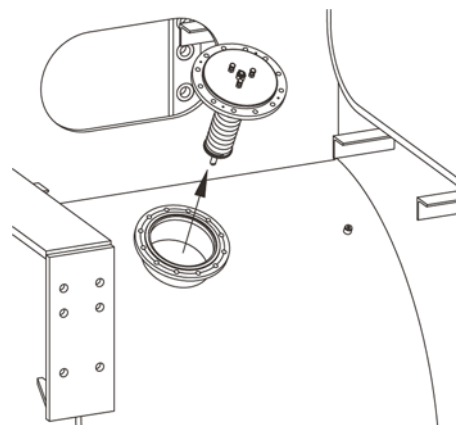
If this operation cannot be performed smoothly, the safety valve must be dismantled and cleaned.



5465-0601-0002C02

1. Dismantle

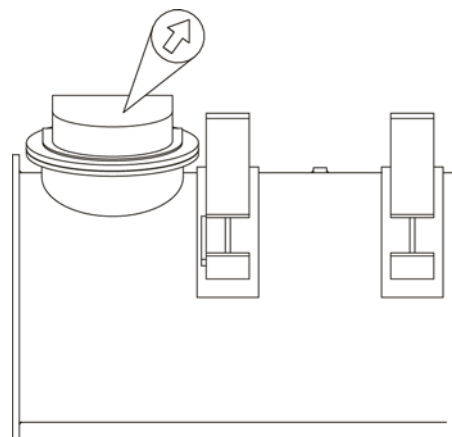
Dismantle the safety valve from the scavenge air receiver.



5465-0601-0001D01

2. Access to safety valve

On some engines a cover has to be removed in order to gain access to the safety valve.



5465-0601-0001D02

1. Disassemble the valve

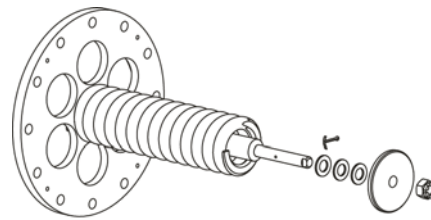
Remove the split pin.

Unscrew the nut thereby relieving the spring tension.

Remove the nut, spring retainer and washers.

Keep count of the washers.

Pull out the spring.

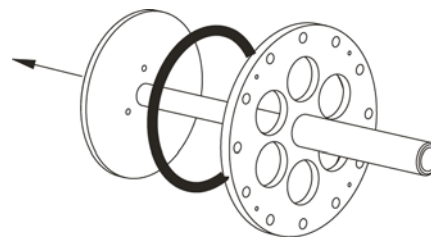


5465-0601-0002001

2. Valve flap

Pull out the valve flap with spindle.

If the O-ring seal is damaged remove it without damaging the O-ring groove.



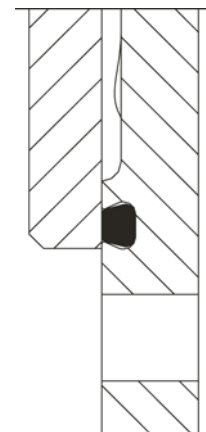
5465-0601-0002002

3. Cleaning

Clean the metal surfaces thoroughly.

4. Replace O-ring

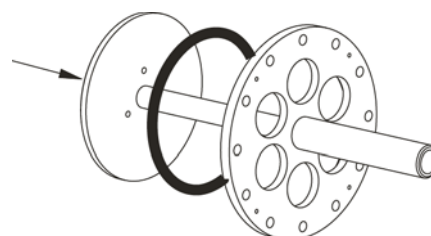
If the O-ring seal has been removed mount a new one using Loctite type AVX and Loctite activator type T or similar.



5465-0601-0002004

5. Valve flap and spindle

Push in the valve flap and spindle while taking care not to damage the O-ring seal.

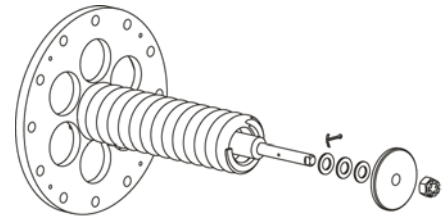


5465-0601-0002005

6. Assembly

Mount the spring, spring retainer and all the washers.

Tighten the nut until the split pin can be mounted.



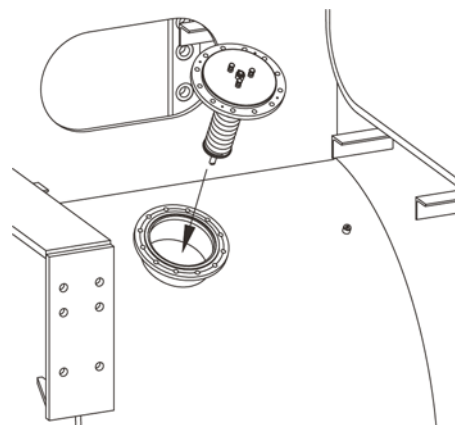
5465-0601-0002001

7. Checking

Check the valve.

See checking procedure.

1. Mount the safety valve
Mount the safety valve on the scavenge air receiver.



5465-0601-0001M01

Safety Precautions**Data**

Ref.	Description	Value	Unit
-	Table is empty on purpose. No Data needed.	-	-

Turbocharger Cleaning, Data

Work Card

5465-0700-0001

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.



Dry cleaning

The dry cleaning method employs compressed air to blow dry, solid, granules through the turbocharger, thus removing most of the deposits which may have formed on the nozzle vanes and turbine blades.

On account of their hardness, nut-shells, or broken or artificially shaped pieces of activated charcoal with a size of between 1.0 and max. 1.5 mm are particularly suited as blasting agents.

NOTICE

We do **not** recommend the use of rice or grain as cleaning materials, as these may possibly stick in the exhaust gas boiler.

1. Removing thick deposits

It is not always possible to remove thick deposits with this dry cleaning method.

Therefore, in order to prevent the build-up of thick deposits, the turbine must be cleaned after every 24 to 50 hours of operation.

Generally, turbocharger cleaning can be carried out without, or with very little, reduction of the engine load.

2. Detailed information

More detailed information regarding the amount of granules to be used is stated on the instruction plate located close to the turbocharger.

NOTICE

Regarding water washing of turbocharger turbine, see turbine manufacturer's instructions.
See description 6345-0320.

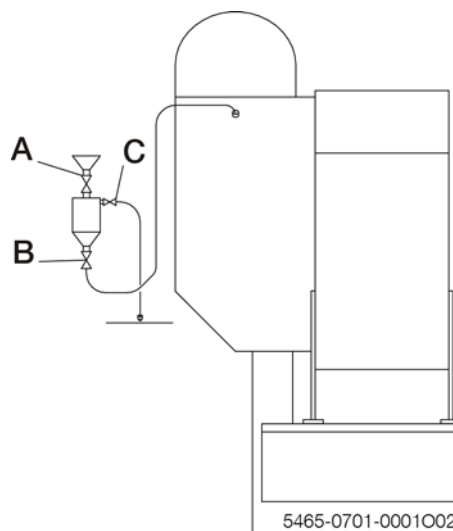
3. Cleaning Procedure
(24-50 hours)
- Carry out cleaning for every 24 to 50 hours of operation, based on observations.

TC type	Amount dm ³
TCR 14	0,1
TCR 16	0,2
TCR 18	0,2
TCR 20	0,3
TCR 22	0,5
TCA 33	0,5
TCA 44	0,5
TCA 55	1,0
TCA 66	1,5
TCA 77	2,0
TCA 88	2,5
TCA 99	3,0
TPL 61	0,5
TPL 65	0,6
TPL 69	0,9
TPL 73	1,2
TPL 77	1,5
TPL 80	2,0
TPL 85	3,0
MET 33	0,4
MET 42	0,7
MET 53	1,6
MET 60	2,1
MET 66	2,6
MET 71	3,0
MET 83	3,5
MET 90	3,5
A165-L	1,0
A170-L	1,5
A175-L	2,0
A180-L	2,5
A185-L	3,0
A190-L	3,5

5465-0701-0002003



4. Preferably Clean the turbocharger at full load. Do not clean below half load.



5. Valve A Close valve **A**.
6. Valve B/C Open valves **B** and **C**, to blow out any deposits and/or condensate in the connecting pipe.

After about two minutes, close valves **B** and **C**.
7. Relieve the pressure Slowly open valve **A** to relieve the pressure in the tank.
8. Fill the tank Fill the tank with the quantity of granules specified in the table.
9. Valve A Close valve **A**.
10. Valve B/C Open valves **B** and **C**, to blow in the granules. After one to two minutes, close valves **B** and **C**.
11. Relieve the pressure in the tank Slowly open valve **A** to relieve the pressure in the tank.



The drain openings in the gas casings must remain closed while dry cleaning the turbine.

It is possible that during dry cleaning of the turbine, some of the blown-in solid particles or sparks will escape through the funnel.

**Safety
Precautions**

*for detailed sketch
see 0545-0100*

☐	Job can be carried out during operation
-----------------------	---

Data

Ref.	Description	Value	Unit
-	Scavenge air pressure below:	0.3	bar

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
-	-	Table is empty on purpose. No special tools needed.

Safety Precautions

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply



Data

Ref.	Description	Value	Unit
T54-28	Gas By-Pass Valve	30	kg
T54-30	Max. Valve turning torque	Smooth torque ± 5	Nm
T54-31	Assembly screws	25	Nm
T54-32	Valve seat screws	25	Nm
T54-33	Valve flap bolts	40	Nm

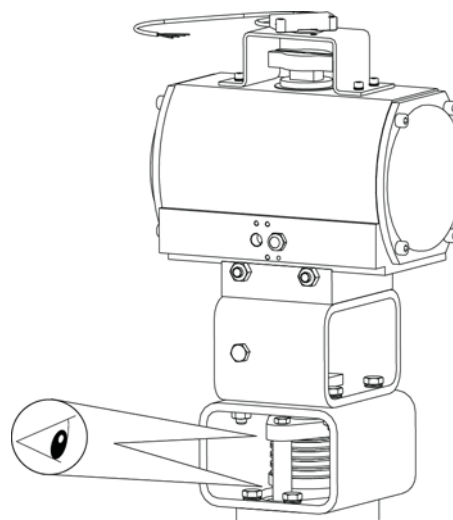
The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
7670-0200	-	Torque spanners
7670-0300	-	Lifting tools, etc

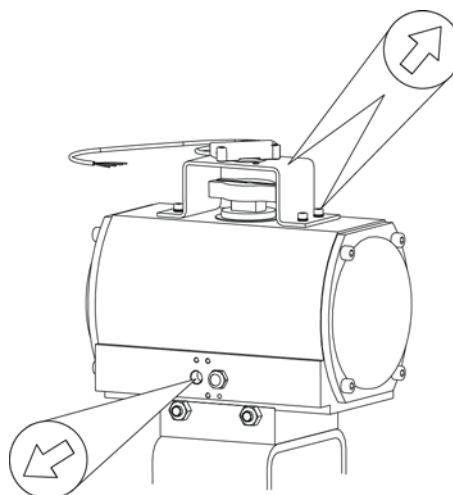
1. **Pneumatic operation** Actuate the valve from the control panel. Look at the coupling and spindle operation to check that the actuator opens and closes the valve smoothly and properly.

If the operation is erratic, the cause should be found and remedied.



5465-0811-0001C01

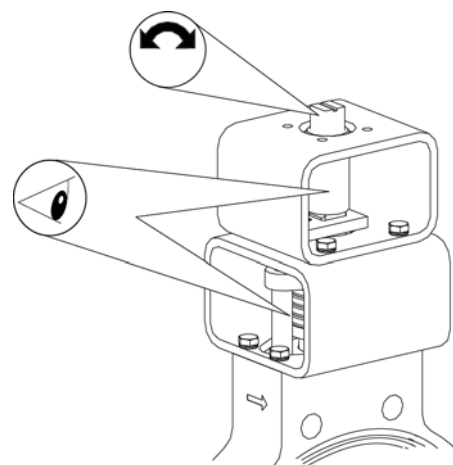
2. **Manual operation** Remove the air supply.
Remove position sensor (if mounted).
Remove the actuator.



5465-0811-0001C02

3. **Turn the valve** Look at the coupling and spindle operation while turning the valve manually.
Check simultaneously that the valve opens and closes smooth and properly.
If the operation is erratic, the cause should be found and remedied.

Remount the actuator, pointer air supply and position sensor.

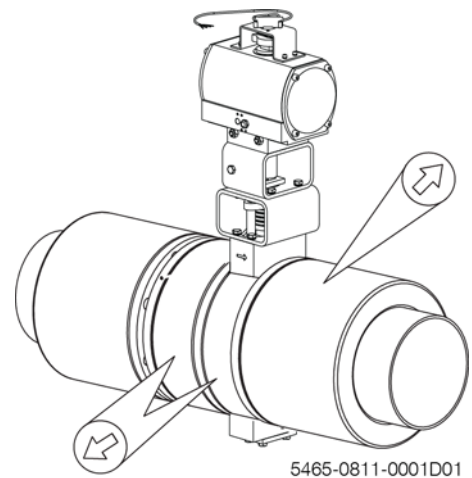


5465-0811-0001C03

1. Preparation

Remove the insulation from the valve.

Where applicable, remove the heat radiation shield, taking note of its position.

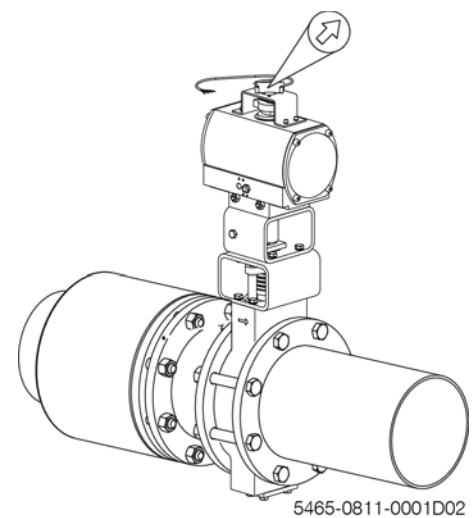


2. Removal of the actuator

Remove the air supply.

Remove position sensor (if mounted).

Mark off the position of the valve on the flange by means of punch marks or similar.

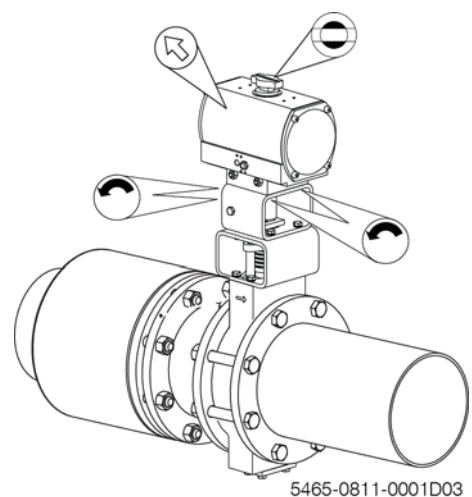


3. Mount ½ ton chain tackle

Make sure that the valve is in the open position.

Loosen the actuator screws.

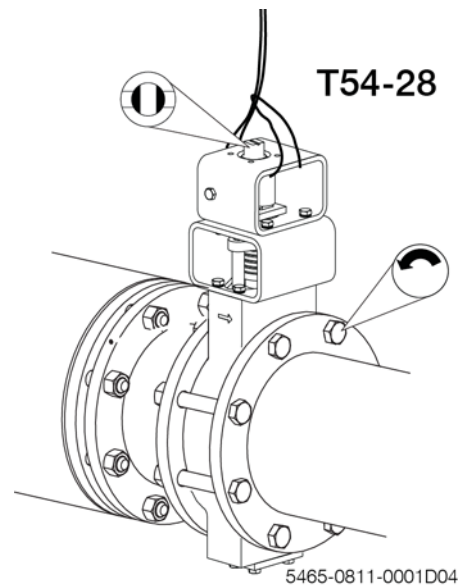
Remove the actuator.



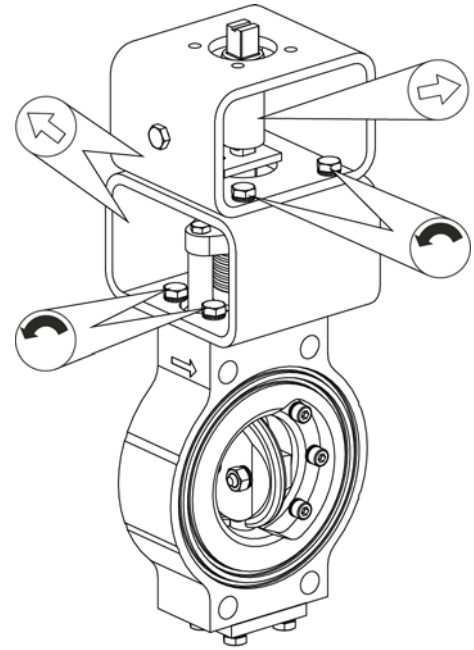
4. Removing the valve Close the valve.

Mount a wire sling through the actuator bracket and suspend it from the engine room crane.

Remove the flange bolts and lift away the valve to a workbench or similar. Place it so that it is accessible from both sides.



1. Remove bracket
 - Remove the spindle extension.
 - Remove the bolts holding the bracket.
 - Remove the bracket.



5465-0811-0003001

2. Dismantling

Remove the screws of the valve seat.

Remove the valve seat. Remove the valve flap bolts.

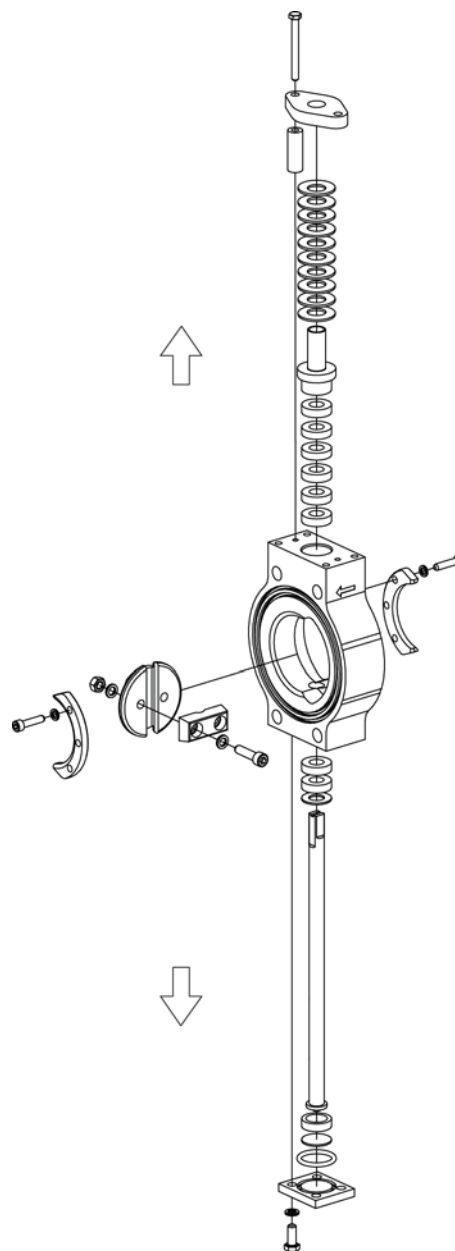
Remove the valve flaps. Gradually loosen the bolts that hold the flanges.

Remove the flanges, the tubular spacers, disc spring and thrust discs.

Pull out the spindle. If necessary, use a brass mandrel and a hammer to knock it out.

Remove the packings, seals, etc. and bushings from the housing.

Clean and inspect all parts, pay special attention to the valve seat and spindles. If necessary, minor wear marks may be ground or polished. Replace parts as necessary.



3. Assembly

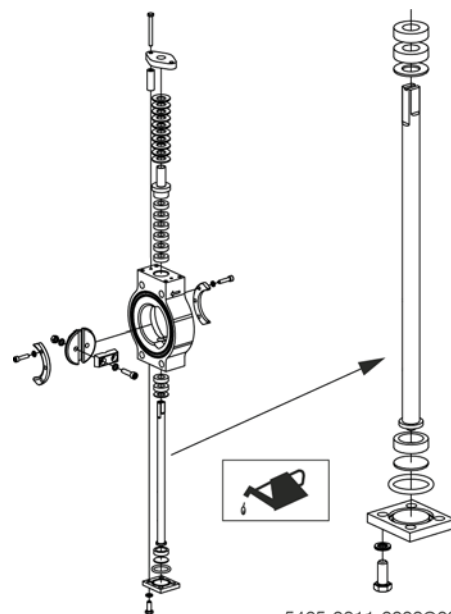
During the assembly process we recommend also to see the plate.
See plate 5472-0810.

4. Preparing valve spindle

Mount the thrust disc, bushing and the packing on the valve spindle.

NOTICE

Lubricate the thrust disc and the bushing thoroughly with grease containing graphite before assembly.



5465-0811-0003O03

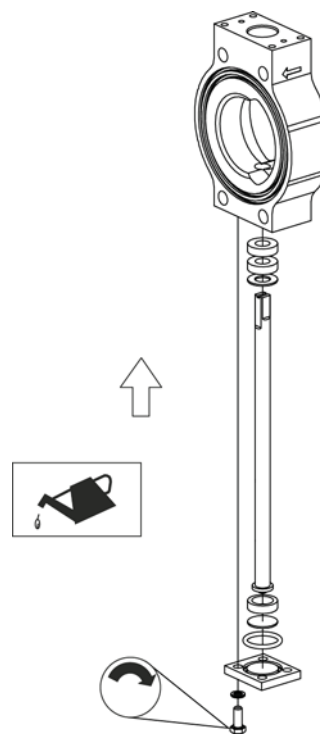
5. Assembly lower part

Mount the spindle in the valve housing.

Mount the distance pipe, thrust disc, packing and the end cover.

NOTICE

Lubricate the distance pipe and the thrust disc with grease containing graphite before assembly.



5465-0811-0003O04

6. Assembly of upper part Mount the packings, sealing rings, bushing and thrust disc.

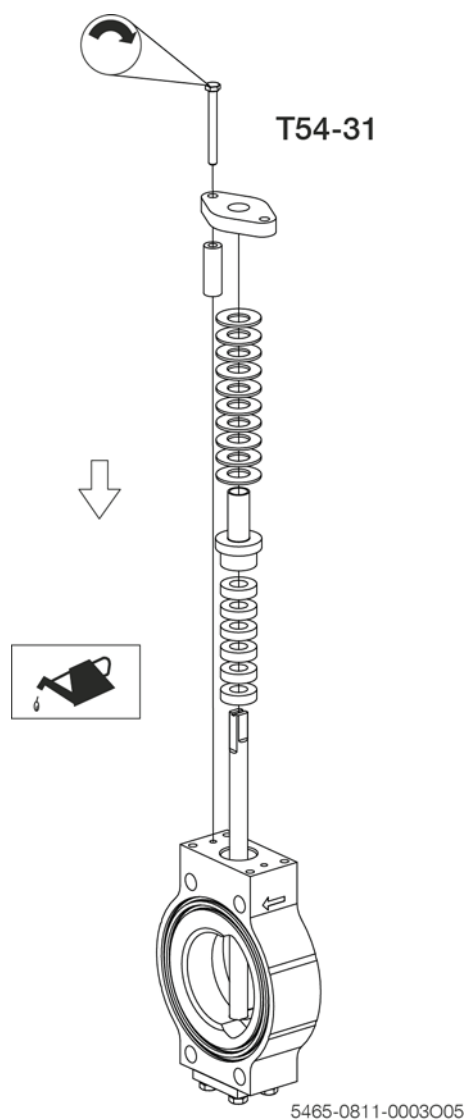
NOTICE

Lubricate the thrust disc and the bushing with grease containing graphite before assembly.

Mount the disc spring.

Mount the distance pipes, the flange and the screws.

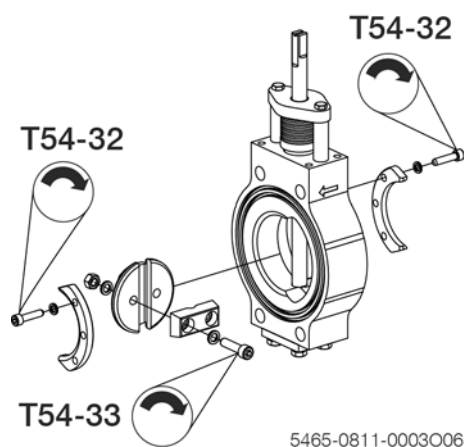
Gradually tighten the screws according to *data*.



7. Valve seat and flaps Mount the valve seats and the screws.

Tighten the screws as stated in *data*.

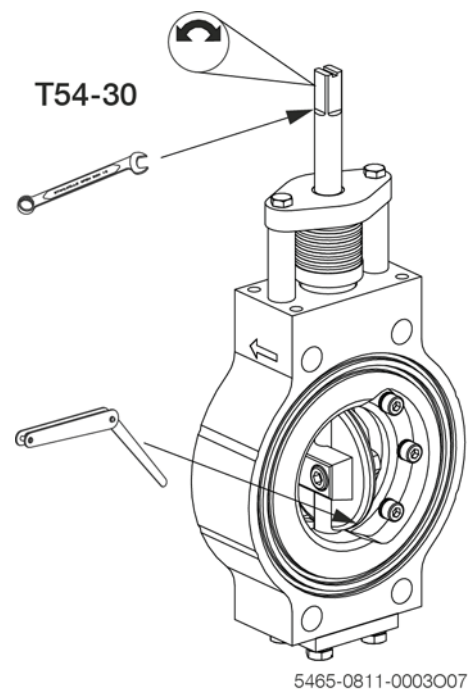
Mount the valve flaps, camlock washers, screws and nuts. Tighten the bolts to the torque stated in *data*.



8. Remove the valve

Activate the valve 50 times by turning the square spindle end with a spanner. This seats the seals.

Check the torque necessary to turn the valve. If *data* is exceeded, the cause should be found and immediate action taken.

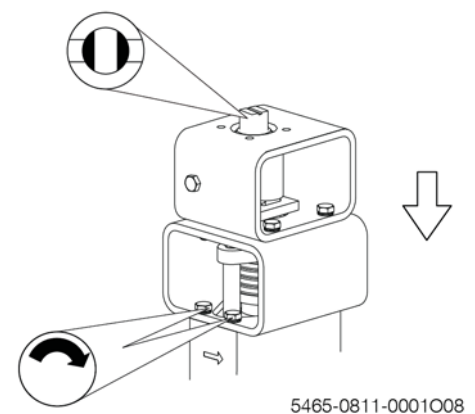


9. Spindle extension

Close the valve.

Mount the bracket.

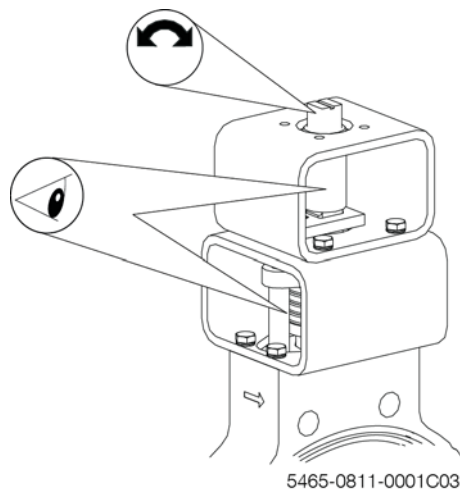
Mount the spindle extension.



1. Check before installation

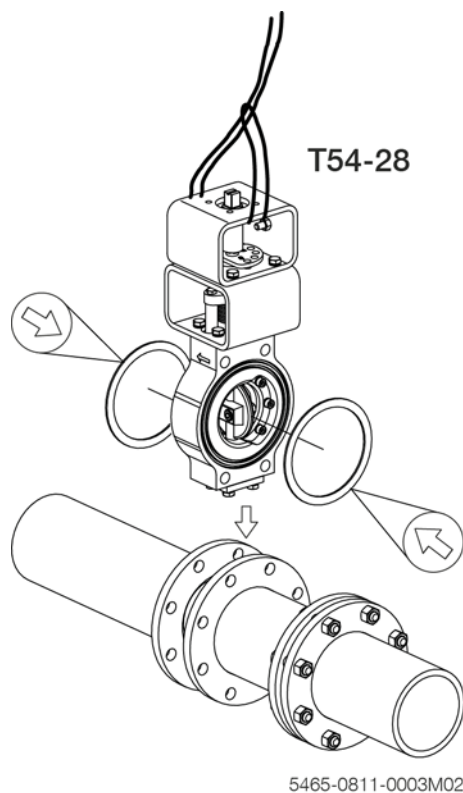
Check that the valve opens and closes smoothly; if not, the cause should be found and remedied.

Make sure that the valve is in the **closed** position.



2. Installation

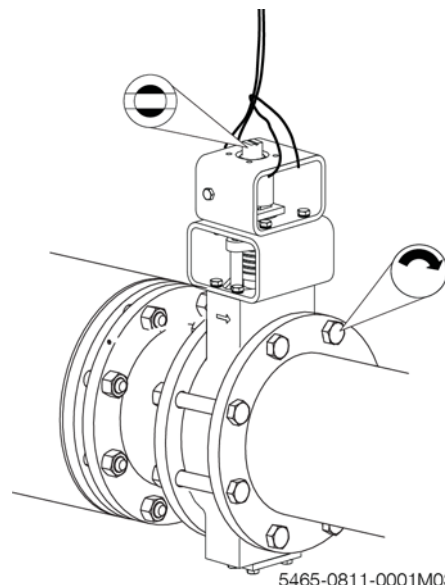
Lift the valve and install it in the exact same position as when removed (use the punch marks as reference). Mount new gaskets on the flanges.



3. Tighten the valve bolts

Mount and tighten all the flange bolts.

Open the valve.

**4. Final mounting**

Mount the actuator.

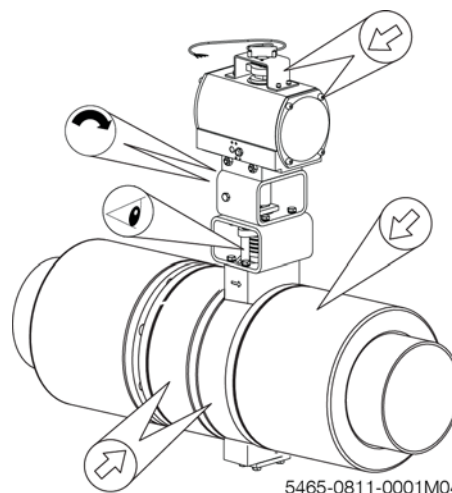
Mount and tighten the actuator screws.

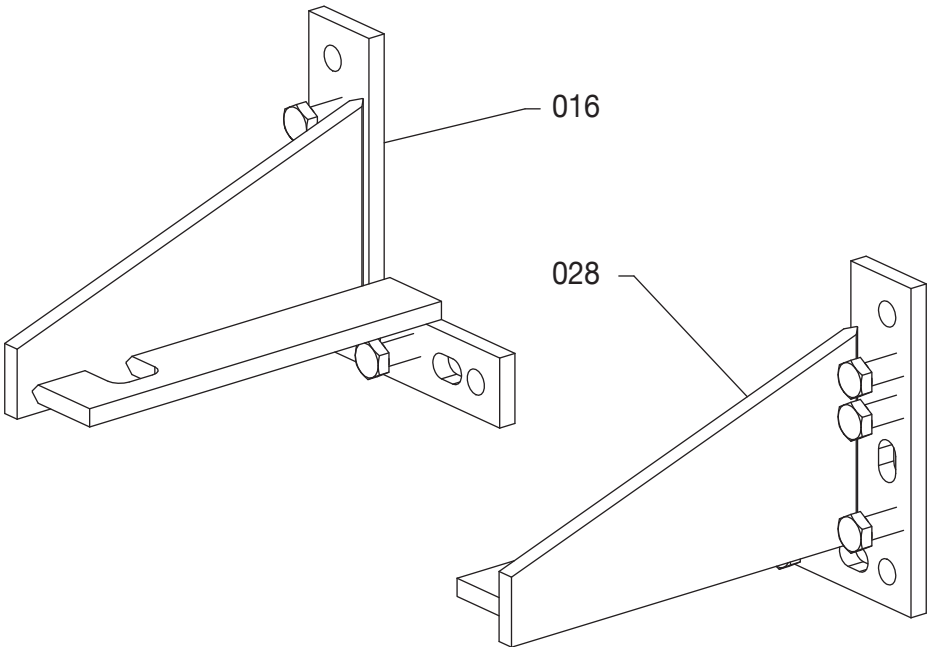
Connect the air supply.

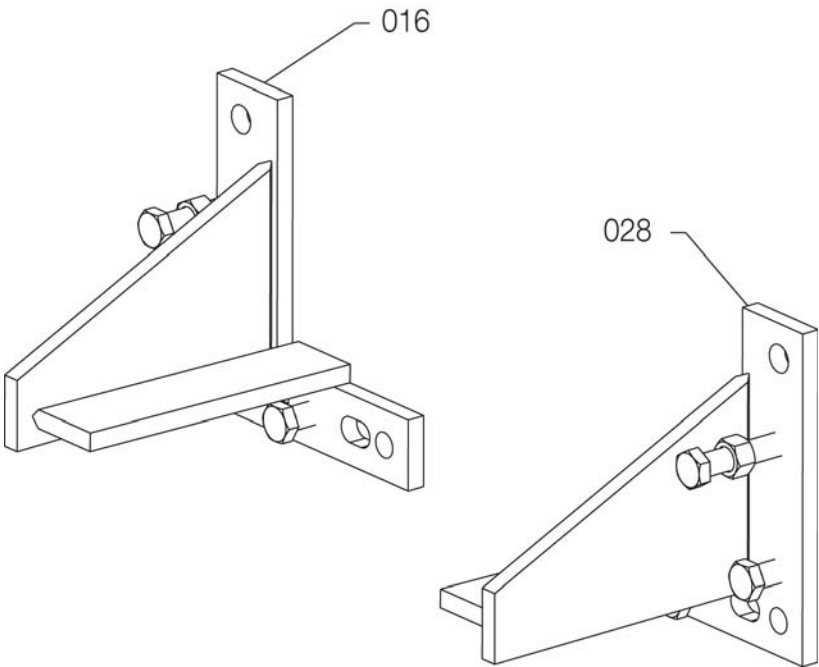
Mount position sensor.

Check that the actuator opens and closes the valve smoothly and properly by looking at the spindle operation.

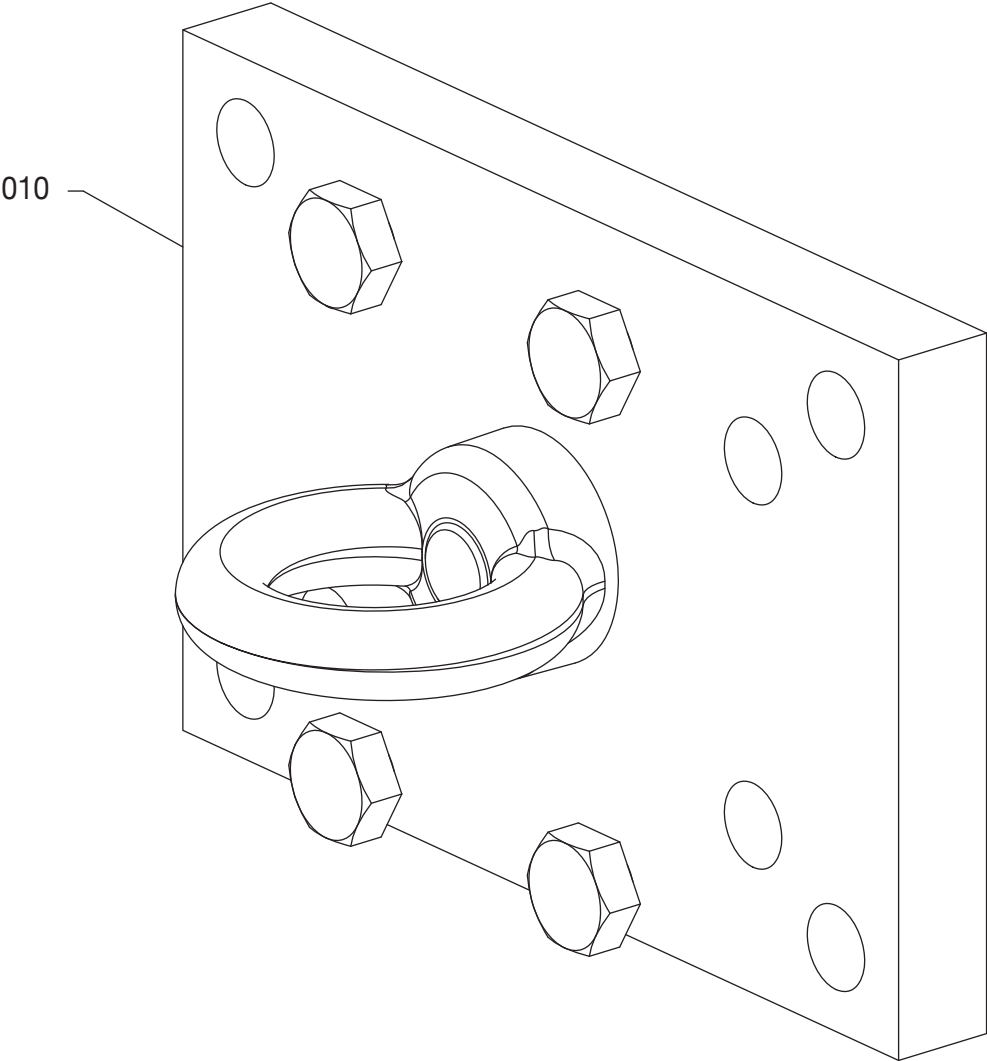
Mount the insulation.







[illegible]



Scavenge Air Cooler Lifting Tools

Plate

5470-0120-0001.0

[illegible]

Preface Chapter

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Drawing

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Performance

This chapter of the instruction book is intended to provide the user with comprehensive information regarding the performance of the engine. Information includes recording, calculation and evaluation of the performance.

TESTBED DATA (ME)	Engine Type:	Water Brake:	No.:	Constant, K:	kW/Kg.RPM											
	Engine Builder:	Engine No.:	Yard:													
Layout kW:	Layout RPM:	Engine Mode:	Sign.:	Test No.:												
Turbocharger(s)	No. of TC:	Serial No.	No. of Cyl.:	Bore, m:	Stroke, m:											
Make:	Type:	1	Cylinder Constant (kW, bar):		Mean Friction Press., bar:											
Max. RPM:	Max. Temp., °C:	2	Lubrication Oil System (Tick box) ☐ Internal ☐ External from M. E. System ☐ External from Gravity Tank													
Compr. Slip Factor:	Compr. Diam., m:	3														
TC specification:		4														
Observation No:																
Fuel Oil Viscosity:	at: °C		Brand		Type											
Bunker Station:			Cylinder Oil													
Oil Brand:	Heat value, kJ/kg:		Circulating Oil													
Density kg/m³, at: °C	Sulphur, %:		Turbo Oil													
Test Date (yyyy-mm-dd)	Test Hour (hh:mm)	Load %	Ambient Pressure mbar	Water Brake Load Kg	Engine RPM	Fuel Index ECU %	Speed Setting RPM									
Effective Power kW	Indicated Power kW	Eff. Fuel Consumption g/kWh	Indicated Fuel Consumption g/kWh	MOP Estimated Engine Load %	MOP Pmax bar	MOP Pcomp bar	MOP Pcomp/Pscav									
Cylinder No.	All	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Ave.
Pi, bar																
Pmax, bar																
Ref. Pmax, bar																
Pcomp, bar																
High Load Offset, %																
Low Load Offset, %																
Fuel Quality Adjust. (FQA), %																
Pmax Offset, bar																
Pcomp Ratio (Pcomp/Pscav)																
Exh. Valve Open Timing, °CA (Correction value)																
Exhaust Gas Temp., °C																
Cool. Water Outlet Temp., °C																
Piston Outlet Lub. Temp., °C																
Cooling Water Temperature, °C		Exhaust Gas Temp., °C		Exhaust Pressure		Turbo Charger	Aux. Blower	Scavenge Air Pressure								
Air Cooler		Main Engine		Turbine				Receiver	Turb. Outl.	▲p Filter	▲p Cooler	Receiver				
Inlet	Outlet	Inlet	Turb. Outlet	Inlet	Outlet	bar	mmWC	RPM	On/Off	mmWc	mmWc	bar				
1	1	1	1	1	1	1	1	1	1	1	1	1				
2	2	Seaw. Temp.	2	2	2	Variable XBP Actual, %	2	2	Axial Vibration	2	2	Pscav Set Point				
3	3		3	3	3	Variable XBP Set Point, %	3	3	mm	3	3	bar				
4	4		4	4	4		4	4		4	4					
Ave.	Ave.		Ave.	Ave.	Ave.		Ave.	Ave.		Ave.	Ave.					
Scavenge Air Temperature, °C		Lubricating Oil		Fuel Oil Pressure		Hydraulic Pressure										
Scav. Air Temp.	Inlet Blower	Before Cooler	After Cooler	Pressure, bar	Temperature, °C		bar	bar								
	1	1	1	System Oil	TC Inlet / Blower end	TC Outlet / Turb. end	Before Filter	Before Filter								
	2	2	2	Cooling Oil	1	1	After Filter	After Filter								
	3	3	3	Turbine Oil	2	2	Temperature, °C	Main Pressure								
	4	4	4	Temperature, °C	3	3	Before Pumps	Swash Plate Position, %								
Ave.	Ave.	Ave.	Inlet Engine	4	4		1	2								
			Thrust Segment	Ave.	Ave.		3	4								

Remarks:

Rel. 2011-10-21

1 The Unified Technical File TF

MAN Diesel & Turbo introduced in connection with the IMO Legislation a "unified" Technical File (TF) for all MAN B&W Low Speed Propulsion engines, as a template for all MAN Diesel & Turbo licensees. The goal is that all MAN B&W customers experience the same type of TF onboard.

The TF is a Flag State approved document that describes the certified engine and explains how the engine needs to be surveyed onboard to stay in compliance with the IMO regulation.

A booklet that explains the unified TF for Tier I engines has been issued.
See "A guideline to the Unified Technical File".

2 Engine group definition

The TF describes engine particulars and engine group information:

- Performance references & tolerances
- NO_x components
- Summary of engine performance & setting values, including emission data from testing of the "parent" engine
(See Chapter 1 to 4 of the Technical File)

3 MAN Diesel & Turbo survey procedure

Onboard, the 'onboard' survey method defined in the engine TF, shall be used for future surveys. *(Provided that the required IMO certificates have been issued based on the engine 'pre-certification' and 'initial' surveys.)*

The standard two-stroke MAN Diesel & Turbo *onboard* survey method (see flow chart *item 3.4*) is defined as a combination of performance parameter checks, and component and setting verification. The extend of the component and setting verification depends on different conditions, but, in general, can be reduced to the fuel nozzle, if the performance data are within the specified tolerances given in TF Table 2.1 and no component changes have been made to the engine.

The necessary performance parameters and corrections are specified in Appendix A of the TF. A description with step-by-step procedures of the actual survey is presented in TF Appendix A.

Onboard, the 'onboard survey' method checks with a minimum of component and adjustment verifications in order not to stop and dismantle the engine. The more extended component and setting adjustment verification can be used, when the engine is apart. Since a performance check can not be performed in dock, the 'missing' setting values are based on recorded data obtained within (a recommended) one-month period from a called (or anticipated) survey. *However, it is strongly recommended to perform a performance check to verify the setting values soonest possible after the docking to ensure continuing compliance.*

The parameter check method defined through the survey code accounts the influence of certain parameters, only. Through the cylinder pressure: adjustments of injection timing, compression shims and exhaust-valve timing, through the scavenge air temperature: a deteriorated scavenge air cooler performance, and through the back pressure: eventually blocking up of the exhaust heat exchanger.

3.1 Onboard survey code

The onboard survey (parameter check) can be performed using the survey code supplied by the manufacturer. If a computer is not available, a manual evaluation can be performed following Appendix A 2.3 & 2.4. The procedure is based on a 'standard MAN Diesel & Turbo performance check'.

Two versions of the code exist. The 'onboard' version is used as the standard survey method onboard. And, the 'test-bed' version, a more detailed version, is used to show compliance on test bed for member engines. The onboard version differs slightly for a sea-water and a central cooling-water system.

To perform the survey, the following steps are to be taken (see flow chart *item 3.4*) independent of the survey-code version:

1. Inspect NO_x components listed in TF and record book
2. Check fuel valve nozzle compliance and ECS, check sums
3. Check remaining NO_x components for compliance (as considered necessary)
4. Register the reference performance parameters
5. Measure ambient performance parameters
6. Calculate ISO corrected maximum combustion and compression pressure
7. Calculate maximum allowed scavenge air temperature

The Tables in Appendix A show input and output from the survey code, based on the parent engine test-bed data, as an example.

3.2 Manual procedure

All the steps in the flow chart (*item 3.4*) must be followed.

To evaluate manually the NO_x compliance, calculate the performance data (corrected to ISO reference ambient conditions) in A2.3 and the cooling water corrected scavenge air temperature in A2.4.

(All these assumptions have been built into the MAN Diesel & Turbo survey code for automatic evaluation).

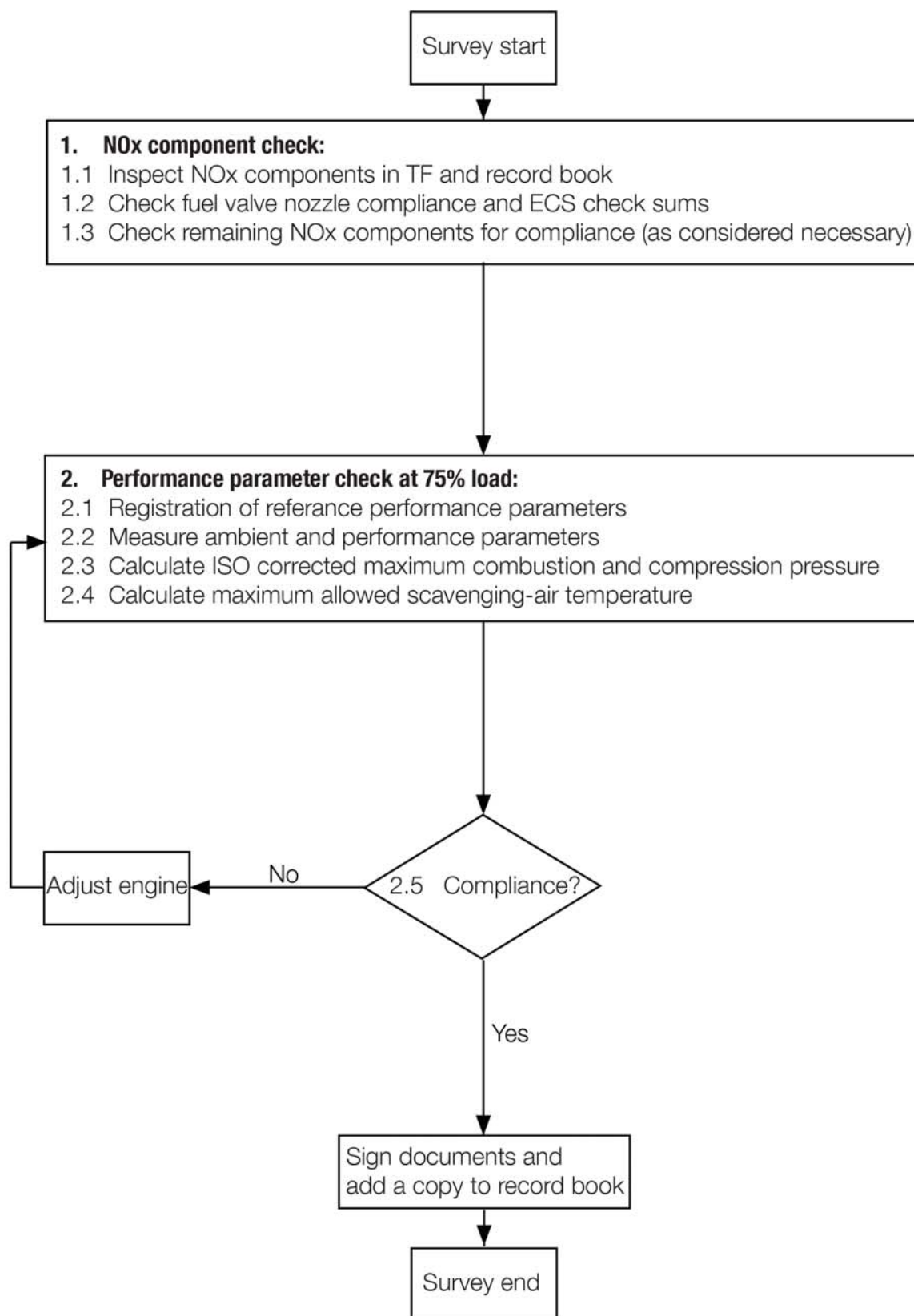
3.3 Comments on component checks

The actual NO_x components are specified in TF Chapter 2.2 and TF Chapter 5.3 + 5.4 specifies the necessary verification procedures. The extend of the component verification is discussed above.

To verify the setting values, a performance check has to be performed using the onboard survey code. When the specified performance data (see TF Table 2.1) corrected to ISO ambient conditions are within the given tolerances, the setting adjustments are within compliance.

For spare part changes (only components as listed in TF Table 2.2 are allowed) a review of the record book would normally be sufficient. Although a standard performance check will reveal changes to many NO_x components, a new combustion chamber or a new fuel nozzle may not be discovered. (The fuel nozzle is the most important component to affect the NO_x emission from an engine.) Therefore, a review of the record book is necessary as a starting point for the survey, and a fuel nozzle should be inspected.

3.4 Flow Chart for Survey Methods



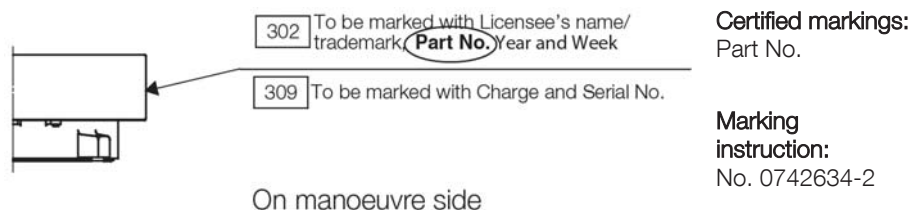
4 Check of IMO-ID, Markings on Components

The components described in the following have been marked with unambiguous identification numbers to enable the relevant drawing and certificate to be traced. The schematic drawings show where to find the markings on the individual component types.

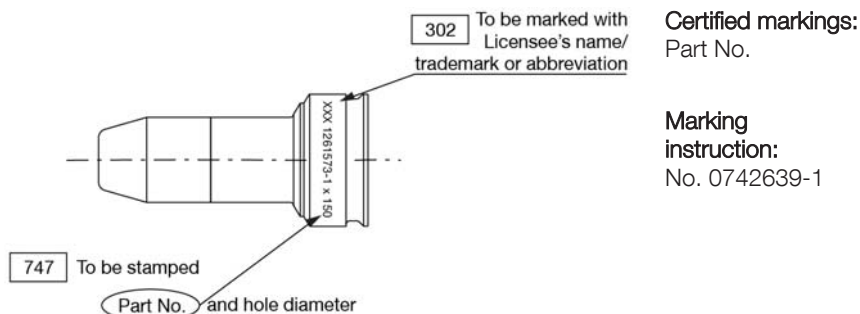
The circled part  of the number is the only part of the entire number that is to be defined as the "IMO number". The component marking may include a revision reference nnnnnnn-n.n, however, that reference is not part of the defining marking and should be ignored.

See also Production Specification No. 0742980-3 regarding marks and stamps on components for MAN Diesel & Turbo two-stroke diesel engines.

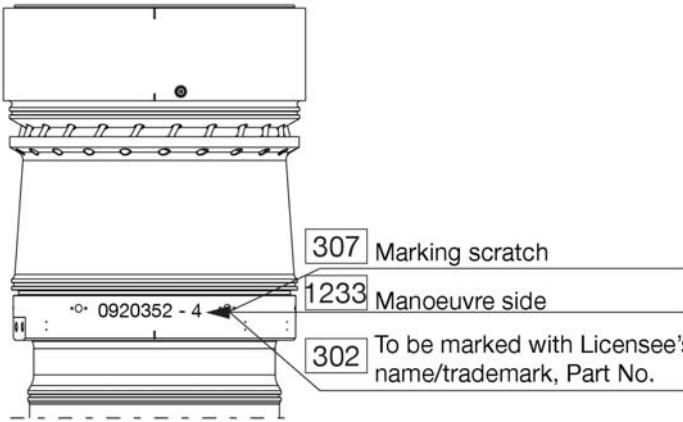
4.1 Cylinder Cover



4.2 Fuel Valve Nozzle



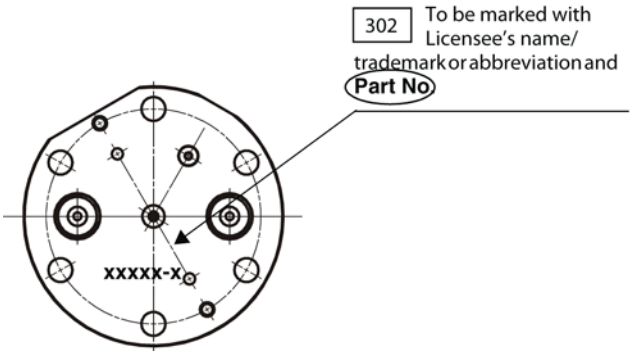
4.3 Cylinder Liner



Certified markings:
Part No.

Marking instruction:
No. 0742637-8

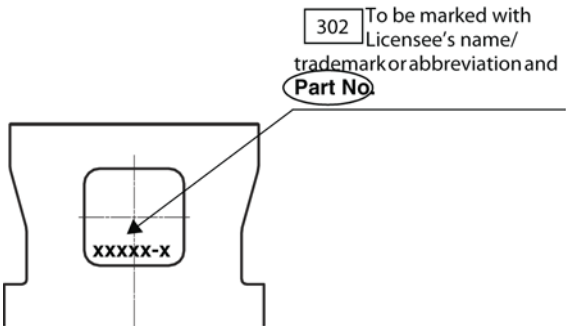
4.4 Pressure booster Top Cover



Certified markings:
Part No.

Marking instruction:
No. 0742962-4

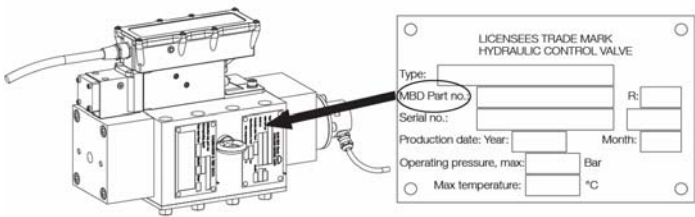
4.5 Hydraulic Piston Housing



Certified markings:
Part No.

Marking instruction:
No. 0742960-0.1

4.6 Multi-Way-Valve



Certified markings:
Part No.

Marking instruction:
No. 0743505-4

4.7 Piston Crown



Certified markings:
Part No.

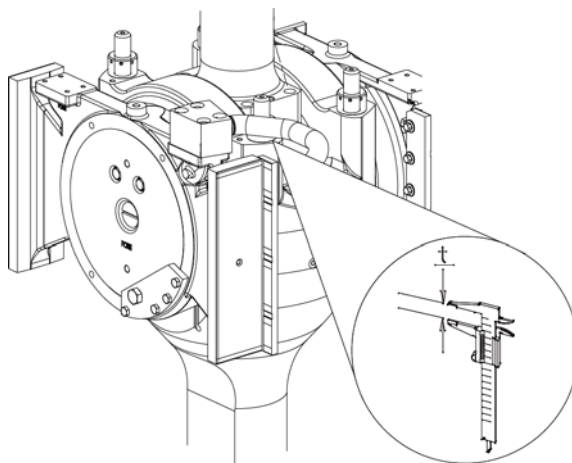
Marking
instruction:
No. 0742392-0

5 Performance adjustment (setting values)

5.1 Shims

Checking the shim thickness, t (compression volume)

Turn the crankthrow towards the exhaust side, to provide access for measuring the thickness of the shim which is inserted between piston rod and crosshead pin.



1 Symbols and Units

The following designations are used:

Parameter	Symbol	Unit
Effective engine power	P_e	kW
Engine speed	speed	r/min
Indicated engine power	P_i	ikW
Fuel pump index	Index	%
Specific fuel oil consumption	SFOC	g/kWh
Fuel oil lower calorific value	LCV	kJ/kg
Turbocharger speed	T/C speed	r/min
Barometric pressure	p_{baro}	mbar
Pressure drop across T/C air filters	Δp_f	mbar
Pressure drop across air cooler	Δp_c	mbar
Scavenge air pressure	p_{scav}	bar
Mean indicated pressure	p_i	bar
Mean effective pressure	p_e	bar
Compression pressure	p_{comp}	bar
Maximum combustion pressure	p_{max}	bar
Exhaust receiver pressure	p_{exhrec}	bar
Pressure after turbine	p_{atc}	mbar
Air temperature before T/C filters	t_{ini}	°C
Air temperature before cooler	t_{bcoo}	°C
Cooling water inlet temp., air cooler	t_{coolinl}	°C
Cooling water outlet temp., air cooler	t_{coolout}	°C
Scavenge air temperature	t_{scav}	°C
Temperature after exhaust valve	t_{exhv}	°C
Temperature before turbine	t_{btc}	°C
Temperature after turbine	t_{atc}	°C

1.1 Conversion factors

1 hp	= 0.736	[J/s]
1 bar = 10 ⁵ Pa	= 1000 hPa or 0.1 MPa	/ [N/m ²]
1 mbar	= 0.001 bar or 1.0	[hPa]
1 kg/cm ²	= 0.981 bar or 980.7	[hPa]
1 kp/cm ²	= 0.981 bar or 980.7	[hPa]
1 psi	= 0.070 bar or 68.9	[hPa]
1 mmHg	= 0.001 bar or 1.3	[hPa]
1 mWC	= 0.098 bar or 98.1	[hPa]

$$\pi = 3.14159$$

NOTICE

Pressure stated in bar (or Pa) is the measured value, i.e. read from an ordinary pressure gauge.

Note: the official designation of bar (or Pa) is Absolute Pressure

2 Operating Range

2.1 Load Diagram

The specific ranges for continuous operation are given in the 'Load Diagrams':

- For propulsion alone
See drawing 6355-0100.
- For propulsion and main engine driven generator
See drawing 6355-0105.

Specific engine calculations (load diagrams) can be ordered by contacting MAN Diesel & Turbo.

2.2 Definitions

The load diagram, in logarithmic scales (*see drawing 6355-0100 and/or drawing 6355-0105*) defines the power and speed limits for continuous as well as overload operation of an installed engine having a specified MCR (Maximum Continuous Rating) point 'M' according to the ship's specification.

The service points of the installed engine incorporate the engine power required for ship propulsion, *see drawing 6355-0100*, and for main engine driven shaft generator, if installed, *see drawing 6355-0105*.

2.3 Limits for Continuous Operation

The continuous service range is limited by four lines:

- Line 3:** Represents the maximum speed which can be accepted for continuous operation.
Running at low load above 100% of the nominal speed of the engine is, however, to be avoided for extended periods.
- Line 4:** Represents the limit at which an ample air supply is available for combustion and gives a limitation on the maximum combination of torque and speed.
- Line 5:** Represents the maximum mean effective pressure (mep) level, which can be accepted for continuous operation.
- Line 7:** Represents the maximum power line for continuous operation.

2.4 Limits for Overload Operation

Many parameters influence the performance of the engine. Among these is: overloading. The overload service range is limited as follows:

- Line 8:** Represents the overload operation limitations.

The area between lines 4, 5, 7 and the heavy dotted line 8 is available as overload for limited periods only (1 hour per 12 hours).

2.5 Recommendations

Continuous operation without limitations is allowed only within the area limited by lines 4, 5, 7 and 3 of the load diagram.

The area between lines 4 and 1 is available for running conditions in shallow water, heavy weather and during acceleration, i.e. for non-steady operation without actual time limitation.

After some time in operation, the ship's hull and propeller will be fouled, resulting in heavier running of the propeller, i.e. loading the engine more. The propeller curve will move to the left from line 6 to line 2 and extra power is required for propulsion. The extent of heavy running of the propeller will indicate the need for cleaning the hull and possibly polishing the propeller.

NOTICE

Point A is a 100% speed and power reference point of the load diagram. Point M is normally equal to point A but may in special cases, for example sometimes when a shaft generator is installed, be placed to the right of point A on line 7.

2.6 Propeller Performance

Experience indicates that ships are – to a greater or lesser degree – sensitive to bad weather (especially with heavy waves, and with head winds and seas), sailing in shallow water with high speeds and during acceleration. It is advisable to notice the power/speed combination in the load diagram and to take precautions when approaching the limiting lines.

3 Performance Observations

3.1 General

During engine operation, several basic parameters need to be checked and evaluated at regular intervals.

The purpose is to follow alterations in:

- the combustion conditions,
- the general cylinder condition,
- the general engine condition

in order to discover any operational disturbances.

This enables the necessary precautions to be taken at an early stage, to prevent the further development of trouble.

This procedure will ensure optimum mechanical condition of the engine components, and optimum overall plant economy.

3.2 Key Parameters

The key parameters in performance observations are:

- Barometric pressure
- Engine speed
- Ship's draught
- Mean indicated pressure
- Compression pressure
- Maximum combustion pressure
- Fuel pump index
- Exhaust gas pressures
- Exhaust gas temperatures
- Scavenge air pressure
- Scavenge air temperature
- Turbocharger speed
- Exhaust gas back pressure in exhaust pipe after turbocharger
- Air temperature before T/C filters
- Δp air filter (if pressure gauge installed)
- Δp air cooler
- Air and cooling water temperatures before and after scavenge air cooler.

3.3 Measuring Instruments

The measuring instruments for performance observations comprise:

- Thermometers,
- Pressure gauges,
- Tachometers,
- PMI – On/Off-line Cylinder pressure measuring equipment
- Eventually the engine diagnosis system CoCos-EDS or similar

It is important to check the measuring instruments for correct functioning.

Regarding check of thermometers and pressure gauges:
See description 6345-0330.

3.4 Intervals between Checks

Constantly:	Temperature and pressure data should be constantly monitored, in order to protect the engine against overheating and failure. In general, automatic alarms and slow-down or shut-down equipment are installed for safety. Guiding values of permissible deviations from the normal service data are given in <i>description 7045-0100</i>.
Daily:	Fill-in the Performance Observation record. <i>See drawing 6355-0110.</i>
Every two weeks:	Take "Pressure Volume (P/V)" diagrams and fill in the complete Performance Observations record. <i>See drawing 6355-0110.</i>

3.5 Evaluation of Observations

Compare the observations to earlier observations and to the testbed / sea trial results.

From the trends, determine when cleaning, adjustment and overhaul should be carried out.

See description 7045-0100, regarding normal service values and alarm limits.

Not all parameters can be evaluated individually. This is because a change of one parameter can influence another parameter. For this reason, these parameters must be compared to the influencing parameters to ensure correct evaluations.

A simple method for evaluation of these parameters is presented in *description 6345-0310*.

1 General

Record the performance observations as described in the previous *description 6345-0300..*

Use the synopsis diagrams to obtain the best and most simple method of plotting and evaluating the parameters:

Engine: *See drawings: 6355-0120, 6355-0125 & 6355-0130*

Turbocharger: *See drawings: 6355-0135 & 6355-0140*

Air cooler: *See drawing: 6355-0145*

Drawings 6355-0120, 6355-0125 & 6355-0130 are sufficient to give a general impression of the overall engine condition.

The drawings comprise:

Model curve: shows the parameter as a function of the parameter on which it is most dependent (based on the testbed/commissioning test results).

Time based deviation curve: shows the deviation between the actual service observations and the model curve, as a function of time. The limits for max. recommended deviation is also shown. The limits are based on the MAN Diesel & Turbo CAPAsystem. (Computer Aided Performance Analysis).

From the deviation curves, it is possible to determine what engine components should be overhauled.

From the slope of the curves, it can be determined approximately when the overhaul should be carried out.

Blank sheets: Blank 'Time based deviation' sheets which can be copied. Use these sheets for plotting the deviation values for the specific engine.

The following items describe the evaluation of each parameter in detail.

2 Engine Synopsis

A 6G70ME-C has been used in these examples.

2.1 Parameters related to the Mean Indicated Pressure (p_i)

Drawing 6355-0120 and drawing 6355-0125 (engine synopsis diagrams) show model curves for engine parameters which are dependent upon the mean indicated pressure (p_i).

NOTICE

Drawing 6355-0120 also includes two charts for plotting the draught of the ship, and the average mean indicated pressure as a function of the engine running hours.

For calculation of the mean indicated pressure:
See description 6345-0340.

2.1.1 Mean Draught

The mean draught is depicted here because, for any particular engine speed, it will have an influence on the engine load.

2.1.2 Mean indicated Pressure (p_i)

The average calculated value of the mean indicated pressure is depicted in order that an impression of the engine's load can be obtained.

Load balance: the mean indicated pressure for each cylinder should not deviate more than 0.5 bar from the average value for all cylinders.

NOTICE

The load balance must not be adjusted on the basis of the exhaust gas temperatures after each exhaust valve.

It is recommended to apply PMI-system for easy access to P-V-diagrams (work diagram), if the indicator drive is not installed.

2.1.3 Engine Speed (p_i)

The model curve shows the relationship between the engine speed and the average mean indicated pressure (p_i).

The engine speed should be determined by counting the revolutions over a sufficiently long period of time.

Deviations from the model curve show whether the propeller is light or heavy, i.e. whether the torque on the propeller is small or large for a specified speed. If this is compared with the draught (under the same weather conditions), *see remarks in description 6345-0300*, then it is possible to judge whether the alterations are owing to:

- changes in the draught,
- or an increase in the propulsion resistance, for instance due to fouling of the hull, shallow water, etc.

Valuable information is hereby obtained for determining a suitable docking schedule.

If the deviation from the model curve is large, (e.g. deviations from shop trial to sea trial), it is recommended to plot the results on the load diagram, *see description 6345-0300*, and from that judge the necessity of making alterations on the engine, or to the propeller.

2.1.4 Maximum Combustion Pressure ($p_{\max}$ - p_i)

The model curve shows the relationship between the average $p_{\max}$ (corrected to ISO reference ambient conditions) and the average p_i .

NOTICE

For correction to reference conditions:
See description 6345-0350.

Deviations from the model curve are to be compared with deviations in the compression pressure and the fuel index (*see further on*).

Constant $p_{\max}$ in the upper load range is achieved by a combination of fuel injection timing and variation of the compression ratio (the latter by varying the timing of closing the exhaust valve).

If an individual $p_{\max}$ value deviates more than 3 bar from the average value, the reason should be found and the fault corrected.

The pressure rise $p_{\max} - p_{\text{comp}}$ must not exceed the specified limit, i.e. 40 bar.

2.1.5 Fuel Index (p_i)

The model curve shows the relationship between the average index and the average p_i .

Deviations from the model curve give information on the condition of the fuel injection equipment.

Worn fuel pumps, and leaking suction valves, will show up as an increased fuel index in relation to the mean pressure. Note, however, that the fuel index is also dependent on:

- The viscosity of the fuel oil, (i.e. the viscosity at the preheating temperature) Low viscosity will cause larger leakages in the fuel pump, and thereby necessitate higher indexes for injecting the same volume.
- The calorific value and the specific gravity of the fuel oil. These will determine the energy content per unit volume, and can therefore also influence the index.
- All parameters that affect the fuel oil consumption (ambient conditions, $p_{\max}$, etc.)

Since there are many parameters that influence the index, and thereby also the $p_{\max}$, it can be necessary to adjust the $p_{\max}$ from time to time.

It is recommended to overhaul (including change of plunger/barrell), the fuel pumps when the index has increased by about 10%.

In case the engine is operating with excessively worn fuel pumps, the starting performance of the engine will be seriously affected.

2.2 Parameters related to the Effective Engine Power (P_e)

Drawing 6355-0130 shows model curves for engine parameters which are dependent on the effective power (P_e).

Regarding the calculation of effective engine power:
See description 6345-0340.

It is recommended to apply PMI-system for easy access to P-V-diagrams (work diagrams) and thereby the effective engine power.

2.2.1 Exhaust Temperature (t_{exhv} - P_e)

The model curve shows the average exhaust temperatures (after the valves), corrected to reference conditions, and drawn up as a function of the effective engine power (P_e).

NOTICE

For correction to ISO reference ambient conditions:
See description 6345-0350.

Regarding maximum exhaust temperatures:
See description 6345-0350.

The exhaust temperature is an important parameter, because the majority of faults in the air supply, combustion and gas systems manifest themselves as increases in the exhaust temperature level.

The most important parameters which influence the exhaust temperature are listed in the table on the next page, together with a method for direct diagnosing, where possible.

Increased Exhaust Temperature Level – Fault Diagnosing

Possible Causes	Diagnosing
a. Fuel injection equipment: - Leaking or incorrectly working fuel valves (defective spindle and seat) - Worn fuel pumps. If a high wear rate occurs, the cause for this must be found and remedied. Note: Inadequate cleaning of the fuel oil can cause defective fuel valves and worn fuel pumps.	As these faults occur in individual cylinders, compare: - fuel indexes - PMI readings <i>See description 6345-0340.</i> Check the fuel valves: - visually - by pressure testing
b. Cylinder condition: - Blow-by, piston rings <i>See description 6645-0140, Running Difficulties', point 6.</i> - Leaking exhaust valves <i>See description 6645-0140, Running Difficulties', point 5.</i>	These faults occur in individual cylinders. - Compare the compression pressures with PMI. <i>See description 6345-0340.</i> - During engine standstill: Carry out scavenge port inspection. Check the exhaust valves. <i>See description 2245-0100.</i>
c. Air coolers: - Fouled air side - Fouled water side	Check the cooling capability. <i>See description 6345-0310.</i>
d. Climatic conditions: Extreme conditions	Check cooling water and engine room temperatures. Correct t_{exhv} to reference conditions. <i>See description 6345-0350.</i>
e. Turbocharger: - Fouling of turbine side - Fouling of compressor side	Use the turbocharger synopsis methods for diagnosing. <i>See description 6345-0310.</i>
f. Fuel oil: - Type - Quality	Using heavy fuel oil will normally increase t_{exhv} by approx. 15°C, compared to the use of gas oil. Further increase of t_{exhv} will occur when using fuel oils with particularly poor combustion properties. In this case, a reduction of p_{max} can also occur.

2.2.2 Compression Pressure (P_{comp} - P_e)

The model curve shows the relationship between the compression pressure p_{comp} (corrected to ISO reference ambient conditions) and the effective engine power P_e .

NOTICE

For correction to reference conditions:
see description 6345-0350.

Deviation from the model curve can be due to:

1. a scavenge air pressure reduction,
2. - mechanical defects in the engine components (blow-by past piston rings, defective exhaust valves, etc. – *see the table on the next page*)
- excessive grinding of valve spindle and bottom piece.

It is therefore expedient and useful to distinguish between '1' and '2', and investigate how large a part of a possible compression reduction is due to '1' or '2'.

This distinguishing is based on the ratio between absolute compression pressure ($p_{comp} + p_{baro}$) and absolute scav. pressure ($p_{scav} + p_{baro}$) which, for a specific engine, is constant over the largest part of the load range (load diagram area).

Constant p_{max} in the upper load range is achieved by a combination of fuel injection timing and variation of the compression ratio (the latter by varying the timing of closing the exhaust valve).

The ratio is first calculated for the "new" engine, either from the testbed results, or from the model curve.

See the example below regarding:

- Calculating the ratio
- Determining the influence of mechanical defects.

It should be noted that, the measured compression pressure, for the individual cylinders, can deviate from the average, owing to the natural consequence of air/gas vibrations in the receivers. The deviations will, to some degree, be dependent on the load.

However, such deviations will be "typical" for the particular engine, and should not change during the normal operation.

When evaluating service data for individual cylinders, comparison must be made with the original compression pressure of the cylinder concerned, at the corresponding load.

Example:

The following four values can be assumed read from the *model curves*:

The barometric pressure was:	1.00 bar
The scavenge pressure was:	2.25 bar
This gave an absolute scavenge pressure of:	3.25 bar
The average (or individual) compression pressure was:	115 bar
which gave an absolute compression pressure of $115 + 1.00 =$	116 bar

$$p_{\text{comp abs}} / p_{\text{scav abs}} = 116 / 3.25 = 35.7 \text{ bar}$$

This value is used as follows for evaluating the data read during service.

Service Values

p_{comp}	: 101 bar (average or individual)
p_{scav}	: 2.0 bar
p_{baro}	: 1.02 bar

Calculated on the basis of p_{scav} and p_{baro} , the absolute compression pressure would be expected to be:

$$p_{\text{comp abs}} = 35.7 \times (2.0 + 1.02) = 107.8 \text{ bar}$$

$$\text{i.e. } p_{\text{comp}} = 107.8 - 1.02 = 106.8 \text{ bar}$$

The difference between the expected 106.8 bar and the measured 101 bar could be owing to *mechanical defects or grinding of exhaust valve spindle and bottom piece*.

Concerning the pressure rise $p_{\text{comp}} - p_{\text{max}}$, see Item 2.1.4, 'Maximum Combustion Pressure ($p_{\text{max}} - p_i$)'.

Mechanical Defects which can influence the Compression Pressure

Possible Causes	Diagnosis / Remedy
a. Piston rings: ▪ Leaking	Diagnosis: <i>See Table Increased Exhaust Temperature Level – Fault Diagnosing</i> Remedy: <i>See description 6645-0140.</i>
b. Piston crown: ▪ Burnt	Check the piston crown by means of the template. <i>See work card 2265-0401.</i>
c. Cylinder liner ▪ Worn	Check the liner by means of the measuring tool. <i>See work card 2265-0601.</i>

Possible Causes	Diagnosis / Remedy
d. Exhaust valve: ▪ Leaking ▪ The exhaust temperature rises ▪ A hissing sound can possibly be heard at reduced load ▪ Timing.	Remedy: <i>See description 6645-0140.</i> Check: ▪ Cam lead (ME-B Only) ▪ Hydraulic oil leakages, e.g. misalignment of high pressure pipe between exhaust valve actuator and hydraulic cylinder ▪ Damper arrangement for exhaust valve closing.
e. Piston rod stuffing box: ▪ Leaking ▪ Air is emitted from the check funnel from the stuffing box.	Small leakages may occur due to erosion of the bronze segments of the stuffing box, but this is normally considered a cosmetic phenomenon. Remedy: Stuffing box overhaul. <i>See work card 2265-0501.</i>

3 Turbocharger Synopsis

See Drawings 6355-0135 and 6355-0140 (Turbocharger synopsis diagrams)

NOTICE

Drawing 6355-0135 and 6355-0140 should be filled out in a number of copies which corresponds to the number of turbochargers.

Regarding cleaning of the turbochargers.
See description 6345-0320.

3.1

3.1.1 Scavenge Air Pressure (p_{scav} – P_e)

The model curve shows the scavenge air pressure (corrected to reference conditions) as a function of the effective engine power (P_e).

See description 6345-0340 and 6345-0370 regarding the effective engine power.

NOTICE

For correction to ISO reference ambient conditions.
See description 6345-0350.



Deviations in the scavenge air pressure are, like the exhaust temperature, an important parameter for an overall estimation of the engine condition. A drop in the scavenge air pressure, for a given load, will cause an increase in the thermal loading of the combustion chamber components.

A simple diagnosis, made only from changes in scavenge air pressure, is difficult.

Fouled air filter, air coolers and turbochargers can greatly influence the scavenge air pressure.

Changes in the scavenge air pressure should thus be seen as a “consequential effect” which is closely connected with changes in:

- the air cooler condition
- the turbocharger condition
- the timing.

Reference is therefore made to the various sections covering these topics.

3.1.2 Turbocharger Speed (T/C speed – pscav)

The model curve shows the speed of the turbocharger as a function of the scavenge air pressure (p_{scav}).

Corroded nozzle ring or turbine blades will reduce the turbine speed. The same thing will happen in case of a too large clearance between the turbine blades and the shroud ring (MAN Diesel & Turbo) / cover ring ABB).

Deviation from the model curve, in the form of too high speed, can normally be attributed to a fouled air filter, scavenge air cooler, turbine side or compressor side.

A more thorough diagnosing of the turbocharger condition can be made as outlined in the ‘turbocharger efficiency’ section below.

3.1.3 Pressure Drop across Turbocharger Air Filter (Δp_f – pscav)

The model curve shows the pressure drop across the air filter as a function of the scavenge air pressure (p_{scav}).

Deviations from this curve give direct information about the cleanliness of the air filter.

Like the air cooler, the filter condition is decisive for the scavenge air pressure and exhaust temperature levels.

The filter elements must be cleaned when the pressure drop is 50% higher than the testbed value.

If a manometer is not standard, the cleaning interval is determined by visual inspection.

3.1.4 Turbocharger Efficiency ($\eta_{T/C}$)

The model curves show the compressor and turbine efficiencies as a function of the scavenge air pressure (p_{scav}).

In order to determine the condition of the turbocharger, the calculated efficiency values are compared with the model curves, and the deviations plotted.

Calculation of the efficiency is explained in *description 6345-0360*.

As the efficiencies have a great influence on the exhaust temperature, the condition of the turbocharger should be checked if the exhaust temperature tends to increase up to the prescribed limit.

Efficiency reductions can normally be related to "flow deterioration", which can be counteracted by regular cleaning of the turbine side (and possibly compressor side).

4 Air Cooler Synopsis

The Drawing 6355-0145 (Air cooler synopsis diagrams)

The plate gives model curves for air cooler parameters, which are dependent on the scavenge air pressure (p_{scav}). Regarding cleaning of air coolers.

See description 6345-0320.

4.1

4.1.1 Temperature Difference between Air Outlet and Water Inlet ($\Delta t(\text{air-water}) - p_{scav}$)

The model curve shows the temperature difference between the air outlet and the cooling water inlet, as a function of the scavenge air pressure (p_{scav}).

This difference in temperature is a direct measure of the cooling ability, and as such an important parameter for the thermal load on the engine. The evaluation of this parameter is further discussed in Item 4.1, 'Evaluation'.

4.1.2 Cooling Water Temperature Difference ($\Delta t_{water} - p_{scav}$)

The model curve shows the cooling water temperature increase across the air cooler, as a function of the scavenge air pressure (p_{scav}).

This parameter is evaluated as indicated in Item 4.1.

4.1.3 Pressure Drop across Air Cooler ($\Delta p_{air} - p_{scav}$)

The model curve shows the scavenge air pressure drop across the air cooler, as a function of the scavenge air pressure (p_{scav}).

This parameter is evaluated as indicated in Item 4.1, 'Evaluation'.

4.2 Evaluation

Generally, for the above three parameters, *changes of approx. 50% of the testbed value can be considered as a maximum*. However, the effect of the altered temperatures should be kept under observation in accordance with the remarks under Exhaust Temperature. (*Point 2.2 earlier in this Section*).

In the case of pressure drop across air cooler, for purposes of simplification, the mentioned "50% margin" includes deviations caused by alterations of the suction temperature, scavenge air temperature, and efficiency of the turbochargers.

Of the three parameters, *the temperature difference between air outlet and water inlet*, is to be regarded as the most essential one.

Deviations from the model curves, which are expressions of deteriorated cooling capability, can be due to:

1. Fouling of the air side
 2. Fouling of the water side
1. **Fouling of the air side:** manifests itself as *an increased pressure drop across the air side*.

Note however, that the heat transmission can also be influenced by an "oily film" on tubes and fins, and this will only give a minor increase in the pressure drop.

Before cleaning the air side, it is recommended that the U-tube manometer is checked for tightness, and that the cooler is visually inspected for deposits.

Make sure that the drainage system from the water mist catcher functions properly, as a high level of condensed water (condensate) – up to the lower measuring pipe – might greatly influence the Δp measuring.
See descripton 6345-0320.

2. **Fouling of the water side:** Normally involves *a reduction of the cooling water temperature difference*, because the heat transmission (cooling ability) is reduced.

Note however that, if the deposits reduce the cross sectional area of the tubes, so that the water quantity is reduced, the cooling water temperature difference may not be affected, whereby diagnosis is difficult (i.e. lower heat transmission, but also lower flow volume).

Furthermore, a similar situation will arise if such tube deposits are present simultaneously with a fault in the salt water system, (corroded water pump, erroneous operation of valves, etc.). Here again the reduced water quantity will result in the temperature difference remaining approximately unaltered.

In cases where it is suspected that the air cooler water side is obstructed, the resistance across the cooler can be checked by means of a differential pressure gauge.



A mercury manometer pressure gauge should not be used, because of environmental considerations.

Before dismantling the air cooler, for piercing of the tubes, it is recommended that the remaining raw water system is examined, and the cooling ability of the other heat exchangers checked.



Be careful when piercing, because the pipes are thin-walled.

5 Specific Fuel Oil Consumption

Calculation of the specific fuel oil consumption (g/kWh) requires that engine power, and the consumed fuel oil amount (kg), are known for a certain period of time.

See drawing 6355-0150.

The method of determining the engine power is illustrated in *description 6345-0340*.

The oil amount is measured as described below.

To achieve a reasonable measuring accuracy, it is recommended to measure over a suitably long period – dependent upon the method employed i.e.:

- If a day tank is used, the time for the consumption of the whole tank contents will be suitable.
- If a flow-meter is used, a minimum of 1 hour is recommended.

The measurements should always be made under constant load conditions.

Since both of the above-mentioned quantity measurements will be in volume units, it will be necessary to know the oil density, in order to convert to weight units. *The density is to correspond to the temperature at the measuring point* (i.e. in the day tank or flow-meter).

The specific gravity, (and thus density) can be determined by means of a hydrometer immersed in a sample taken at the measuring point, but the density can also be calculated on the basis of fuel specifications.

Normally, in fuel specifications, the specific gravity is indicated at 15°C/60°F.

The actual density (g/cm³) at the measuring point is determined by using the curve on *drawing 6355-0150*, where the change in density is shown as a function of temperature.

The consumed oil quantity in kg is obtained by multiplying the measured volume (in litres) by the density (in kg/litre).

In order to be able to compare consumption measurements carried out for various types of fuel oil, allowance must be made for the differences in the lower calorific value (LCV) of the fuel concerned.

Normally, on the testbed, gas oil will have been used, having a lower calorific value of approx. 42,707 kJ/kg. If no other instructions have been given by the ship owner, it is recommended to convert to this value.

Usually, the lower calorific value of a fuel oil is not specified by the oil companies. However, by means of the graph, *drawing 6355-0150*, the LCV can be determined with sufficient accuracy, on the basis of the sulphur content, and the specific gravity at 15°C.

The corrected consumption can then be determined by multiplying the "measured consumption", by:

$$\frac{\text{LCV}}{42,707} \quad \text{LCV} = \begin{array}{l} \text{The specific lower calorific value,} \\ \text{in kJ/kg, of the fuel oil concerned.} \end{array}$$

Example: (6G70ME-C9.2)

Effective engine power, P_e :	21,840 kW
Consumption of fuel oil, C_o :	13.145 m ³ over 3 hours
Measuring point temperature :	119°C
Fuel data:	
(Specific gravity at 15°C, 3% sulphur)	0.9364 g/cm ³
Density at 119°C: ($p_{119} = 0.9364 - 0.068$)	0.8684 g/cm ³
(See drawing 6355-0150)	

$$\text{Specific consumption} = \frac{C_o \times p_{119} \times 10^6}{h \times P_e} \quad [\text{g/kWh}]$$

where:

C_o	= Fuel oil consumption over the period, m ³
p_{119}	= Corrected gravity, g/cm ³
h	= Measuring period, hours
P_e	= Brake power, kW

$$\text{Specific consumption} = \frac{13.145 \times 0.8684 \times 10^6}{3 \times 21,840} \quad [\text{g/kWh}]$$

Correction to ISO reference conditions regarding the *specific lower calorific value*:

LCV = 40,700 kJ/kg, derived from *drawing 6355-0150*.

Consumption corrected for calorific value:

$$\frac{174.2 \times 40,700}{42,707} = 166.0 [\text{g/kWh}]$$

NOTICE

The ambient conditions (blower inlet temperature and pressure and scavenge air coolant temperature) will also influence the fuel consumption. Correction for ambient conditions is not considered important when comparing service measurements.

1 Turbocharger

1.1 General

We recommend to clean the turbochargers regularly during operation.

This prevents the build-up of heavy deposits on the rotating parts and keeps the turbochargers in the best running condition between manual overhauls.

The intervals between cleaning during operation should be determined from the degree of fouling of the turbocharger in the specific plant.

This is because the tendency to form deposits depends, among other things, on the combustion properties of the actual fuel oil.

Guiding intervals between cleaning are given for each cleaning method in the following items.

NOTICE

If the cleaning is not carried out at regular intervals, the deposits may not be removed uniformly. This will cause the rotor to be unbalanced, and excite vibrations.

If	Then
Vibrations occur after cleaning	Clean again
Vibrations occur after repeated cleaning	See description 6645-0320 Clean the turbochargers manually at the first opportunity.

Manual overhauls are still necessary to remove deposits which the cleaning during operation does not remove, in particular on the non-rotating parts.

Regarding intervals between the manual overhauls, see the maker's instructions.

1.2 Cleaning the Turbine Side

1.2.1 Dry Cleaning

Intervals between cleaning: 24-50 hours of operation.
See drawing 5455-0110.

The cleaning is effected by injecting a specified volume of crushed nut shells or similar. The "grain size" is to be about 1.5 mm.

Since the cleaning is mechanical, the highest efficiency is obtained at full load, and cleaning should not be carried out below half load.

Carry out the cleaning according to the instruction given on the “instruction plate” located at the turbocharger.
See drawing 5455-0110 and work card 5465-0701.

1.2.2 Water Cleaning (Not TCA, TCR and MET-Turbochargers)

Intervals between cleaning: Approx. every 50 to 500 operating hours.
See drawing 5455-0115.

The cleaning is effected by injecting atomised water through the gas inlet, at reduced engine load.

Carry out the cleaning according to the instruction given on the “instruction plate” located at the turbocharger.
See drawing 5455-0115.

Be aware that water cleaning can cause corrosion on the shroud ring surrounding the T/C turbine blading.

Note that, during normal running, some of the scavenge air is led through a three-way cock, from pipe No. 2 to pipe No. 1, at the turbine outlet drainage hole, whereby this pipe is kept clean.

1.3 Cleaning the Compressor Side

Guiding intervals between cleaning: 25-75 hours of operation.

NOTICE

Always refer to the maker's special instruction.

The cleaning is effected by injecting water through a special pipe arrangement during running at high load and normal temperatures.

Regarding the cleaning procedure, see the maker's special instructions.

NOTICE

If the deposits are heavy and hard, the compressor must be dismantled and cleaned manually.

If the in-service cleaning is carried out when the compressor side is too contaminated, the loosened deposits can be trapped in the narrow passages of the air cooler element. **This reduces the air cooler effectiveness.**

Regarding air cooler cleaning, see Item 2., 'Air Cooler Cleaning System', below.

We recommend to wrap a thin foam filter gauze around the turbocharger intake filter, and fasten it by straps. This greatly reduces fouling of the compressor side, and even makes inservice cleaning unnecessary.

Replace and discard the filter gauze, when it becomes dirty.

2 Air Cooler Cleaning System

See drawing 5455-0120, and description 7045-0100 regarding the basis for intervals between cleaning.

NOTICE

Carry out the cleaning only when the engine is at standstill.

This is because the water mist catcher is not able to retain the cleaning fluid. Thus there would be a risk of fluid being blown into the cylinders, causing excessive liner wear.

Cleaning of the air side of the scavenge air cooler is effected by injecting a chemical fluid through 'AK' to a spray pipe arrangement fitted to the air chamber above the air cooler element.

The polluted chemical cleaning agent returns from 'AM', through a filter to the chemical cleaning tank.

The procedure is described in *work card 5465-0101*.

3 Drain System for Water Mist Catcher

3.1 Condensation of Water

A combination of high air humidity and cold cooling water will cause an amount of condensed water to be separated from the scavenge air in the water mist catcher.

Estimation of condensate from the water mist catcher drain

The amount of condensate from the water mist catcher(s) can be estimated based on the below listed measurements and figure 1 and 2.

- Engine load (kW)
- Ambient air temperature (°C)
- Relative humidity of ambient air (%)
- Scavenge air pressure (Bar abs)
- Scavenge air temperature (°C)

Figures of water vapour in ambient and scavenge air can be seen in full figure on *drawing 2255-0135*.

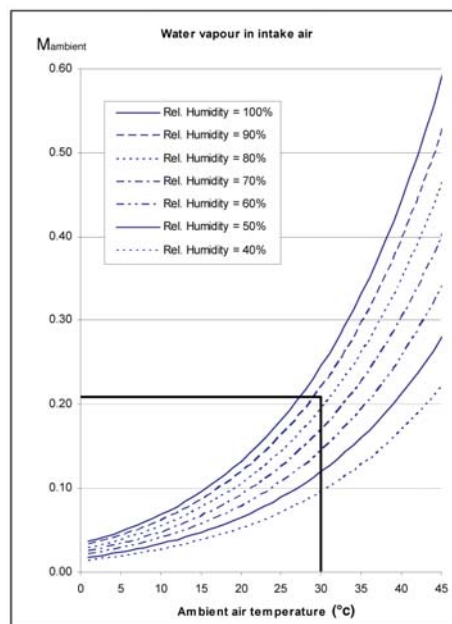


Figure 1

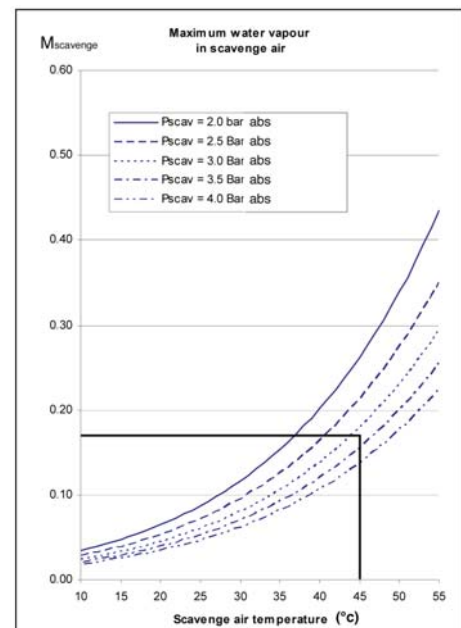


Figure 2

Calculation procedure

1. The amount of water vapour in the intake air (M_{ambient}) is found in *figure 1* based on measurements of ambient air temperature and relative humidity.
2. The maximum amount of water vapour in the scavenge air (M_{scavenge}) is found in *figure 2* based on measurements of scavenge air pressure and temperature.
3. The expected amount of condensate is calculated by:

$$M_{\text{Condens}} = k \times \text{Engine load} \times (M_{\text{ambient}} - M_{\text{scavenge}})^* \text{ [kg/h]}$$

where,

$k = 1.05$ for K80-K98 type engines

$k = 1.00$ for S50-S90 and L50-L70 type engines

$k = 0.90$ for S26-S46 and L35-L42 type engines

*) The tolerance of the result is $\pm 10\%$

No water condensation occurs, if the result is negative.

The sea water temperature may alternatively be used in *figure 1* instead of the ambient air temperature and relative humidity. The 100% relative humidity curve applies, if the sea water temperature is used.

Example of estimation of condensate amount:

Readings:

Engine type:	7K80MC-C
Engine load:	22,700 kW
Ambient air temperature:	30 °C
Relative humidity:	85 %
Scavenge air pressure:	3.25 Bar abs
Scavenge air temperature:	45 °C

Calculation procedure:

1) $M_{\text{ambient}} = 0.21 \text{ kg/kWh}$ found from *figure 1* (as outlined)

2) $M_{\text{scavenge}} = 0.17 \text{ kg/kWh}$ found from *figure 2* (as outlined)

3a) $k = 1.05$ for K80 type engine

3b) $M_{\text{condens}} = 1.05 \times 22700 \times (0.21 - 0.17) = 953 \text{ kg/h}$

The condensate amount is estimated to be 950 kg/h ($\pm 10\%$) or 22.8 t/day for the 7K80MC-C engine.

The estimation of condensate amount is based on nominal air amount for the engine and even distribution of the air outlet temperature from the scavenge air cooler. The expected condensate amount should, therefore, be taken as rough guidance in case of small amounts of condensate (between -0.01 and 0.01 kg/kWh).

3.2 Drain System

See drawing 5455-0120.

Condensed water will be drained off from the water mist catcher through the sight glass, the orifice and flange AL to bilge.

The size of the orifice in the drain system is designed to be able to drain off the amount of condensed water under average running conditions.

In case of running under special conditions with high humidity, it can be necessary to open the bypass valve on the discharge line a little.

Close the bypass valve when possible to reduce the loss of scavenge air.

A level-alarm (*description 7045-0100*) will set off alarm in case of too high water level at the drain.

Check the alarm device regularly to ensure correct functioning.

3.3 Checking the Drain System by the Sight Glass

1. A mixed flow of air and water indicates a correctly working system where condensation takes place.
2. A flow of water only, indicates malfunctioning of the system.
Check the orifice for blocking.
Check for any restrictions in the discharge pipe from AL.
Check and overhaul the level alarm.
3. *A flow of air is only normal when running under dry ambient conditions*

NOTICE

A sight glass which is completely filled with clean water, and with no air flow, visually looks like an empty air-filled sight glass.

1 Thermometers and Pressure Gauges

The thermometers and pressure gauges fitted on the engine are often duplicated with instruments for remote indication.

Owing to differences in the installation method, type and make of sensing elements, and design of pockets, the two sets of instruments cannot be expected to give exactly the same readings.

During shoptest and sea trials, readings are taken from the local instruments. Use these values as the basis for all evaluations.

NOTICE

In case the local and the remote sensors are installed in separate pockets, a temperature difference of up to 50 °C can be expected. Consider this when evaluating performance measurements.

Check the thermometers and pressure gauges at intervals against calibrated control apparatus.

Thermometers should be shielded against air currents from the engine-room ventilation.

If the temperature permits, keep thermometer pockets filled with oil to ensure accurate indication.

Keep all U-tube manometers perfectly tight at the joints.

Check the tightness from time to time by using soap-water.

To avoid polluting the environment, do not use mercury instruments.

Check that there is no water accumulation in tube bends, as this could falsify the readings.

If cocks or throttle valves are incorporated in the measuring equipment, check these for free flow, prior to taking readings.

If an instrument suddenly gives values that differ from normal, consider the possibility of a defective instrument.

The easiest method of determining whether an instrument is faulty or not, is to exchange it for another.

2 PMI System

The PMI System is designed to provide engineers and service personnel onboard ship and at power plants with a computerised tool for pressure measurements and analysis on two-stroke diesel engines. The main advantages of the system are:

- On-line measurement of cylinder pressure. Fully automated measurement routine for measurements conducted from engine control room.
- Graphic display and print out of PT, PV and Balance Diagrams, together with Mean Indicated Pressure and Max. Pressure deviation limits.
- Calculated values of Effective Power, Mean Indicated Pressure p_i , Compression Pressure p_{comp} , Max. Pressure p_{max} , and Scavenge Pressure p_{scav} , including proposed values for index adjustments, etc.
- Software interface for use with MAN Diesel & Turbo's engine performance and engine diagnostics software, e.g. CoCos-EDS.

3 Indicator Valve

During the running of the engine, soot and oil will accumulate in the indicator bore.

Clean the bore by opening the indicator valve for a moment.

To protect the valve against burning:

- Open the valve only partially,
- Close the valve after one or two ignitions.

1 Calculation of the Indicated and Effective Engine Power

NOTICE

Regarding the diagrams and PMI system,
see description 6345-0330.

For engines without PMI-system,
see description 6345-0370.

Calculation of the indicated and effective engine power consists of the following steps:

Calculate:

- The mean indicated pressure, p_i
- The mean effective pressure, p_e
- The cylinder constant, k_2
- The indicated engine power, P_i
- The effective engine power, P_e

The mean indicated pressure, p_i

$$p_i = \frac{A}{L \times C_s} = [\text{bar}]$$

where:

- | | | |
|------------------------|---|---|
| A [mm ²] | = | area of the indicator diagram, as found by planimetering. |
| L [mm] | = | length of the indicator diagram (= atmospheric line). |
| C_s [mm/bar] | = | spring constant (= vertical movement of the indicator stylus [mm] for a 1 [bar] pressure rise in the cylinder). |

p_i corresponds to the height of a rectangle with the same area and length as the indicator diagram.

- I.e., if p_i was acting on the piston during the complete downwards stroke, the cylinder would produce the same total work as actually produced in one complete revolution.

The mean effective pressure, p_e

$$p_e = p_i - k_1 [\text{bar}]$$

where:

k_1 = the mean friction loss

The mean friction loss has proved to be practically independent of the engine load. By experience, k_1 has been found to be approx. 1 [bar].

The cylinder constant, k_2

k_2 is determined by the dimensions of the engine, and the units in which the power is wanted.

For power in [kW] : $k_2 = 1,309 \times D^2 \times S$

D [m] = cylinder diameter

S [m] = piston stroke

Examples:

Engine type	For power in [kW] k_2
S50ME	0.6250
S50ME-C	0.6545
L60ME	0.9161
S60ME	1.0801
S60ME-C	1.1310
L70ME	1.4547
S70ME	1.7151
S70ME-C	1.7959
L80ME	2.1715
S80ME	2.5602
K80ME-C	1.9268
L90ME	3.0918
K90ME	2.7037
K90ME-C	2.4387
K98ME-C	3.0172

The indicated engine power, P_i

$$P_i = k_2 \times n \times p_i \text{ [kW]}$$

where:

n [rpm] = engine speed.

The effective engine power, P_e

$$P_e = k_2 \times n \times p_e \text{ [kW]}$$

where:

n [rpm] = engine speed.

Due to the friction in the thrust bearing, the shaft power is up to 1% less than the effective engine power, depending on speed and load conditions and plant type (FPP/CPP).

1 General

Some measured performance parameters need to be corrected to ISO ambient conditions to facilitate reliable evaluation.

These parameters are: $p_{\max}$, t_{exhv} , p_{comp} and p_{scav} .

See description 6345-0300.

Making such corrections enables comparison to earlier (corrected) readings or model curves, regardless of deviations of the actual t_{inl} and t_{coolinl} from reference conditions.

I.e. the correction provides the values which would have been measured if t_{inl} and t_{coolinl} had been 25°C.

In extreme cases, the divergencies can be large.

Record the corrected value as described in description 6345-0310.

Use the following reference conditions:

t_{inl} = Air inlet temperature = 25°C

The air inlet temperature can vary greatly, depending on the position in which it is measured on the intake filter. Experience has shown that two thermometers situated at ten o'clock and four o'clock positions (i.e. 180° apart) and at the middle of the filter, give a good indication of the average temperature.

t_{coolinl} = Cooling water inlet temp. to air cooler = 25°C.

See drawing 6355-0145, regarding Δt ($t_{\text{scav}} - t_{\text{coolinl}}$).

See description 6345-0300.

2 Correction

The correction for deviations of t_{inl} and $t_{coolinl}$ from reference conditions can be carried out in two ways:

By reading
See drawing 6355-0180.

By calculation
The corrections can be determined by the general equation:

$A_{corr} = (t_{meas} - t_{ref}) \times F \times (K + A_{meas})$

where:

- A_{corr} = the correction to be applied to the parameter, i.e. to p_{max} , t_{exh} , p_{comp} or p_{scav} .
- t_{meas} = measured t_{inl} or $t_{coolinl}$.
- t_{ref} = reference t_{inl} or $t_{coolinl}$ (in case of Standard Conditions, 25°C).
- F_1, F_2 = constants, *see the table below.*
- K = constant, *see the table below.*
- A_{meas} = the measured parameter to be corrected, i.e. p_{max} , t_{exh} , p_{comp} or p_{scav} .

For instructions, how to use the formulas,
see drawing 6355-0180.

Parameter to be corrected	F_1 : for air inlet temp	F_2 : for cooling water inlet temp	K
t_{exhv}	$- 2.466 \times 10^{-3}$	$- 0.59 \times 10^{-3}$	273
p_{scav}	$+ 2.856 \times 10^{-3}$	$- 2.220 \times 10^{-3}$	$p_{baro} = 1 \text{ bar or } 750 \text{ mm Hg}$
p_{comp}	$+ 2.954 \times 10^{-3}$	$- 1.530 \times 10^{-3}$	$p_{baro} = 1 \text{ bar or } 750 \text{ mm Hg}$
p_{max}	$+ 2.198 \times 10^{-3}$	$- 0.810 \times 10^{-3}$	$p_{baro} = 1 \text{ bar or } 750 \text{ mm Hg}$

3 Examples of calculations:

See drawing 6355-0180, which states a set of service readings.

1. Correction of t_{exhv} (drawing 6355-0180).

Measured:

Exhaust temperature after valve = 425°C

Air inlet temp. = 42°C

Cooling water inlet temp. (air cooler) = 40°C

Correction for air inlet temperature:

$(42 - 25) \times (-2.466 \times 10^{-3}) \times (273 + 425)$ = -29.3°C

Correction for cooling water inlet temperature:

$(40 - 25) \times (-0.59 \times 10^{-3}) \times (273 + 425)$ = -6.2°C

Corrected t_{exhv} value = 425 - 29.3 - 6.2 = 389.5°C

2. Correction of p_{scav} (drawing 6355-0180).

Measured:

Scavenge air pressure = 2.0 bar

Air inlet temp. = 42 °C

Cooling water inlet temp. (air cooler) = 40 °C

Correction for air inlet temp.:

$(42 - 25) \times (2.856 \times 10^{-3}) \times (1 + 2.0)$ = 0.146 bar

Correction for cooling water inlet temp.:

$(40 - 25) \times (-2.220 \times 10^{-3}) \times (1 + 2.0)$ = -0.10 bar

Corrected p_{scav} value = 2.0 + 0.146 - 0.10 = 2.046 bar

Corrections of p_{comp} and p_{max} can be made in a similar manner, see drawing 6355-0180.

4 Maximum Exhaust Temperature

The engine is designed to allow a limited increase of the thermal loading, i.e. increase of t_{exh} .

- This enables the engine to operate under climatic alterations and under normally deteriorated service condition.

Whether the engine exceeds this built-in safety margin for thermal loading can be evaluated as follows:

The factors contributing to increased exhaust temperature levels (and thereby thermal loads) and the largest permissible deviation values are:

Factor	Max. temp. increase
due to fouling of turbocharger (incl. air intake filters), and exhaust uptake. <i>See description 7045-0100 (PT8708)</i>	+ 30°C
due to fouling of air coolers	+ 10°C
due to deteriorated mechanical condition (estimate)	+ 10°C
due to climatic (ambient) conditions	+ 45°C
due to operation on heavy fuel, etc.	+ 15°C
Total	110°C

Regarding increasing exhaust temperatures, see description 6345-0310.

For new engines it is not unusual to observe a temperature increase of 50-60°C from the shop test to sea trial.

- This is due to the operation on heavy fuel oil and altered climatic conditions.

If the temperature increases further during service:

- Find the cause of the temperature increase.
- Clean, repair or overhaul the components in question at the first opportunity, to improve the engine performance.

NOTICE

The exhaust temperature must not exceed the alarm limit.
See description 7045-0100 'Guidance Value Automation'.

To evaluate the exhaust temperature correctly, it is important to distinguish between:

- Exhaust temperature increase due to fouling and mechanical condition, and
- Exhaust temperature increase due to climatic alterations.

The method to distinguish between the factors is shown in the example:

Example:

According to a model curve, the exhaust temperature (approx. 95% engine load) should be 375°C. The observed exhaust temperature is 425°C.

Correct t_{exhv} according to *drawing 6355-0180*.

Air inlet temp. (t_{inl}) = **42°C** corresponding to $(42 - 25) = 17^\circ\text{C}$ above the reference value.

Cooling water inlet temp. to the air cooler (t_{coolinl}) = **40°C**, corresponding to $(40 - 25) = 15^\circ\text{C}$ above the reference value.

Using the curves, the following temperature corrections are obtained:

Correction due to increased engine room temperature:	-27.0°C
Correction due to increased cooling water inlet temp.:	-6.0°C
Total	-33.0°C

Distinguish between the factors:

The total exhaust temp. increase of $425^\circ\text{C} - 375^\circ\text{C} = 50^\circ\text{C}$, is caused by:

- an increase of 33.0°C on account of climatic alterations,
- an increase of $50^\circ\text{C} - 33^\circ\text{C} = 17^\circ\text{C}$, due to mechanical conditions and operation on heavy fuel oil.

1 General

To record the turbocharger efficiencies.
See description 6345-0310.

Drawing 6355-0140 shows model curves for compressor and turbine efficiencies, based on the scavenge air pressure.

For general evaluation of the engine performance, it is unnecessary to calculate turbocharger efficiencies.

However, if such calculations are desired, they can be carried out as described below.

2 Calculating the Efficiencies

The total turbocharger efficiency is the product of the compressor, turbine, and mechanical efficiencies.

However, the last one has almost no effect on the efficiency calculations, and is therefore omitted.

When calculating the turbocharger efficiency, it is necessary to distinguish between:

- Plants without turbo compound system (TCS) and exhaust by-pass.
- Plants with TCS and/or exhaust by-pass.

2.1 Plants without TCS and Exhaust By-Pass

Measure the parameters listed in Table 1.

It is essential that, as far as possible, the measurements are taken simultaneously.

Convert all pressures to the same unit.
About conversion factors, *see description 6345-0300.*

		Unit	Example of Measurements
Barometric pressure	p_{baro}	bar	1.022 bar
Pressure drop, air cooler	Δp_c	bar	0.0168 bar
Temperature before compr.	t_{inl}	°C	21°C
Turbocharger speed	n	rpm	11950 rpm
Scavenge air pressure	p_{scav}	bar	2.533 bar *)
Exhaust receiver pressure	p_{exh}	bar	2.393 bar *)

		Unit	Example of Measurements
Pressure after turbine	p_{atc}	bar	0.026 bar *)
Temperature before turbine	t_{btc}	°C	400°C

Table: Measurements for calculation of efficiencies *) "Gauge" Pressure

Note that the official designation of bar (HPa) is "absolute pressure".

Total Efficiency: The total efficiency η_{tot} is given by the equation

Example:

M_F : Fuel mass flow injected for combustion: 0.88 kg/s

M_X : Exhaust gas mass flow through turbine: 48.05 kg/s

M_A : Air mass flow through compressor

$$M_A = M_X - M_F$$

$$\eta_{tot} = 0.9265 \times \frac{M_A \times T_1 \times (R_1^{0.286} - 1)}{M_X \times T_2 \times (1 - R_2^{0.265})}$$

if M_A or M_X unknown:

$$\frac{M_A}{M_X} \approx 0.9817$$

Example of Calculation, η_{tot}
See measurements in Table 1

$T_1 = t_{inl} + 273.15$	$T_1 = 21 + 273.15$	=
$R_1 = \frac{p_{baro} + p_{scav} + \Delta p_{cc}}{p_{baro}}$	$R_1 = \frac{1.022 + 2.533 + 0.017}{1.022}$	
$T_2 = t_{btc} + 273.15$	$T_2 = 400 + 273.15$	=
$R_2 = \frac{p_{baro} + p_{atc}}{p_{baro} + p_{exh}}$	$R_2 = \frac{1.022 + 0.026}{1.022 + 2.393}$	= 0.307
$(R_1^{0.286} - 1)^*$	$(R_1^{0.286} - 1)$	= 0.430
$(1 - R_2^{0.265})^*$	$(1 - R_2^{0.265})$	= 0.269
	M_X	= 48.05 kg/s
	$M_A = 48.05 - 0.88$	= 47.17 kg/s
$\eta_{tot} = 0.9265 \times \frac{M_A \times T_1 \times (R_1^{0.286} - 1)}{M_X \times T_2 \times (1 - R_2^{0.265})}$	$\eta = 0.9265 \times \frac{47.17 \times 294.15 \times 0.430}{48.05 \times 673.15 \times 0.269}$	
	$\eta =$	= <u>0.635</u>

Compressor efficiency:

The compressor efficiency η_{compr} is given by the equation

$$\eta_{\text{compr}} = \frac{3628800 \times T_1 (R_1^{0.286} - 1)}{\mu \times U^2}$$

μ = slip factor, *see drawing 6355-0220*.

U = $(\pi \times D \times n)$ is the peripheral speed of the compressor wheel.

D = Diameter of compressor wheel, *see drawing 6355-0220*.

n = Turbocharger revolution per minute.

The turbocharger used in this example is a MAN Diesel & Turbo, type TCA77.

From *drawing 6355-0220* is taken:

$$D = 0.752 \text{ m}$$

$$\mu = 0.745$$

Example of Calculation, η_{comp} See measurements in Table 1		
$T_1 = t_{\text{inl}} + 273.15 \text{ } ^\circ\text{K}$	$21 + 273.15$	$= 294.15$
$R_1 = \frac{p_{\text{baro}} + p_{\text{scav}} + \Delta p_c}{p_{\text{baro}}}$	$\frac{1.022 + 2.533 + 0.017}{1.022}$	$= 3.495$
$(R_1^{0.286} - 1)^*$		$= 0.430$
$U^2 = (\pi \times D \times n)^2$	$(\pi \times 0.656 \times 13350)^2$	$= 797022356$
$\eta_{\text{compr}} = \frac{3628800 \times T_1 (R_1^{0.286} - 1)}{\mu \times U^2}$	$\frac{3628800 \times 294 \times 0.430}{0.745 \times 797022356}$	$= \underline{\underline{0.77}}$

* Determine the values of the expressions $(R_1^{0.286} - 1)$ and $(1 - R_2^{0.265})$.

Use a mathematical calculator or use the curves in *drawing 6355-0205* and *6355-0210*.

Turbine efficiency: The turbine efficiency η_{turb} appears from $\eta_{\text{total}} = \eta_{\text{compr}} \times \eta_{\text{turb}}$

$$\text{i.e. } \eta_{\text{turb}} = \frac{\eta_{\text{total}}}{\eta_{\text{compr}}} = \frac{0.64}{0.77} = \underline{\underline{0.83}}$$

2.2 Plants with TCS and/or Exhaust By-Pass

The equation:

$$\eta_{\text{tot}} = 0.9265 \times \frac{M_A \times T_1 \times (R_1^{0.286} - 1)}{M_x \times T_2 \times (1 - R_2^{0.265})}$$

- stated in item 2.1 is based on a situation where the mass flow through the turbine is equal to the mass flow through the compressor plus the fuel oil amount.

If a TCS or an exhaust by-pass is fitted, the mass flow through the turbine is reduced by the mass flow through the TCS or the exhaust by-pass.

The mass flows through the turbine and the TCS or through the turbine and the exhaust by-pass are proportional to the effective areas in the turbines or the orifice in the exhaust by-pass.

Calculate the turbocharger efficiency as described in Item 2.1 'Plants without TCS and exhaust by-pass'. Then correct the results in accordance with the following:

Total efficiency:

$$\eta_{\text{tot TCS/by-pass}} = \eta_{\text{tot}} \times \frac{A_{\text{eff}} + a_{\text{eff}}}{A_{\text{eff}}}$$

where

A_{eff} = Effective area in turbocharger turbine

a_{eff} = Effective area in TCS or exhaust by-pass.

See 'Remarks', below

Turbine Efficiency:

$$\eta_{\text{turb TCS/by-pass}} = \eta_{\text{turb}} \times \frac{A_{\text{eff}} + a_{\text{eff}}}{A_{\text{eff}}}$$

See also 'Remarks', below

Compressor Efficiency:

η_{compr} is unchanged, as it is not affected by whether the plant operates with TCS/by-pass or not.

Remarks

The relation:

$$\frac{A_{\text{eff}} + a_{\text{eff}}}{A_{\text{eff}}}$$

- can vary from plant to plant, but is most often about 1.07. This value can be used when evaluating the trend of the efficiency in service.

When using a computer program in which the relation $A_{\text{eff}} + a_{\text{eff}} / A_{\text{eff}}$ is not introduced, the value for η_{tot} and η_{turb} will have to be multiplied by the above-mentioned factor of about 1.07.

1 General

The estimation is based on nomograms involving engine parameter measurements made on testbed.

The nomograms are shown in *drawing 6355-0215*. The following relationships are illustrated:

Chart I - fuel index and mean effective pressure.

Chart II - mean effective pressure and effective engine power (kW), with the engine speed as a parameter.

Chart III - turbocharger speed and effective engine power (kW), with the scavenge air temperature and ambient pressure as parameters.

A condition for using these charts is that the engine timing and turbocharger matching are unchanged from the testbed.

2 Methods

In the following refer to *drawing 6355-0215*.

2.1 Fuel Index(an approximate method)

Chart I: Draw a horizontal line from the observed fuel index to the nomogram curve, and then a vertical line down to the observed engine speed on

Chart II: From this intersection a horizontal line is drawn to the effective engine power scale, i.e. 12.100 kW.

This method should only be used as a quick (rough) estimation, because the fuel oil, as well as the condition of the fuel pump, may have great effect on the index. In particular, worn fuel pumps or suction valves tend to increase the index, and will thus result in a too high power estimation.

2.2 Turbocharger Speed(A more accurate method)

Chart III: Draw a horizontal line from the observed t_{scav} value and an inclined line from the observed turbocharger speed.

From the intersection point, draw a vertical line down to the nomogram curve and then a horizontal line to the vertical line from the observed ambient pressure (point x in the ambient pressure scale).

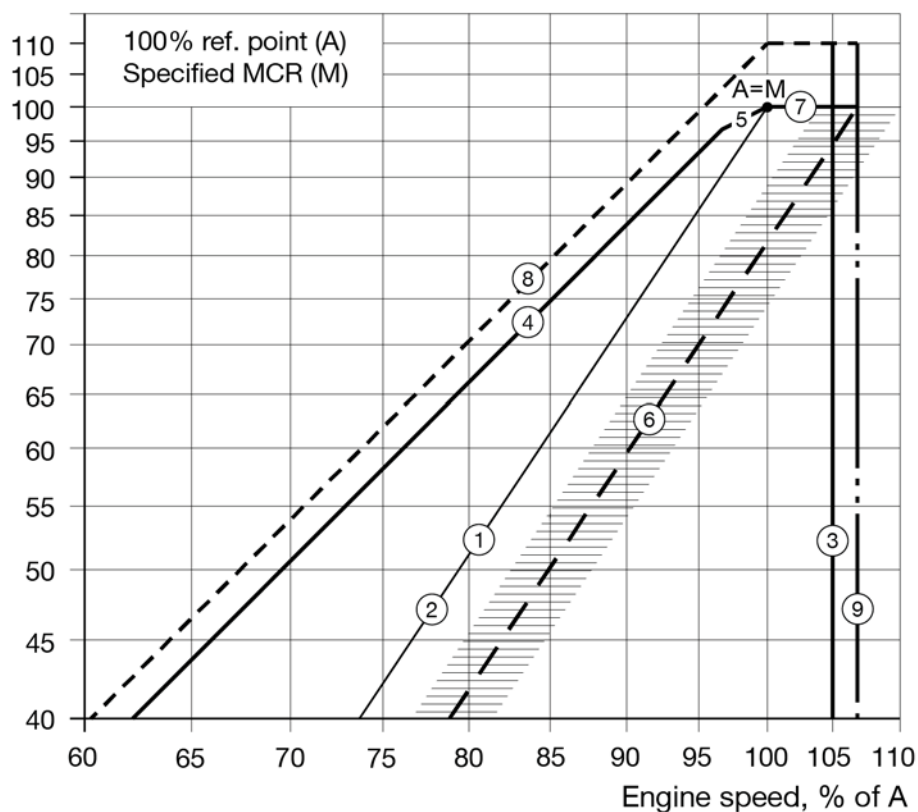
Finally, a line is drawn parallel with the inclined 'ambient pressure correction' lines. The effective engine power can then be read on the scale at the right hand side, i.e. 11.500 kW.

This method is more reliable, and an accuracy to within $\pm 3\%$ can be expected. However, the accuracy obtained will depend on the condition of the engine and turbocharger. A fouled or eroded turbocharger will in most cases tend to decrease the turbocharger speed, and thus result in a too low power estimation. This situation is characterized by increased exhaust gas temperatures and a decreased scavenge air pressure.

It is recommended to apply PMI-system, for easy access to P-V-diagrams (work diagrams) for power calculation.

See description 6345-0340.

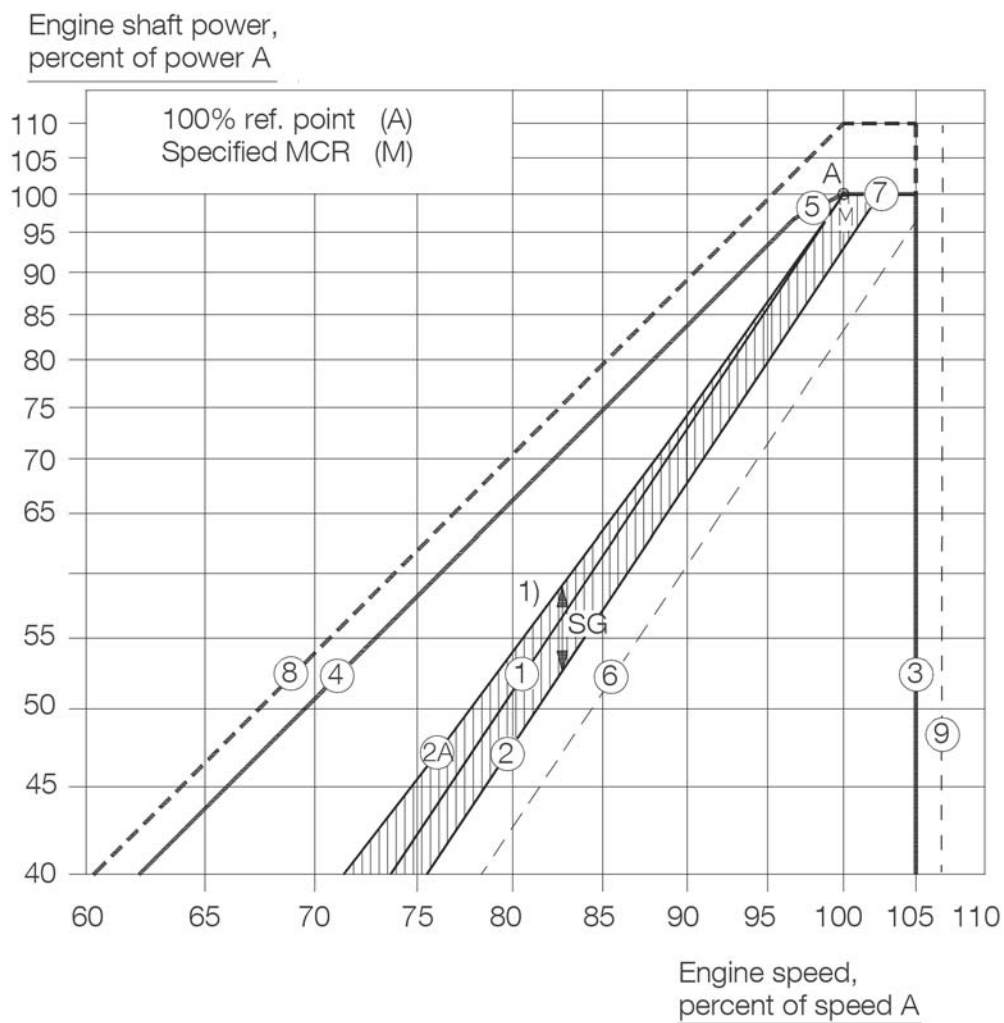
Engine shaft power, % of A



- Line 1: Propeller curve through point A – layout curve for engine
- Line 2: Propeller curve – heavy running, recommended limit for fouled hull at calm weather conditions
- Line 3: Speed limit
- Line 4: Torque/speed limit
- Line 5: Mean effective pressure limit
- Line 6: Propeller curve – light running (range: 4.0-10.0%) for clean hull and calm weather conditions – for propeller layout
- Line 7: Power limit for continuous running
- Line 8: Overload limit
- Line 9: Speed limit at sea trial

Load Diagram for Propulsion alone

Drawing
6355-0100-0002



- Line 1: Propeller curve through point A – layout curve for engine
- Line 2: Propeller curve – heavy running, recommended limit for fouled hull at calm weather conditions
- Line 2A: Engine service curve for heavy running propulsion (line 2) and shaft generator (SG)
- Line 3: Speed limit
- Line 4: Torque/speed limit
- Line 5: Mean effective pressure limit
- Line 6: Propeller curve – light running (range: 4.0-10.0%) for clean hull and calm weather conditions – for propeller layout
- Line 7: Power limit for continuous running
- Line 8: Overload limit
- Line 9: Speed limit at sea trial

NOTICE

The propeller curve for propulsion alone is found by subtracting the actual shaft generator power (incl. generator efficiency) from the effective engine power at maintained speed.

SERVICE DATA (ME)	Engine Type:		Name of vessel:				
	Engine Builder:		Engine No.:				Yard:
Layout kW:		Layout RPM:		Engine Mode:		Sign.:	Test No.:
Turbocharger(s)		No. of TC:		Serial No.		No. of Cyl.:	Bore, m:
Make:		Type:		1		Cylinder Constant, (HP, bar):	
Max. RPM:		Max. Temp., °C:		2		Mean Friction. Press., bar:	
Compr. Slip Factor:		Compr. Diam., m:		3		Lubrication Oil System (Tick box)	
TC specification:		4		☐ Internal ☐ External from M. E. System ☐ External from Gravity Tank			
Observation No. :							
Fuel Oil Viscosity:				at:		°C	
Bunker Station:				Cylinder Oil		Brand	
Oil Brand:				Heat value, kcal/kg:		Circulating Oil	
Density at 15 °C:				Sulphur, %:		Turbo Oil	
Test Date (yyyy-mm-dd)	Test Hour (hh:mm)	Load %	Ambient Pressure mbar	Engine RPM	Total Running Hours	Fuel Index ECU %	Speed Setting RPM
Effective Power BHP	Effective Power kW	Indicated Power kW	Eff. Fuel Consumption g/BHP	Eff. Fuel Consumption g/kWh	Draft Fore, m	Log Knots	Wind, m/s
					Draft Aft, m	Obs. Knots	Wave Height, m
							Direction, °
Cylinder No.	1	2	3	4	5	6	7
Pi, bar							
Pmax, bar							
Ref. Pmax, bar							
Pcomp, bar							
Fuel Index Offset, HIGH Load							
Fuel Index Offset, LOW Load							
Pmax Adjustment, bar							
Pcomp Ratio (Pcomp/Pscav)							
Exh. Valve Open Timing, °CA (Correction value)							
Exhaust Gas Temp., °C							
Cooling Water Outlet Temp., °C							
Piston Outlet Lub. Temp., °C							
Cooling Water Temperature, °C		Exhaust Gas Temp., °C		Exhaust Pressure		Turbo Charger	
Air Cooler		Main Engine		Turbine		Receiver	
Inlet	Outlet	Inlet	Turb. Outlet	Inlet	Outlet	bar	mmWC
1	1	1	1	1	1	1	1
2	2	Seaw. Temp.	2	2	2	mmHg	2
3	3		3	3	3		3
4	4		4	4	4		4
Ave.	Ave.		Ave.	Ave.	Ave.		Ave.
Scavenge Air Temperature, °C		Lubricating Oil		Fuel Oil Pressure		Hydraulic Pressure	
Scav. Air Temp.	Inlet Blower	Before Cooler	After Cooler	Pressure, bar	Temperature, °C	bar	bar
°C	1	1	1	System Oil	TC Inlet / Blower end	Before Filter	Before Filter
	2	2	2	Cooling Oil	TC Outlet / Turb. end	After Filter	After Filter
	3	3	3	Turbine Oil	2	2	Temperature, °C
	4	4	4	Temperature, °C	3	3	Before Pumps
	Ave.	Ave.	Ave.	Inlet Engine	4	4	Swash Plate Position, %
				Thrust Segment	Ave.	Ave.	1
							2
							3
							4

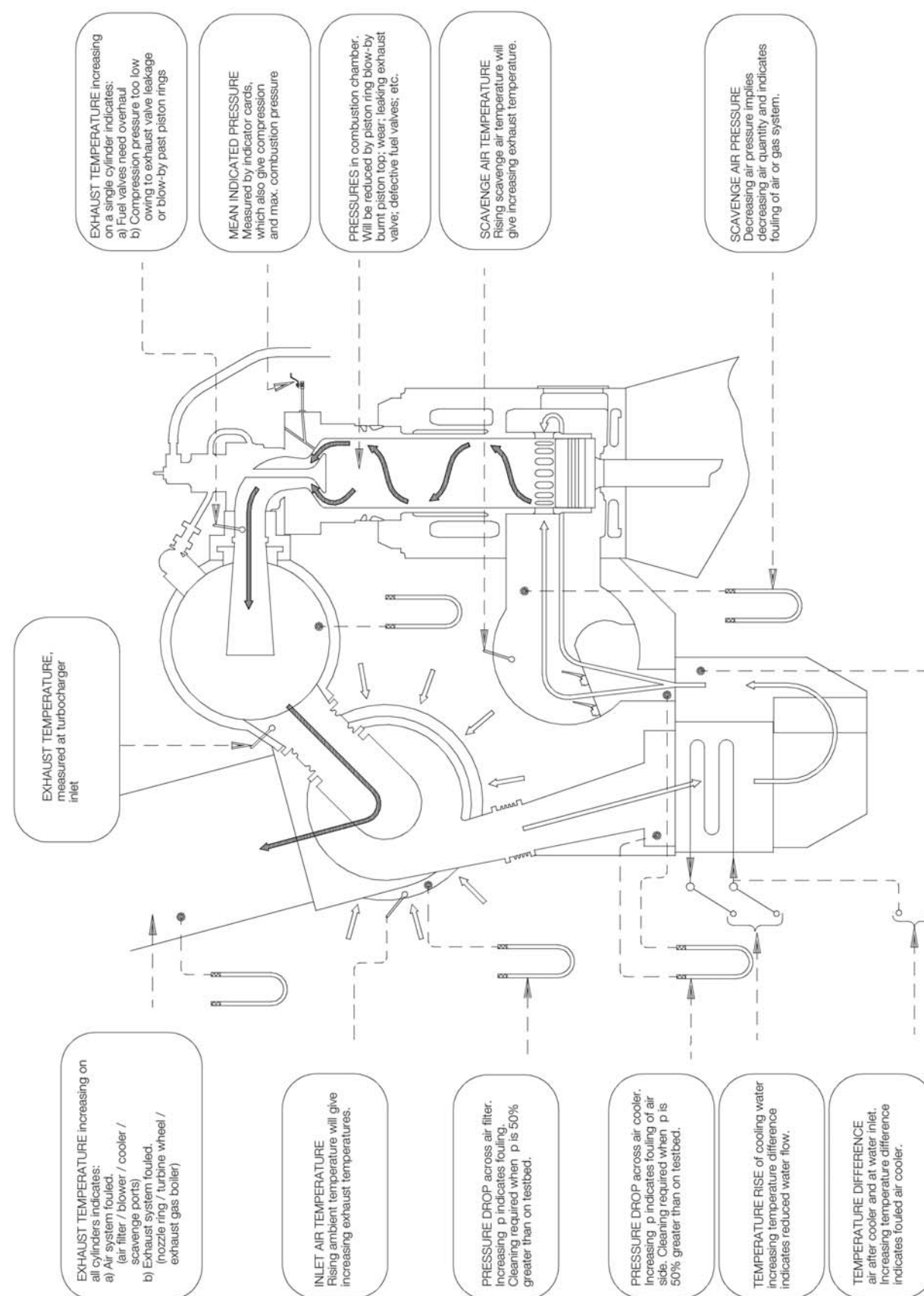
Remarks:

Performance Observations

Drawing
6355-0110-0001

TESTBED DATA	Engine Type:		Water Brake:		No.:		Constant, K:		BHP/Kg.RPM										
	Engine Builder:		Engine No.:		Yard:														
Layout BHP:		Layout RPM:		Entry Date:		Sign:		Test No.:											
Turbochargers(s):		Nos.:		Serial No.:		No. of cyl.:		Bore (m):		Stroke (m):									
Make:		1				Cylinder Constant (HP,bar)													
Type:		2				Governor:		Type:											
Max. RPM:		3				TC specification:													
Max. Temp. °C:		4				MFP:		Compr. Slip Factor:		Compr. Diameter:									
Lub. Oil System:																			
Observation No:																			
Fuel Oil Viscosity:				at:		°C		Brand		Type									
Bunker Station:						Cylinder Oil													
Oil Brand:				Heat value, kcal/kg:		Circulating Oil													
Density at 15 °C:				Sulphur, %:		Turbo Oil													
Test Date (yyyy-mm-dd)	Test Hour (hh:mm)	Load %	Ambient Pressure mbar	Water Brake Load Kg	Engine RPM	Governor Index	Speed Setting bar	VIT Control Press. bar											
Effective Power BHP	Effective Power kW	Indicated Power kW	Eff. Fuel Consumption g/BHP	Eff. Fuel Consumption g/kWh	Indicated Fuel Consumption g/IHP	Indicated Fuel Consumption g/kWh													
Cylinder No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Ave.
Pi, bar																			
Pmax, bar																			
Ref. Pmax, bar																			
Pcomp, bar																			
Fuel Pump Index																			
VIT Index																			
Exhaust Gas Temp. °C																			
Cooling Water Outlet Temp. °C																			
Piston Outlet Lub. Temp. °C																			
Cooling Water Temperature °C			Exhaust Gas Temp. °C			Exhaust Pressure		Turbo Charger	Aux. Blower	Scavenge Air Pressure									
Air Cooler		Main Engine		Turbine		Receiver	Turb. Outl.	RPM	On/Off	▲p Filter		▲p Cooler	Receiver						
Inlet	Outlet	Inlet	Turb. Outlet	Inlet	Outlet	bar	mmWC			mmWc	mmWc	bar							
1	1		1	1	1		1	1		1	1								
2	2	Seaw. Temp.	2	2	2	mmHg	2	2	Axial Vibration	2	2		mmHg						
3	3		3	3	3		3	3	mm	3	3								
4	4		4	4	4		4	4		4	4								
Ave.	Ave.		Ave.	Ave.	Ave.		Ave.	Ave.		Ave.	Ave.								
Scavenge Air Temperature °C				Lubricating Oil				Fuel Oil Pressure											
Scav. Air	Inlet Blower	Before Cooler	After Cooler	Pressure, bar	Temperature, °C	Temperature, °C			bar										
	1	1	1	System Oil	Inlet Engine	TC Inlet / Blower end	TC Outlet / Turb. end		Before Filter										
	2	2	2	Cooling Oil	Inlet Camshaft	1	1		After Filter										
	3	3	3	Camshaft Oil	Outlet Camshaft	2	2		Temperature, °C										
	4	4	4	Turbine Oil	Thrust Segment	3	3		Before Pumps										
	Ave.	Ave.	Ave.			4	4												
						Ave.	Ave.												

Remarks:

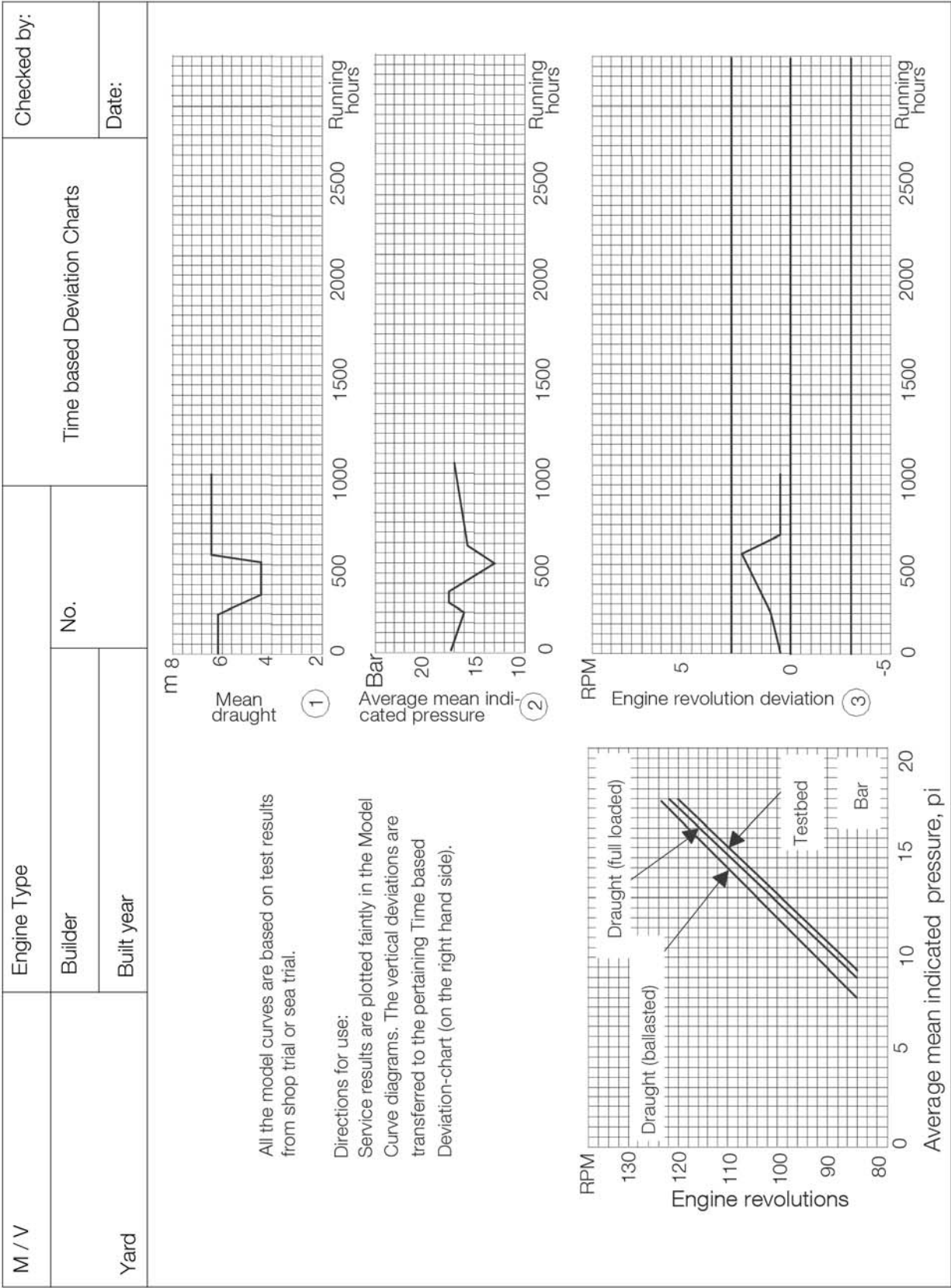


Readings relating to Thermodynamic Conditions

Drawing

6355-0115-0001

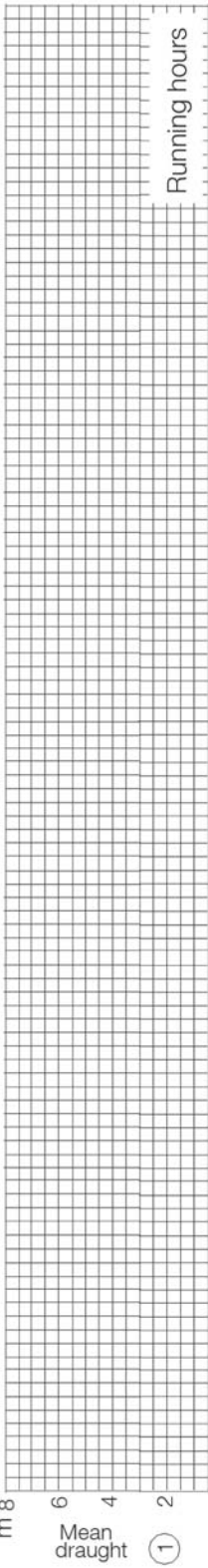
Time based deviation charts for: mean draught and average mean indicated pressure (pi). Model curves + time based deviation chart for: r/min as a function of pi.



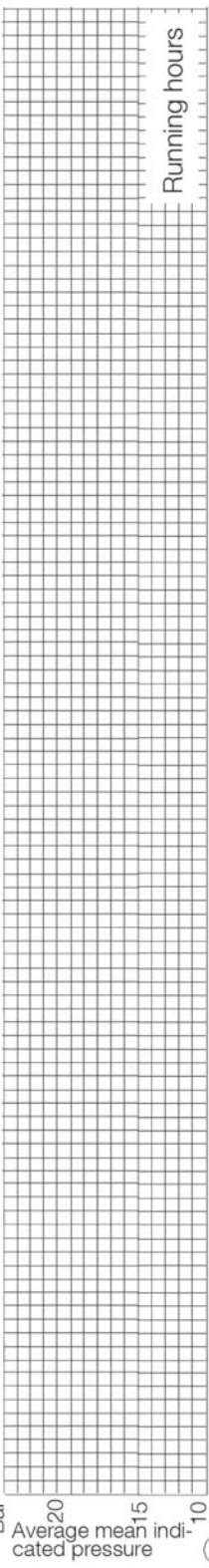
Time based deviation charts for: mean draught and average mean indicated pressure (p_i). Model curves + time based deviation chart for: r/min as a function of p_i .

M / V	Engine Type		Time based Deviation Charts	Checked by:
	Builder	No.		Date:
Yard	Built year			

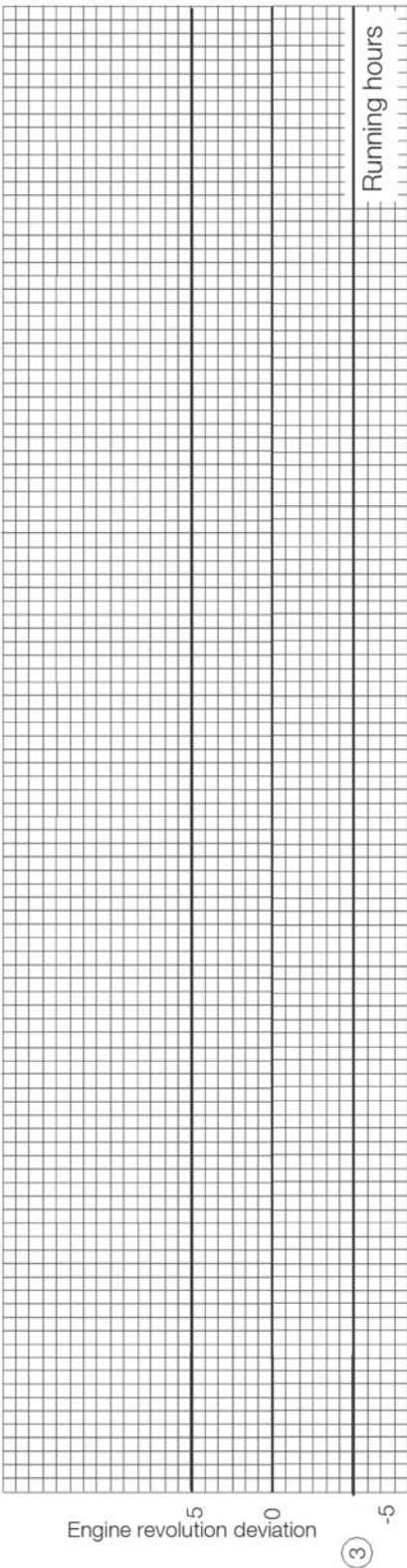
m 8
6
4
2
Mean draught ①



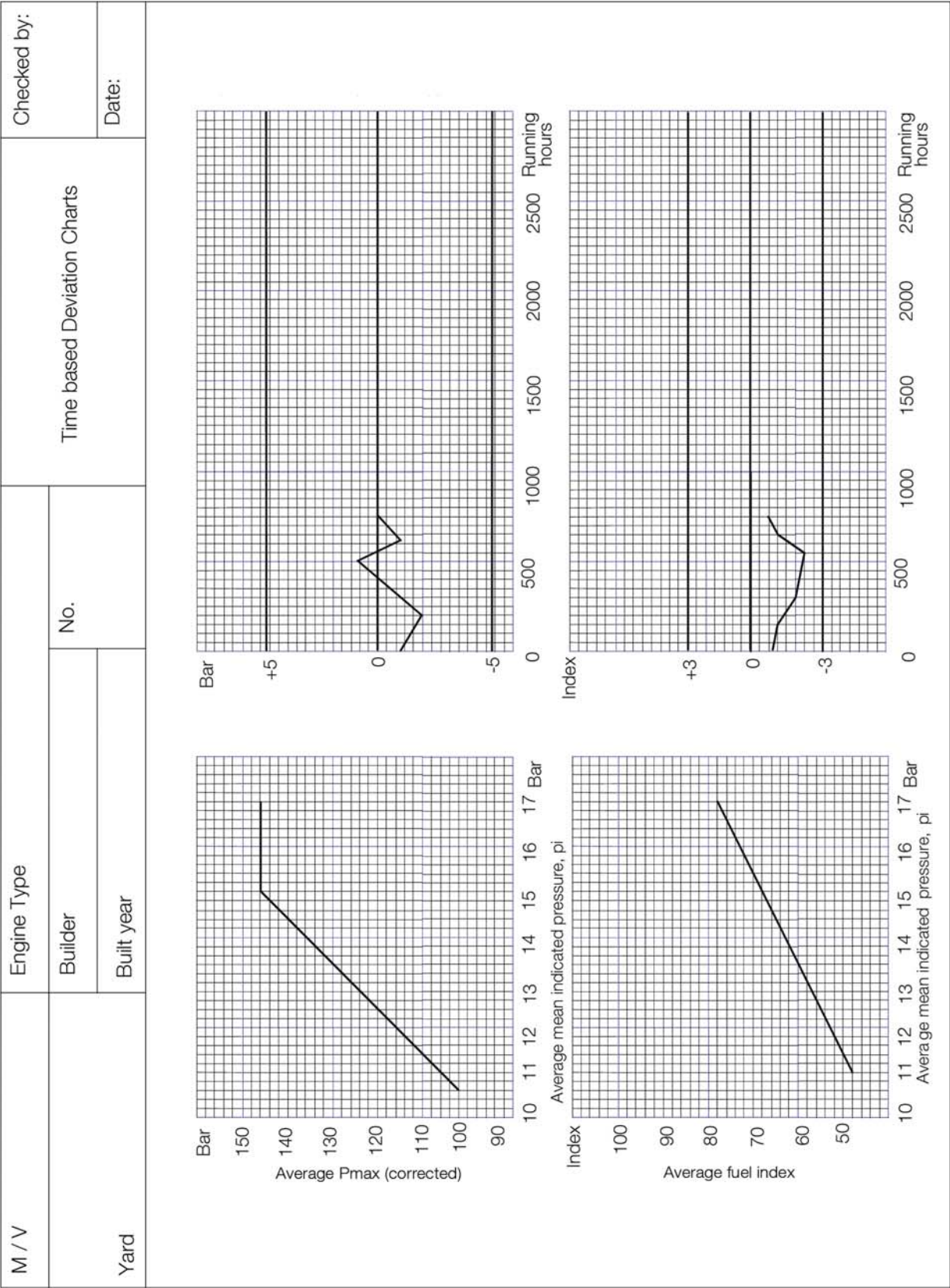
Bar 20
15
10
Average mean indicated pressure ②



RPM 5
0
-5
Engine revolution deviation ③



Model curves and time based deviation chart for:
 p_{max} and fuel index as a function of p_i



Synopsis Diagrams - for engine (Pmax)

Drawing
6355-0125-0002

Time based deviation chart for:
p_{max} and fuel index

M / V	Engine Type		Checked by:
	Builder	No.	
	Built year		
Yard			Date:

Bar

+5

0

-5

Pmax deviation

Running hours

Index

+3

0

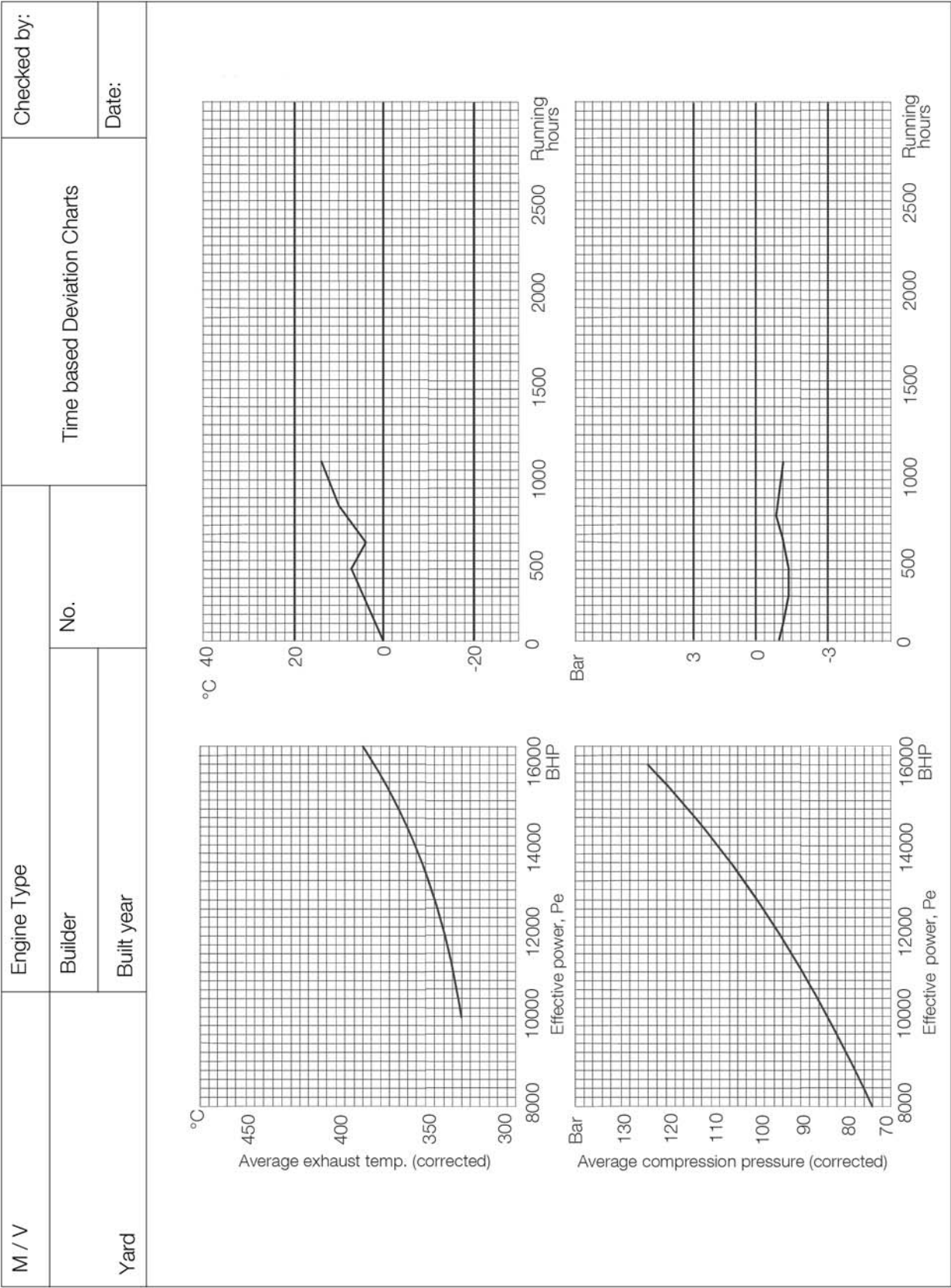
-3

Fuel index deviation

Running hours



Model curves and time based deviation chart for:
 t_{exhv} and p_{comp} as a function of p_e



Time based deviation chart for:
 t_{exhv} and p_{comp}

M / V	Engine Type		No.	Checked by:
Yard	Builder	Built year	Time based Deviation Charts	Date:

40
20
0
-20

°C

t_{exhv} deviation

Running hours

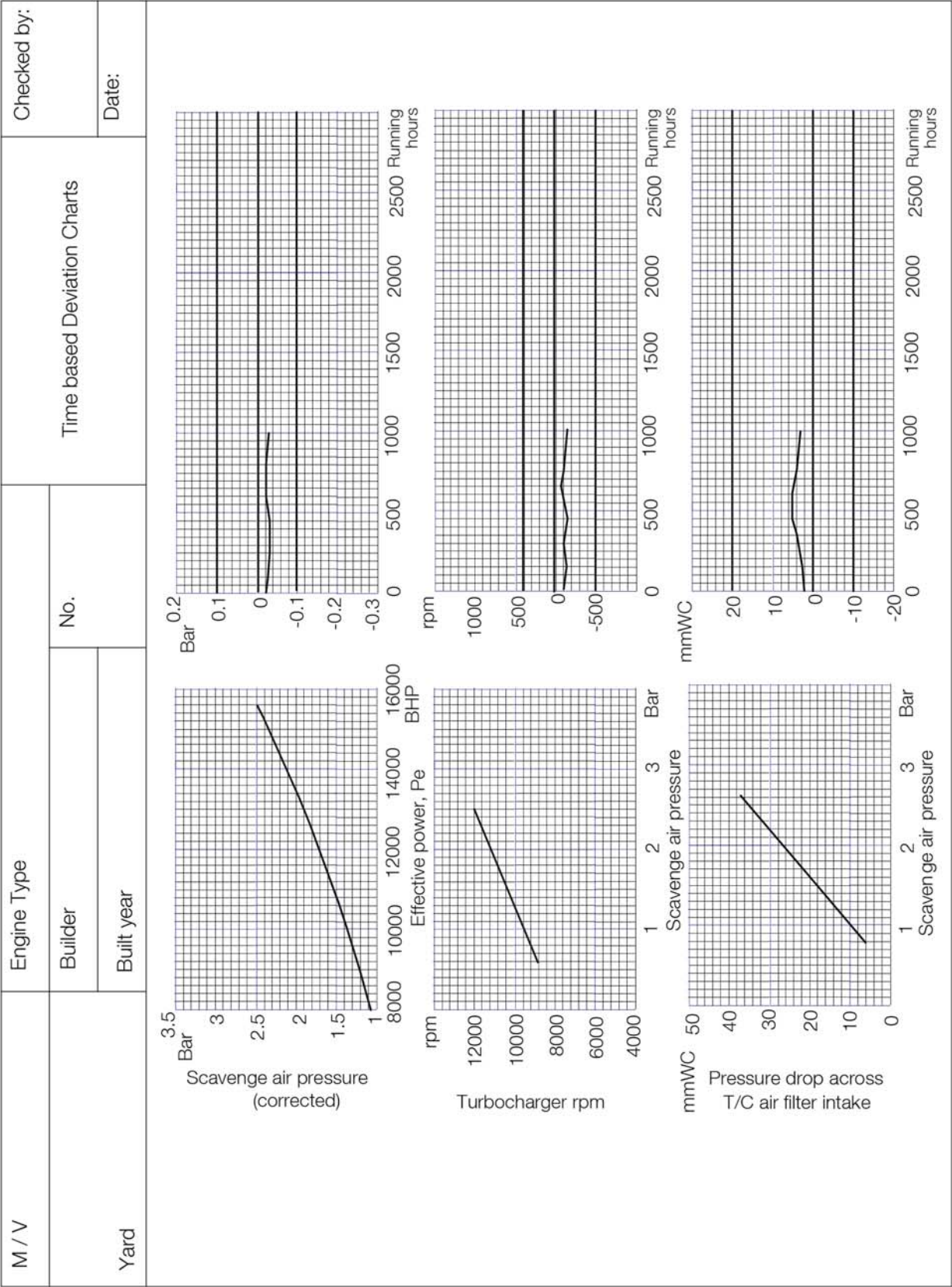
Bar

3
0
-3

p_{comp} deviation

Running hours

Model curves and time based deviation chart for:
 p_{scav} as a function of p_e T/C r/min and Δp_f as a function of p_{scav}



Time based deviation chart for:
 p_{scav} T/C r/min and Δp_f

M / V	Engine Type		Time based Deviation Charts		Checked by:
Yard	Builder	No.	Date:		
	Built year				

Bar
0.2
0.1
0
-0.1
-0.2
-0.3

Pscav deviation

Running hours

rpm
1000
500
0
-500

T/C rpm deviation

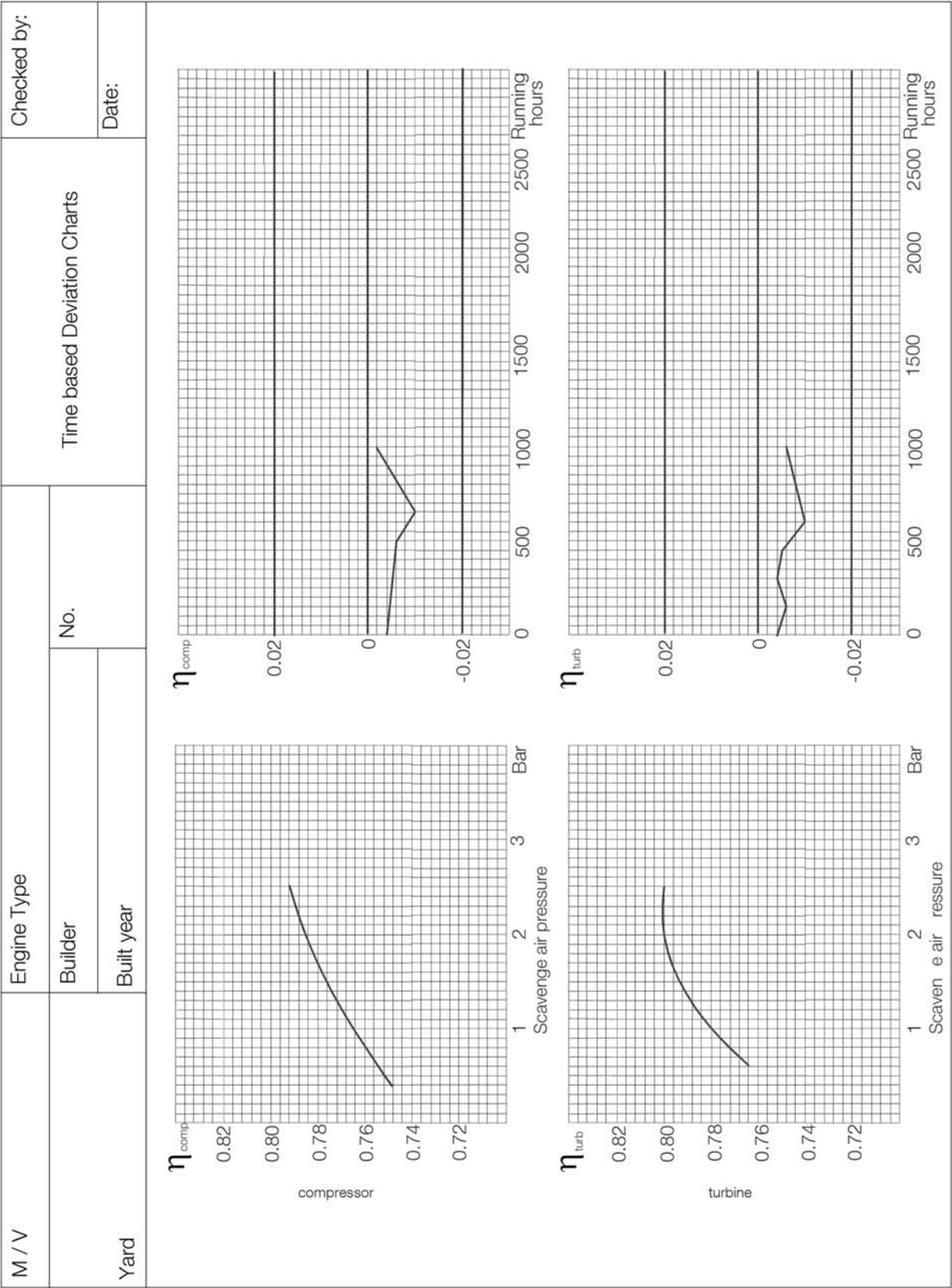
Running hours

mmWC
20
10
0
-10
-2

T/C air filter
 Δp_f deviation

Running hours

Model curves and time based deviation chart for:
Compressor and turbine efficiencies as a function of p_{scav}



Synopsis Diagrams - for turbocharger (Pscav - Compressor)

Drawing
6355-0140-0002

Time based deviation chart for:
compressor and turbine efficiencies

M / V	Engine Type		Time based Deviation Charts	Checked by:	
	Builder	No.		Date:	
Yard		Built year			

η_{comp}

0.02

0

-0.02

Compressor efficiency deviation

Running hours

η_{turb}

0.02

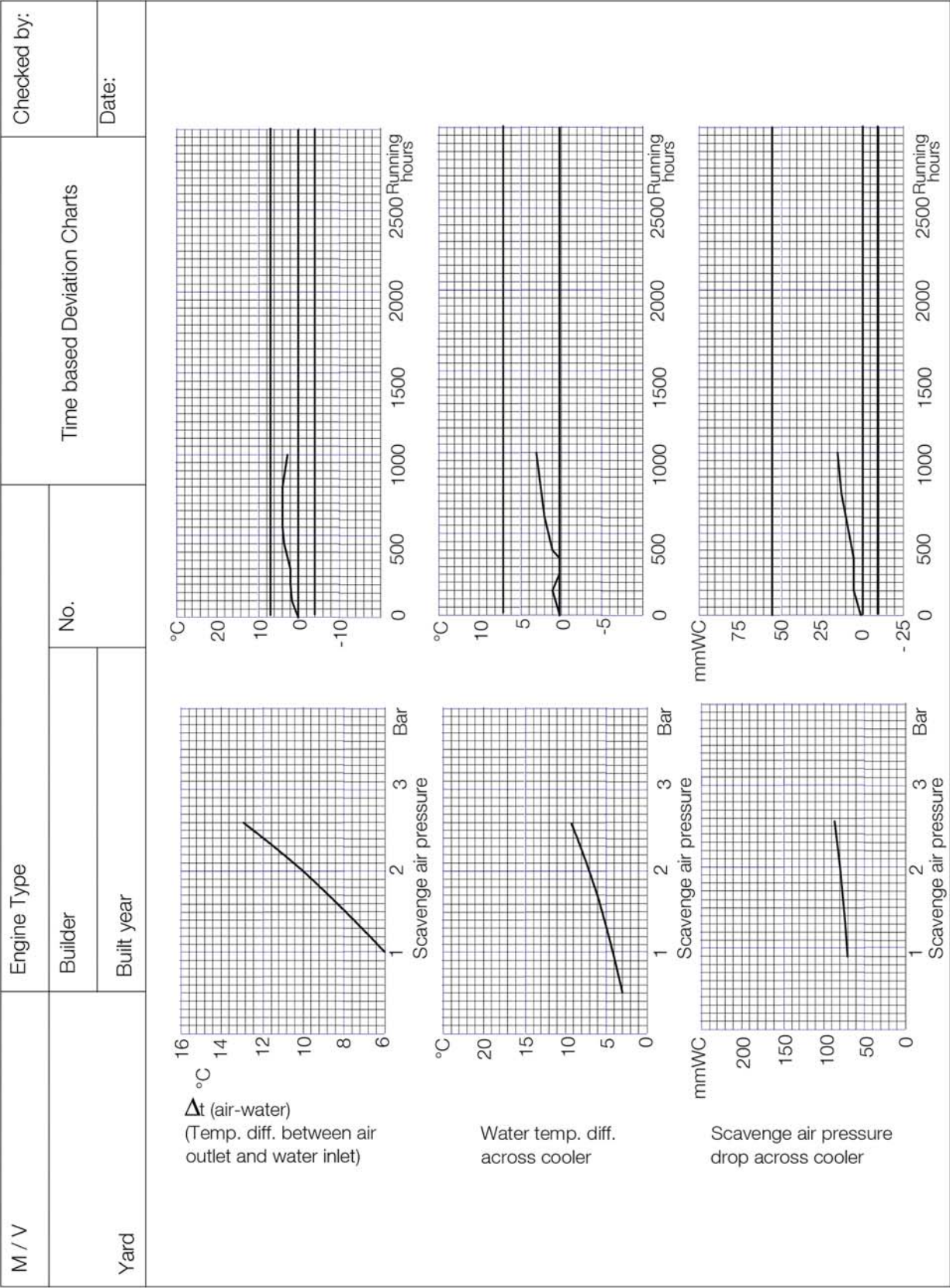
0

-0.02

Turbine efficiency deviation

Running hours

Model curves and time based deviation chart for:
 $t_{\text{air-water}}$, t_{water} and p_{air} , as a function of p_{scav}



Time based deviation chart for:
 $\Delta t_{\text{air-water}}$ Δt_{water} and Δp_{ai}

M / V	Engine Type		Time based Deviation Charts	Checked by:
	Builder	No.		Date:
Yard	Built year			

$\Delta t_{\text{air-water}}$ deviations

°C

20

10

0

-10

Running hours

Δt_{water} deviations

°C

10

5

0

-5

Running hours

Δp_{air} deviations

mmWC

75

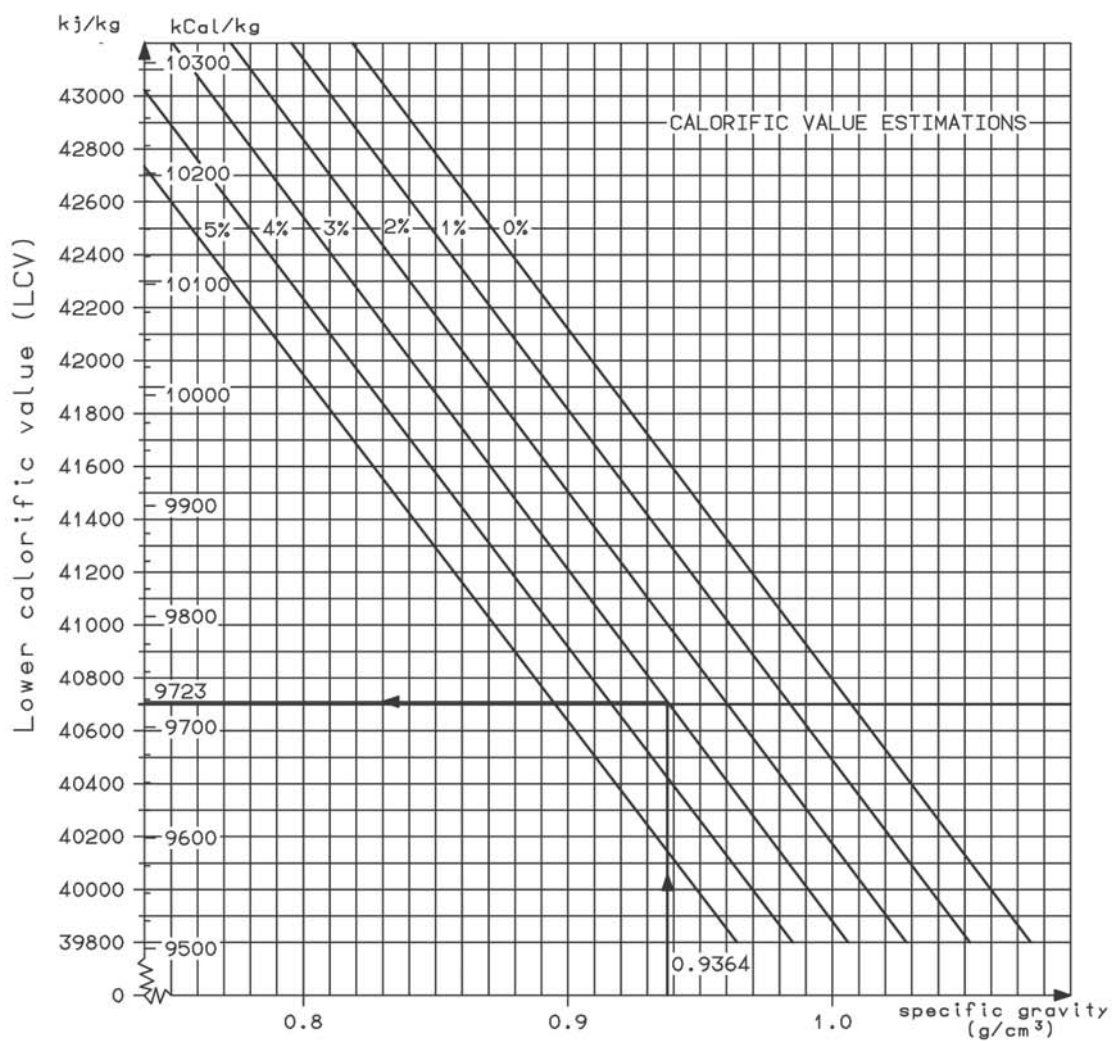
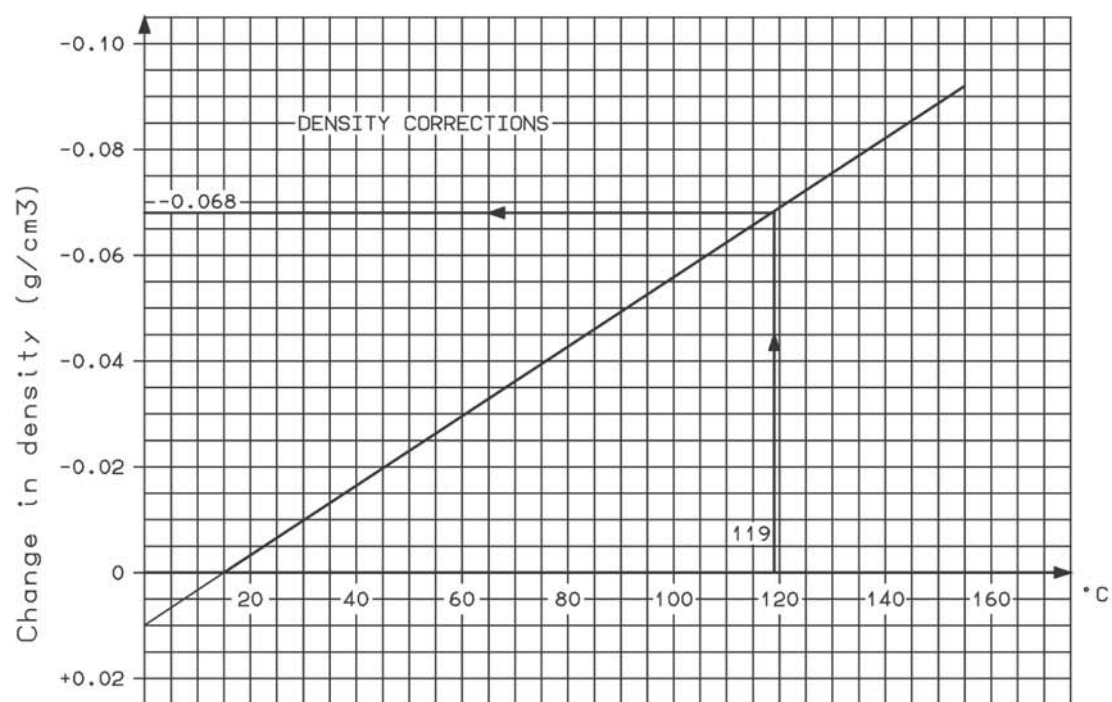
50

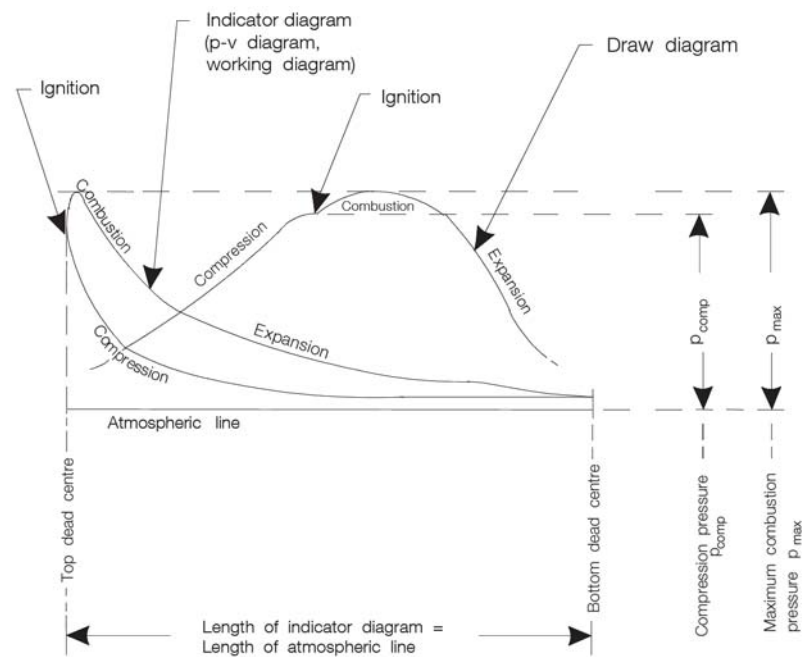
25

0

-2

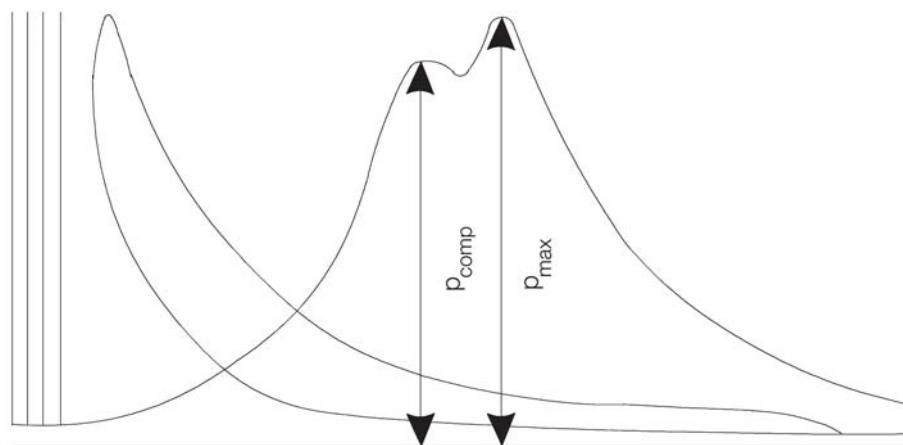
Running hours



K/L-MC Engines:**S-MC Engines:**

For this type of engine it has been necessary to delay the point of ignition to 2 - 3° after TDC, in order to keep the pressure rise, $p_{comp} - p_{max}$, within the specified 35 bar, while still maintaining optimum combustion and thereby low SFOC.

Due to this delay in ignition, the draw diagram will often show two pressure peaks, as shown in the figure below.

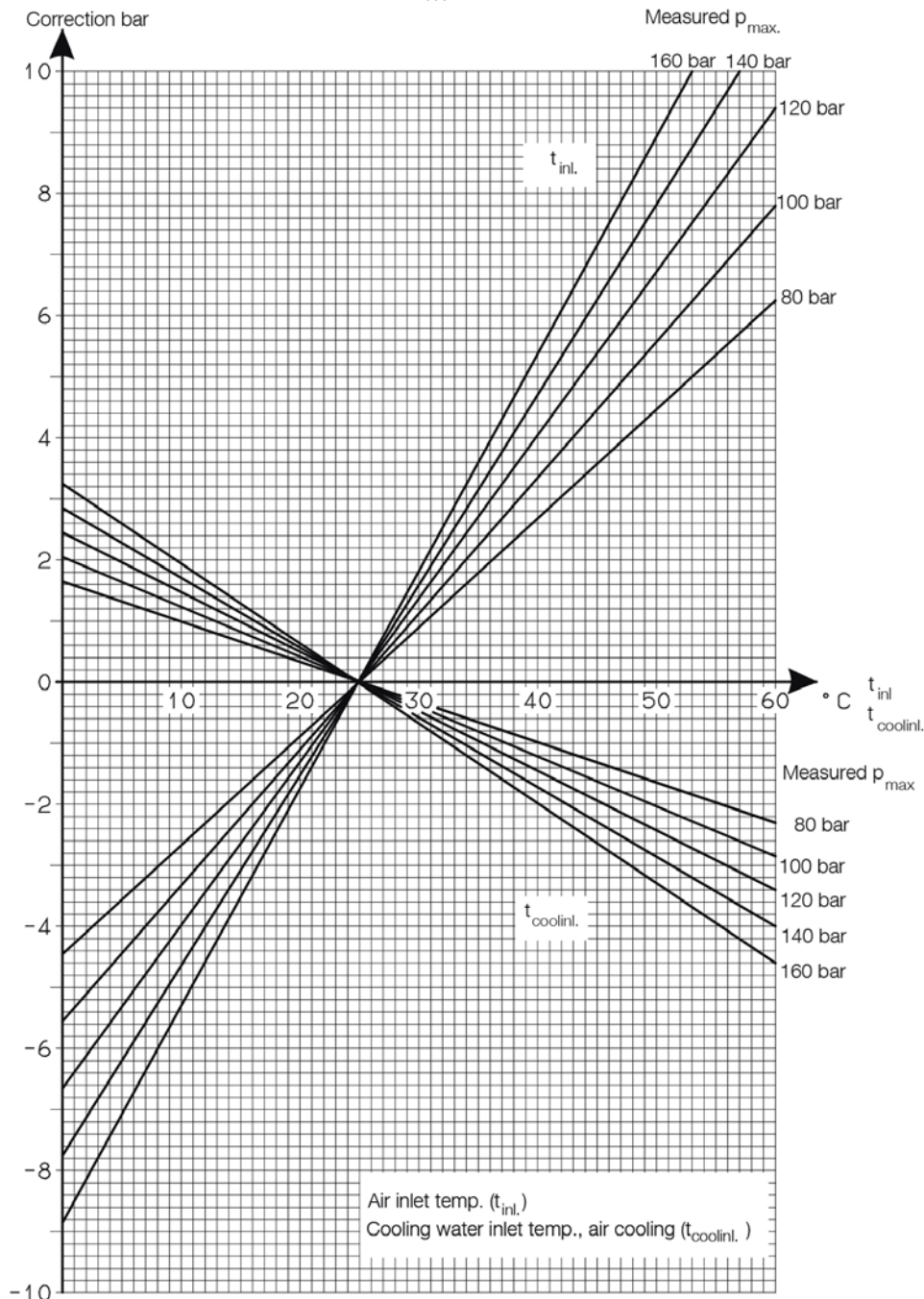


Normal Indicator Diagram

Drawing
6355-0155-0001

Maximum Combustion Pressure

Correction of measured $p_{\max}$
because of deviations between $t_{\text{inl}} / t_{\text{coolinl}}$ and standard conditions



Calculating the corrections:

$$t_{\text{inl}}: A_{\text{corr}} = (t_{\text{meas}} - 25) \times 2.198 \times 10^{-3} \times (1 + A_{\text{meas}}) \text{ Bar}$$

$$t_{\text{coolinl}}: A_{\text{corr}} = (t_{\text{meas}} - 25) \times -0.810 \times 10^{-3} \times (1 + A_{\text{meas}}) \text{ Bar}$$

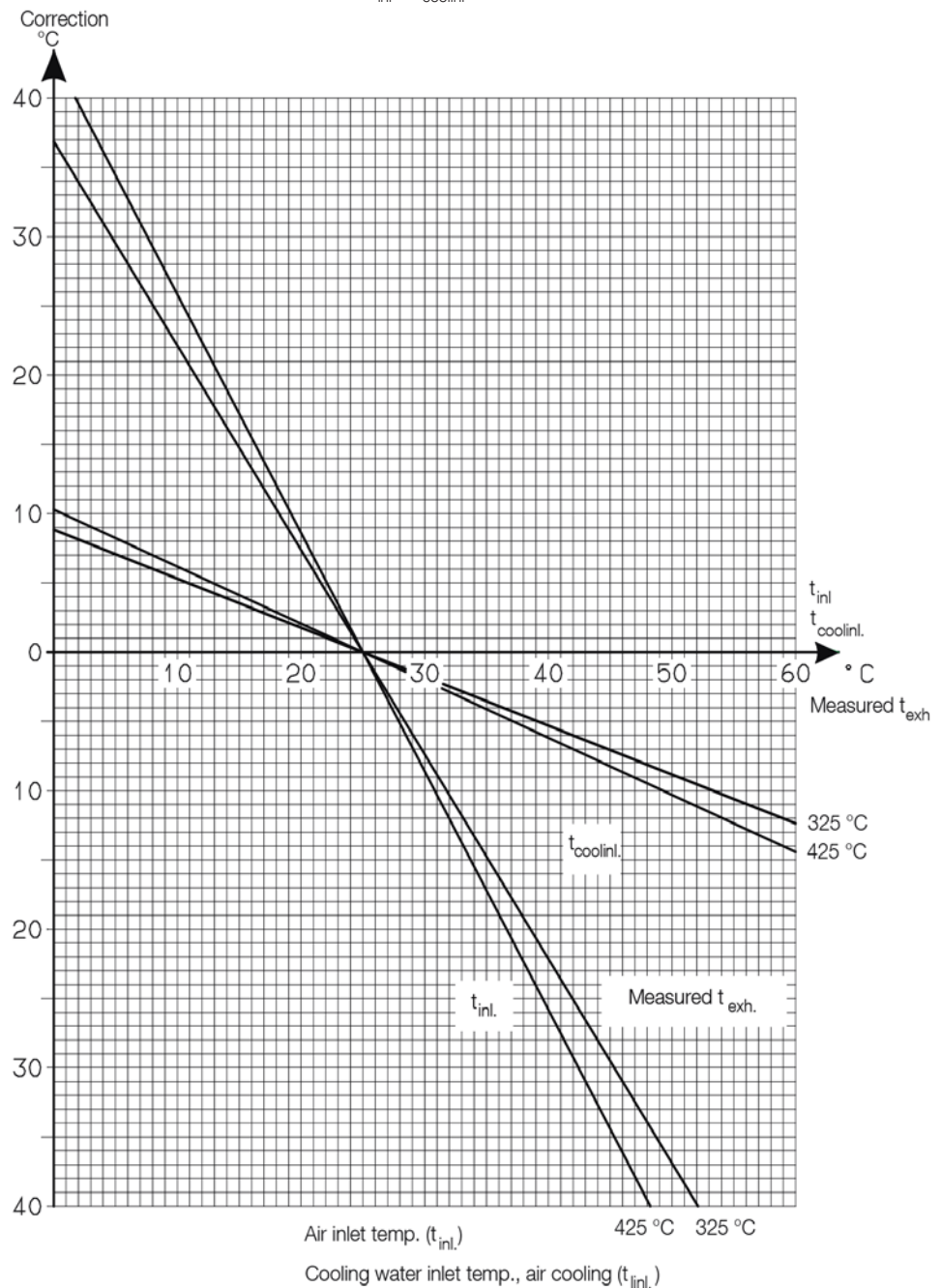
See page 5.

Correction to ISO Reference Ambient Conditions

Drawing
6355-0180-0003

Exhaust Temperature (after exhaust valves)

Correction of measured exhaust temperature (t_{exh})
because of deviations between $t_{\text{inl}} / t_{\text{coolinl}}$ and standard conditions



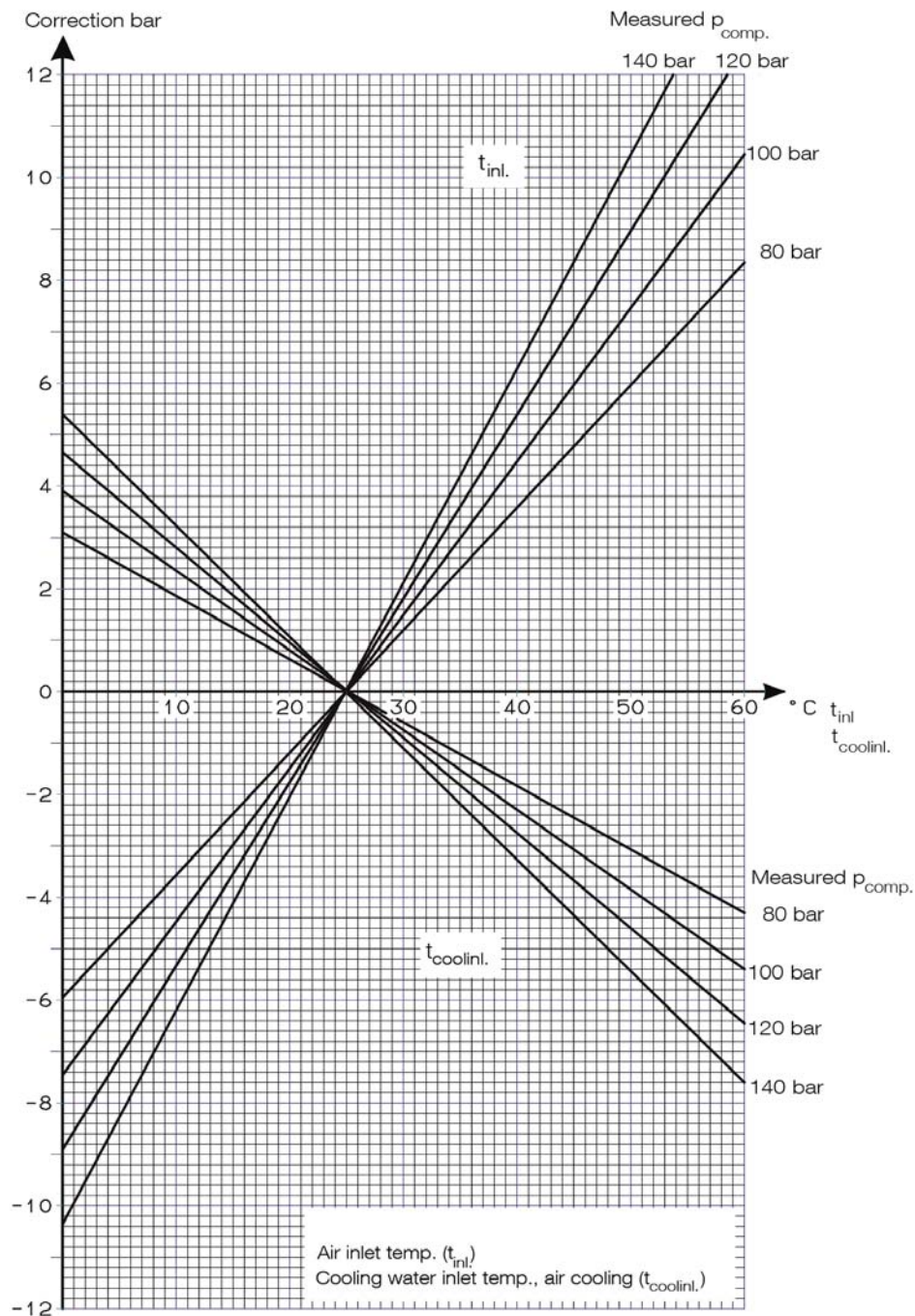
Calculating the corrections:

$$t_{\text{inl}} : A_{\text{corr}} = (t_{\text{meas}} - 25) \times 2.466 \times 10^{-3} \times (273 + A_{\text{meas}}) \text{ °C}$$

$$t_{\text{coolinl}} : A_{\text{corr}} = (t_{\text{meas}} - 25) \times -0.590 \times 10^{-3} \times (273 + A_{\text{meas}}) \text{ °C}$$

See page 5.

Maximum Combustion Pressure

Correction of measured $p_{\max}$ because of deviations between $t_{\text{inl.}} / t_{\text{coolinl.}}$ and standard conditions

Calculating the corrections:

$$t_{\text{inl.}} : A_{\text{corr}} = (t_{\text{meas}} - 25) \times 2.954 \times 10^{-3} \times (1 + A_{\text{meas}}) \text{ Bar}$$

$$t_{\text{coolinl.}} : A_{\text{corr}} = (t_{\text{meas}} - 25) \times -1.530 \times 10^{-3} \times (1 + A_{\text{meas}}) \text{ Bar}$$

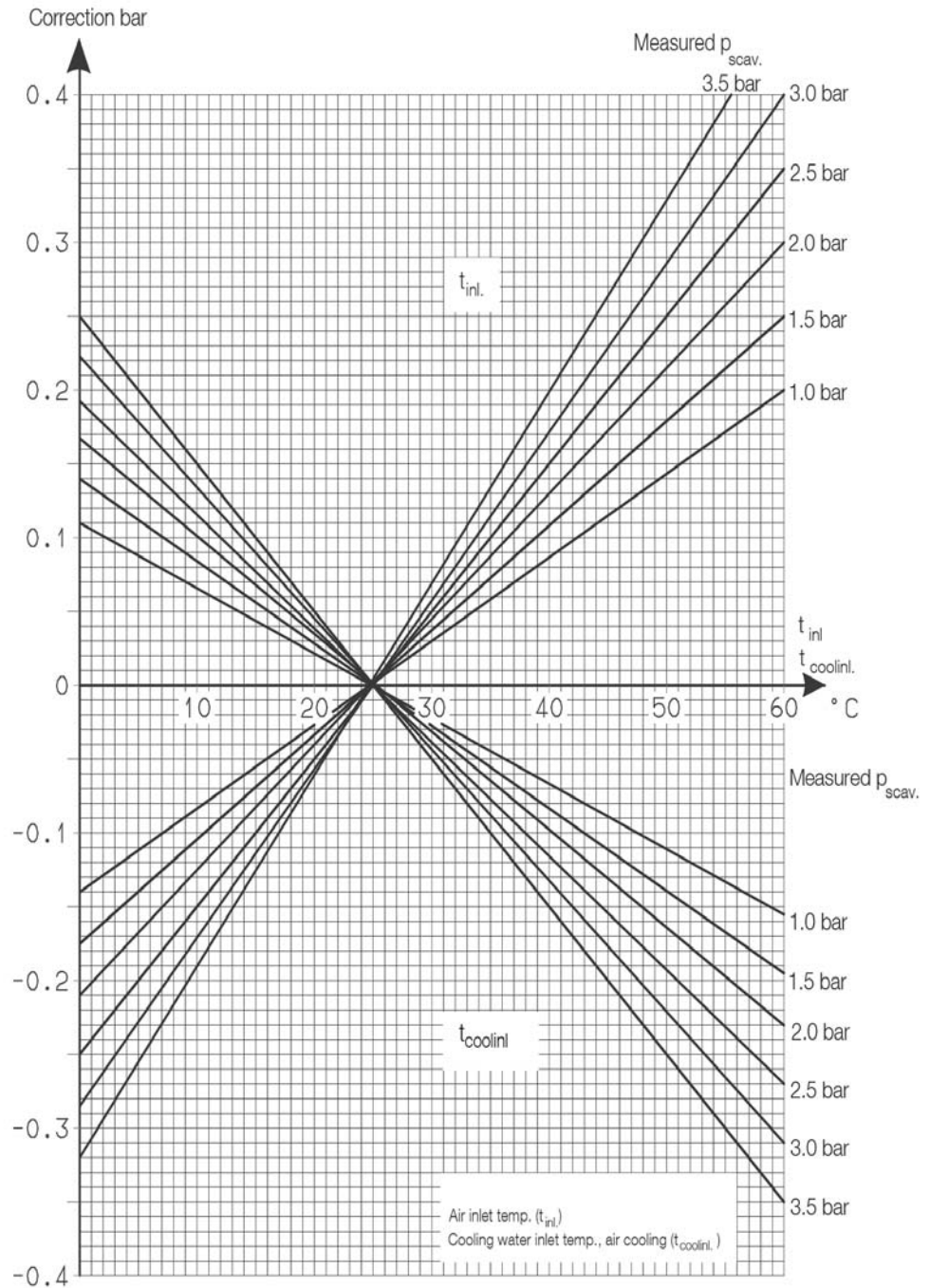
See page 5.

Correction to ISO Reference Ambient Conditions

Drawing
6355-0180-0003

Scavenge Pressure

Correction of measured scavenge pressure
because of deviations between $t_{inl} / t_{coolinl}$ and standard conditions



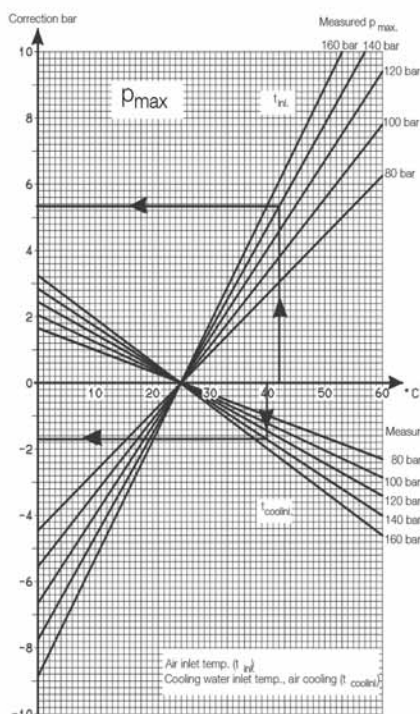
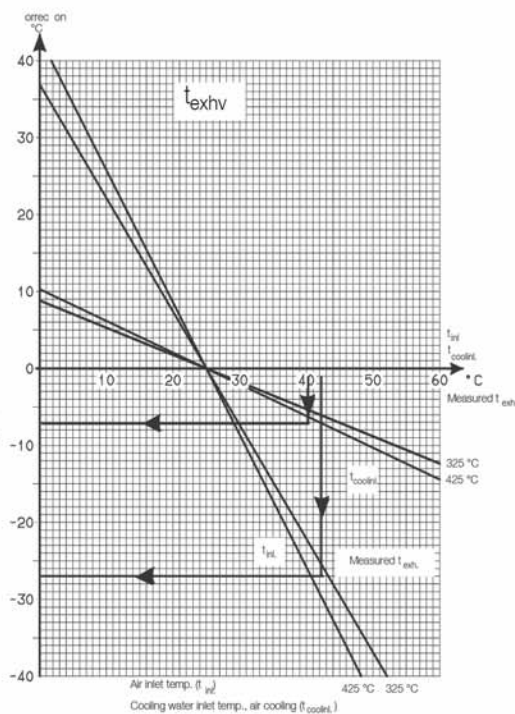
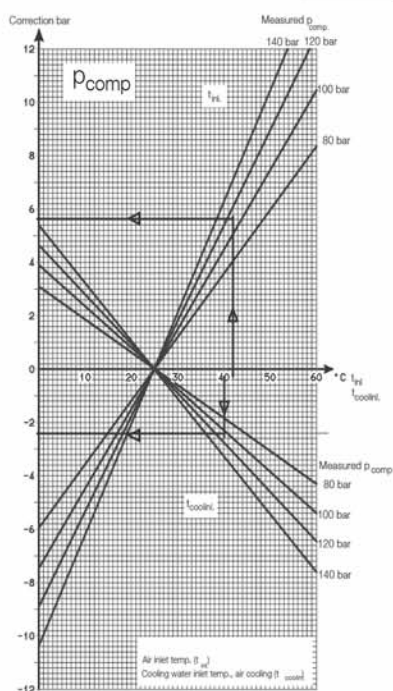
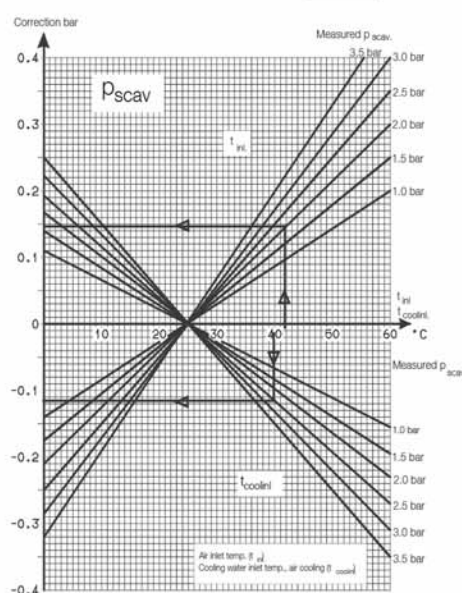
Calculating the corrections:

$$t_{inl}: A_{corr} = (t_{meas} - 25) \times 2.856 \times 10^{-3} \times (1 + A_{meas}) \text{ Bar}$$

$$t_{coolinl}: A_{corr} = (t_{meas} - 25) \times -2.220 \times 10^{-3} \times (1 + A_{meas}) \text{ Bar}$$

See page 5.

Example of readings:

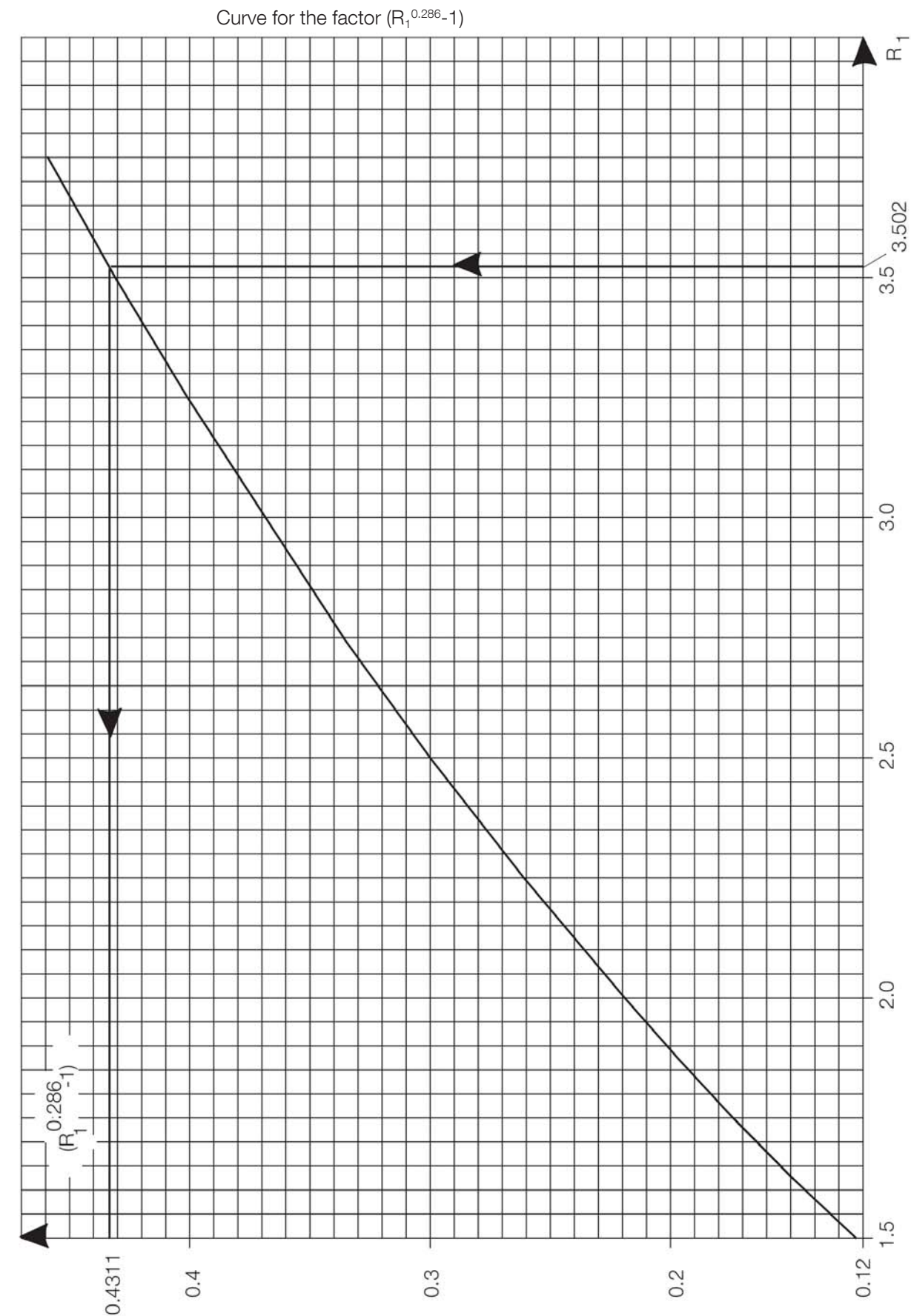
 $p_{\max}$: 140 bar p_{scav} : 2.0 bar t_{exhv} : 425 °C t_{inl} : 42 °C p_{comp} : 110 bar p_{coolinl} : 40 °CCorrection for t_{inl} : +5.3 barCorrection for t_{coolinl} : -1.7 barCorrection 5.3 - 1.7 : +3.6 barCorrection for t_{inl} : -27 °CCorrection for t_{coolinl} : -6 °CCorrection -27 - 6 : -33 °CCorrection for t_{inl} : +5.6 barCorrection for t_{coolinl} : -2.5 barCorrection 5.6 - 2.5 : +3.1 barCorrection for t_{inl} : +0.145 barCorrection for t_{coolinl} : -0.1 barCorrection 0.145 - 0.1 : +0.045 bar

Correction to ISO Reference Ambient Conditions

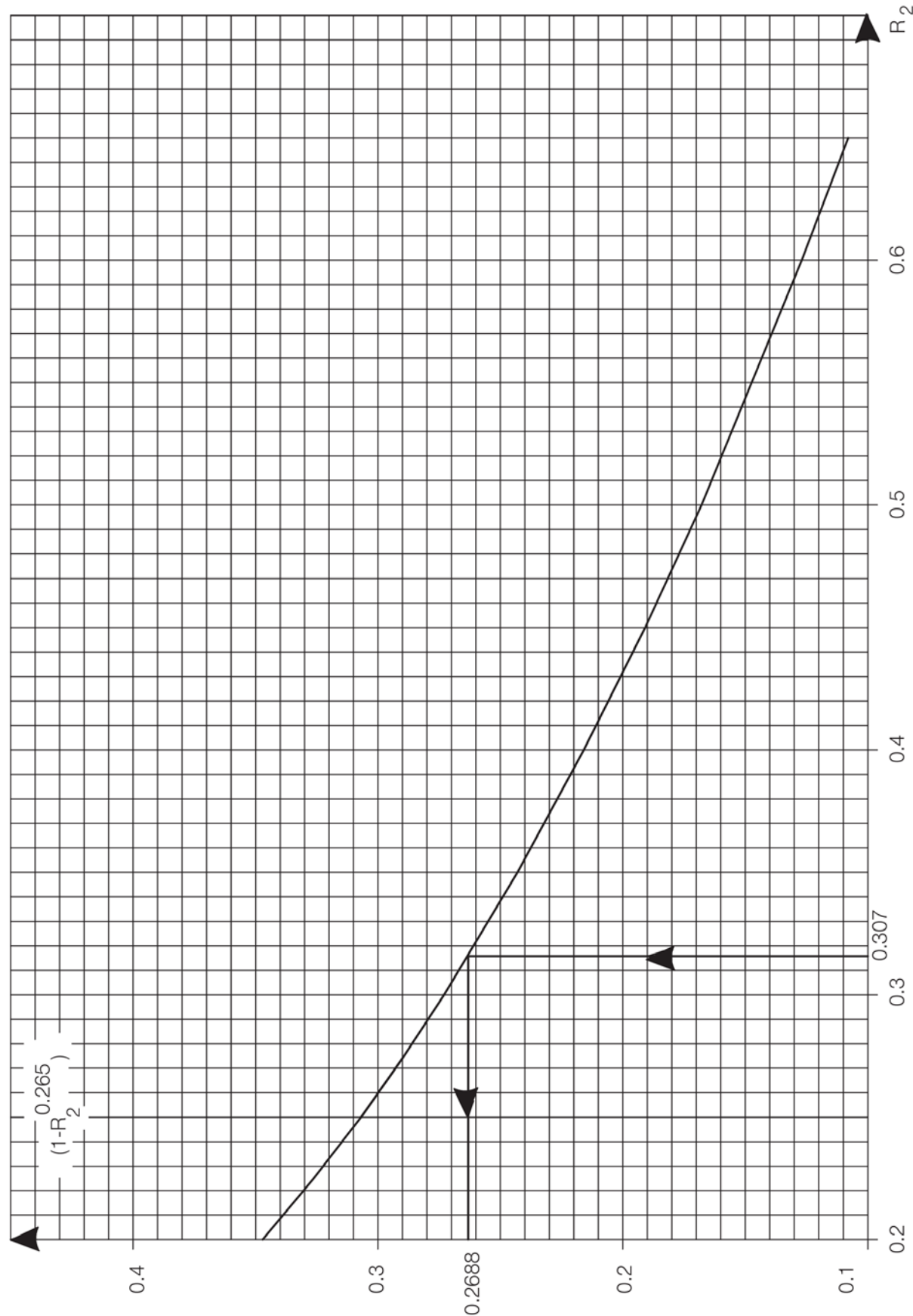
Drawing

6355-0180-0003

2013-10-21 - en



Curve for the factor $(1 - R_2^{0.265})$



Calculation of Total Turbocharger Efficiency

Drawing
6355-0210-0001

Power Estimation

Drawing
6355-0215-0002



Turbocharger Make: MAN Diesel & Turbo		
Type Designation	Diameter, D(m)	Slip Factor μ
TCR18	0.264	0.727
TCR20	0.318	
TCR22	0.415	
TCA44	0.449	0.745
TCA55	0.533	
TCA66	0.633	
TCA77	0.752	
TCA88	0.893	

Turbocharger Make: Mitsubishi H.I. (MET)						
Type Designation	Diameter, D(m)		Slip Factor μ			
Impeller Profile	All		V, Z, W		S, O or R	
Impeller Size	2	3	2	3	2	3
MET33SD,SE	0.352	0.373	0.72		0.69	
MET42SD,SE	0.436	0.462				
MET53SD,SE	0.553	0.586				
MET60MA		0.652				
MET66SD,SE	0.689	0.730				
MET71SE		0.790				
MET83SD,SE	0.873	0.924				
MET90SE		1.020				

Turbocharger Make: ABB TPL					
Type Designation	Diameter, D(m)	Slip Factor μ	Type Designation	Diameter, D(m)	Slip Factor μ
TPL65-A10	0.3390	0.69	VTR254	0.2943	0.77
TPL69-BA10	0.3999		VTR304	0.3497	
TPL73-B11	0.4879		VTR354	0.4157	
TPL73-B12	0.5065		VTR454D-VA12	0.5233	
TPL77-B11	0.5799		VTR454D-VA13	0.5756	
TPL77-B12	0.6020		VTR564D-VA12	0.6588	
TPL80-B11	0.6729		VTR564D-VA13	0.7247	
TPL80-B12	0.6985		VTR714D-VA12	0.8294	
TPL85-B11	0.8239		VTR714D-VA13	0.9123	
TPL85-B12	0.8553				
TPL91-B12	0.9430				

Preface Chapter
Description

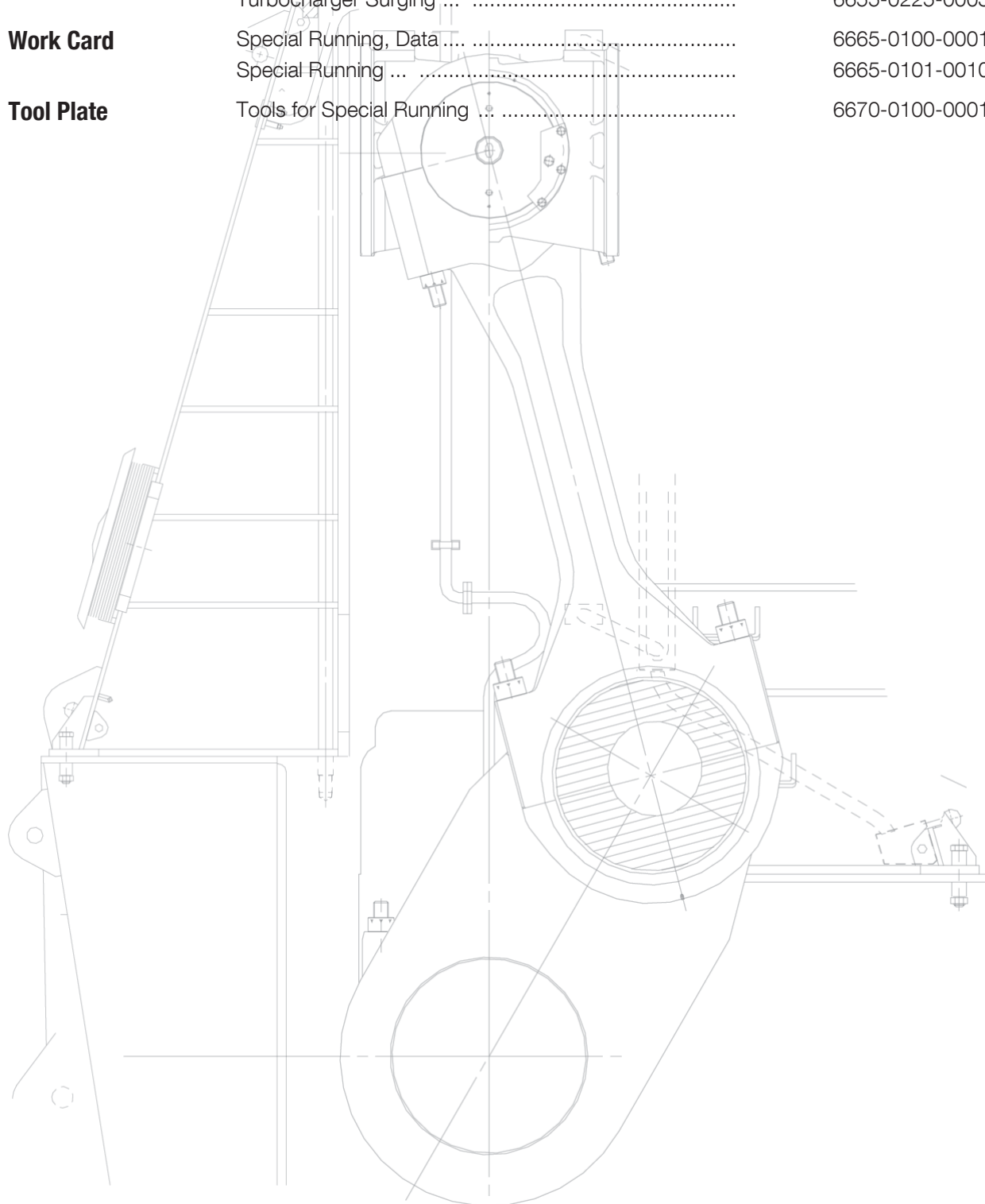
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Operation

This chapter of the instruction book is intended to provide the user with information regarding operation of the engine. Information includes starting, running and stopping of the engine as well as descriptions of special running conditions.

1 General

The present chapter describes how to check up on the condition of the engine while it is at a standstill.

To keep the engine-room staff well informed regarding the operational condition, we recommend recording the results of the inspections in writing.

The checks mentioned below follow a sequence which is suited to a forthcoming period of major repairs.

Checks 2.1-2.9

- should be made regularly at engine standstill during normal service.

Checks 2.1 to 2.9 should be coordinated and evaluated together with the measurements described in: *description 6345-0310, 'Engine Synopsis'*.

Checks 3.1-3.5

- should be made at engine standstill *during* the repairs.

Checks 4.1-4.7

- should be made at engine standstill *after* the repairs.

If repair or alignment of bearings, crankshaft, camshaft or pistons has been carried out, repeat checks 2.1, 2.2 and 2.6.

Checks to be made just before starting the engine are mentioned in *description 6645-0110*.

2 Regular Checks at Engine Standstill during Normal Service

The work should be adapted to the sailing schedule of the ship, such that it can be carried out at suitable intervals – for instance as suggested in the 'Checking and Maintenance Schedule'.

See Maintenance Schedule 0760-0300.

The maintenance intervals stated therein are normal for sound machinery. If, however, a period of operational disturbances occurs, or if the condition is unknown due to repairs or alterations, the relevant inspections should be repeated more frequently.

Based upon the results of Checks 2.1-2.9, combined with performance observations, it is determined if extra maintenance work (other than that scheduled) is necessary.

2.1 Oil Flow

While the circulating oil pump is still running and the oil is warm, open up the crankcase and check that the oil is flowing freely from all crosshead, crankpin and main bearings.

The oil jets from the axial oil grooves in the crosshead bearing lower shells should be of uniform thickness and direction. Deviations may be a sign of "squeezed white-metal" or clogged-up grooves, *See description 2545-0100*.

By means of the sight glasses at the piston cooling oil outlets, check that the oil is passing through the pistons.

Check also the thrust bearing and step-up gear lubrication.

NOTICE

After a major overhaul of pistons, bearings, etc., this check 2.1 should be repeated before starting the engine.

2.2 Oil Pan, and Bearing Clearance

After stopping the circulating oil pump, check the bottom of the oil pan for fragments of white metal from the bearings.

Check crosshead, crankpin, main bearing and thrust bearing clearances with a feeler gauge, and note down the values, as described in *description 2545-0100*.

2.3 Filters

Open up all filters, (also automatic filters), to check that the wire gauze and/or other filtering material is intact, and that no foreign bodies are found, which could indicate a failure elsewhere.

2.4 Scavenge Port Inspection

Inspect the condition of the piston rings, cylinder liners, pistons, and piston rods, as detailed in *description 2245-0100*.

Note down the conditions as described in *description 2245-0100*.

During this inspection, circulate the cooling water and cooling oil through the engine so that leakages, if any, can be discovered.

Remove any coke and sludge from the scavenge air ports and boxes.

(In case of prolonged port calls or similar, follow the precautions mentioned in point 4.2).

2.5 Exhaust Receiver

Open up the exhaust receiver and inspect for deposits and/or any metal fragments, (which could indicate a failure elsewhere). Examine also the gas grid to make sure that it is clean and undamaged.

2.6 Crankshaft

Take deflection measurements as described in *description 2545-0110*.

2.7 Circulating Oil Samples

Take an oil sample and send it to a laboratory for analysis and comments.
See description 3045-0130.

2.8 Turbocharger

Unscrew the drain plugs or open the cocks at the bottom of the turbocharger housings. Also drain from the drain box/pipe in the exhaust gas uptake (also used when cleaning the exhaust gas evaporator).

This prevents the possible accumulation of rain water, which could cause corrosion in the gas ducts, and partial wash-off of soot deposits, which again may result in unbalance of the turbocharger rotor.

Open inspection covers (if fitted) or remove the gas inlet pipe on the turbine side of the charger, and check for deposits on the turbine wheel and nozzle ring.

See Check 4.4 regarding precautions to avoid turbocharger bearing damage during engine standstill.

2.9 Regular tests of the ME control system

Most failures will be indicated by alarms or malfunction during daily use (malfunction which will not prevent continuous safe operation)

However the following tests listed below have to be carried out regularly in service, to secure proper operation and keeping the redundancy.

The tests are:

1. LOP lamp test.
2. Test of the pilot valves to the main start valve.
3. Function test of cylinder start valves.
4. Start up pumps.
5. HCU Safety by-pass.
6. Test of shut down signals to all MPC units.
7. Cylinder lubricator level sensor slow down function.
(For plant with level sensor, flow sensor is tested automatically)
8. Leakage test of the hydraulic system.
9. Leakage test of pipes and alarm function (Hydraulic oil system).
10. Visual inspection of the inside of the electronic boxes and check of the tightening torque of the terminals.

See table on the next pages.

Test	When	Preconditions and initial state	Action	Expected result
1	Weekly	Stopped Engine	Press the lamp test bottom and confirm that the light is on in all lamps (after some time).	
2	After arrival in Port	Stopped Engine Permission from the bridge before FWE	Activate the pilot valves one by one via the MOP-Screen: 'Maintenance -> System View I/O Test -> CCUX -> Change MPC mode to TEST mode -> Wait until the screen has changed to TEST mode -> Ch. 50.'. By toggle the input to the pilot valve on this screen, is it possible to hear the solenoid valve moving. When the test is completed the MPC mode must be set back to NORMAL mode. Please see MOP description -> 'Maintenance' -> 'System View I/O Test'. <i>See drawing: 7055-0155 pos. 26.</i> This test is to be made together with the cylinder starting valves test 3.	
3	After arrival in Port	Stopped Engine Permission from the bridge before FWE	Make a manual Slow Turn and Air run, via the MOP-Screen: 'Engine Operation', both more than one revolution. Confirm by visual inspection that the rotation has the same regularity during the full revolution.	
4	Monthly		Change master pump via the MOP-Screen: 'Auxiliaries -> Hydraulic System'.	
5	Every 6 month	Engine stopped. MOP Access level = Chief HPS Mode = manual Start-up pumps running.	Open manual connection valve 316 (P1-P2) From MOP-Screen: 'Auxiliaries -> Hydraulic System':	
			- Open Pump Bypass from ACU1	Pressure drops towards zero
			- Close Pump Bypass from ACU1	Pressure increases to 230 bar
			- Open Pump Bypass from ACU3	Pressure drops towards zero
			- Close Pump Bypass from ACU3 NOTE: Valve 316 must be closed after the test is completed.	Pressure increases to 230 bar
6	Every 6 month	Engine stopped	Activate emergency stop, check that both ECUA, ECUB and all CCU's gives alarm for shut down. MOP-Screen: 'Alarms -> Alarm List'.	
7	Every 6 month	Engine stopped	Close the manual valve for lube oil supply on all cylinders and activate from the MOP-Screen: 'Auxiliaries -> Cylinder Lubrication' the Lubricator Test Sequence for all cylinders. NOTE: Lubricator Test Sequence must be All Off when checked	Cylinder lube oil alarm for all cylinders. Slow Down request activated.
8	Every 6 month		<i>See work card 4565-0301.</i>	

Test	When	Preconditions and initial state	Action	Expected result
9	Every 6 month		<i>See work card 4565-0301.</i>	
10		Engine in standby	<i>See work card 4265-2301.</i>	
11		Engine stopped	As described above. <i>See chapter 0545-0100 Safety Precautions</i> regarding general cleanliness, order and tidiness.	

3 Checks at Engine Standstill during Repairs

3.1 Bolts, Studs and Nuts

Check all bolts, studs and nuts in the crankcase and chain casing to make sure that they have not worked loose.

The same applies to the holding-down bolts in the bedplate. Check that side and end chocks are properly positioned.
See work card 1065-0201.

Check all locking devices.
See work card 7665-0501.

3.2 Leakage and Drains

Remedy any water or oil leakages. Clean drain and vent pipes of possible blockages by blowing-through.

3.3 Pneumatic Valves in the Control Air System

Clean the filters.

3.4 Bottom Tank

If not done within the previous year, pump the oil out of the bottom tank and remove the sludge. After brushing the tank ceiling (to remove rust and scale), clean the tank and coat the ceiling with clean oil.

After brushing the tank ceiling (to remove rust and scale), clean the tank and coat the ceiling with clean oil.

4 Checks at Engine Standstill after Repairs

If repair or alignment of bearings, crankshaft, camshaft or pistons has been carried out, repeat Checks 2.1, 2.2 and 2.6.

4.1 Flushing

If during repairs (involving opening-up of the engine or circulating oil system) sand or other impurities could have entered the engine, flush the oil system while bypassing the bearings, as described in *description 3045-0130*. Continue the flushing until all dirt is removed.

4.2 Piston Rods

If the engine is to be out of service for a prolonged period, or under adverse temperature and moisture conditions, coat the piston rods with clean oil, and turn the engine while the circulating oil pump is running.

Repeat this procedure regularly in order to prevent corrosion attack on piston rods and crankcase surfaces.

4.3 Turning

After restoring normal oil circulation, check the movability of the engine by turning it one or more revolutions using the turning gear.

NOTICE

Before leading oil to the exhaust valve actuators, via the main lube oil pump, check that air supply is connected to the pneumatic pistons of the exhaust valves, and that the exhaust valves are closed.
See description 6645-0110.

4.4 Turbocharger

Mount the drain plugs, (or close the cocks) and re-fit the inspection covers.

Make sure that the turbocharger shafts do not rotate during engine standstill, as the bearings may suffer damage if the shafts rotate while the lube oil supply is stopped.

4.5 Cylinder Lubricators

Check that all pipe connections and valves are tight.

Press the 'Lubricator Test Sequence' button on the MOP and inspect that all LED's for feedback indication on the intermediate boxes are flashing. This indicates that the lubricators are functioning correctly. If in doubt, dismantle the pipe at the cylinder liner to observe the oil flow.
See description 6645-0260.

4.6 Air Cooler

With the cooling water pump running, check if water can be seen through the drain system sight glass or at the small drain pipe from the water mist catcher.

If water is found, the cooler element is probably leaking. In that case the element should be changed or repaired.

5 Laid-up Vessels

During the lay-up period, and also when preparing the engine for a long time out at service, we recommend that our special instructions for preservation of the main engine are followed.

General Introduction

The following descriptions cover the standard manoeuvring system for the engine.

Since the manoeuvring and hydraulic system supplied for a specific engine may differ from the standard system, 'Plant Installation Drawings' should always be consulted when dealing with questions regarding a specific plant.

See description 4245-0120 regarding correct fuel oil temperature before starting.

Regarding checks to be made before starting, when cylinders are out of operation, see description 6645-0320.

1 Compressed Air Systems

- Drain water, if any, from the starting air system. *See drawing 3455-0100.*
- Drain water, if any, from the control air system at the receivers.
- Pressurise the compressed air systems. Check the pressures.
See description 0545-0100. 'Safety Precautions'.
- Pressurise the compressed air system to the air cylinders (air springs) on the exhaust valves.



Compressed air pressure must be applied **before the lube oil pump is started. This is necessary to prevent the exhaust valves from opening too much.**

See description 6645-0100.

The exhaust valve activation is controlled by the FIVA valve. Each open and close movement, performed by the exhaust valve spindle is measured by the ECS. The actual mechanical delay is determined and used for the next activation. The ECS tells whether an exhaust valve is open or closed. The exhaust valves must be closed when the engine has been stopped for some time.

2 Lube Oil Systems

1. Start the lube oil pumps for:
 - The engine
 - Turbochargers

If the turbochargers are equipped with a separate, built-in, lubrication system, check the oil levels through the sight-glasses.

Check the oil pressures.

See description 7045-0100.

2. Check the oil flow, through the sight-glasses, for:

- Piston cooling oil
 - Turbochargers
3. Check that the cylinder lubricators are filled with the correct type of oil.
See drawing 2255-0125.



If the sub-telegraph state is in STAND-BY, the ECS will initiate a pre-lubrication sequence, by the cylinder lubricators, when the MOP button PREPARE START is pressed.

3 Cooling Water Systems



The engine must **not** be started if the jacket cooling water temperature is below 20°C.

Preheat to minimum 20°C or, preferably, to 50°C.
See descriptions 6645-0130 and 6645-0170.

- Start the cooling water pumps.
- Check the pressures.
See description 7045-0100.

4 Slow-Turning the Engine

This must be carried out to prevent damage caused by fluid in one of the cylinders.

Before beginning the slow-turning, obtain permission from the bridge.

NOTICE

Always carry out the slow-turning at the latest possible moment before starting and, under all circumstances, within the last 30 minutes if it is more than 30 minutes since last rotation and the engine is in STAND-BY mode, at control room or bridge control, the slow turn is performed automatically.

The slow turning device is standard on ME-engines, and the slow turning follows item 4.1. However it is still possible to turn the engine manually with the turning gear. See item 4.2.

4.1 Slow-turn with Slow-Turning Device

1. Disengage the turning gear.
Check that it is locked in the out position.
On the MOP Screen 'Engine > Status' check that the turning gear status is 'Disengaged'.
2. Change the sub-telegraph state from FINISHED WITH ENGINE to STAND-BY.
3. Lift the locking plate of the main starting valve to the SERVICE position.
Check the indicator lamp.
 - The locking plate must remain in the upper SERVICE position during running.
 - The locking plate must remain in the lower BLOCKED position during repairs.
4. Open the indicator valves.
5. On the MOP Screen 'Engine > Operation' press the 'Prepare Start' button. A pre-lubrication of the cylinders will now be initiated and the auxiliary blowers will start in sequence. Select 'Slow Turn' on the MOP screen when the pre-lubrication is finished.



All personnel must stand clear from the engine before starting the slow turning sequence

6. Move the regulating handle to RUN position. Check to see if fluid flows out of any of the indicator valves.
7. When the engine has turned one revolution, move the regulating handle back to STOP position.
8. On the MOP Screen 'Engine > Operation' select 'Auto'.
9. Close the indicator valves.

4.2 Slow-turn with Turning Gear

1. Ensure that the sub-telegraph state is in FINISHED WITH ENGINE.
2. Open the indicator valves.
3. Engage the turning gear.
4. Turn the engine one revolution with the turning gear.
Check to see if fluid flows out of any of the indicator valves.
5. Close the indicator valves.
6. Disengage the turning gear.
7. Check that it is locked in the out position.
8. On the MOP Screen 'Engine > Status' check that the turning gear status is 'Disengaged'.

5 Fuel Oil System

Regarding fuel oil temp. before starting, see description 4245-0120.

- Start the fuel oil supply pump and circulating pump.
If the engine was running on heavy fuel oil until stop, the circulating pump is already running.

Check the pressures and temperatures.
See description 7045-0100.

6 Hydraulic Power Supply (HPS)

If the HPS is in normal Auto mode, the electrically driven pumps will start when the sub-telegraph state is changed from FINISHED WITH ENGINE to STAND-BY.

The ECS monitors that the oil pressure is correct.

More information about the HPS operation and Manual mode is available here:
Description 6645-0260 Auxiliaries.

7 Scavenge Air

Check that all drain valves from the scavenge air receiver and boxes to tank are open and that test cocks are closed.

See drawing 5455-0100.

If the scavenge air blowers are in normal Auto mode, the blowers will start in intervals of approximately 6 seconds when 'Prepare Start' on the MOP screen is pressed. For more information about the scavenge air system, see:
Description 6645-0260 Auxiliaries.

NOTICE

See the warning of scavenge air box fire due to incorrectly working auxiliary blowers in description 6645-0290.

If the engine has been out of service for some time, starting-up is usually performed as a quay trial.

Prior to this, it must be ascertained that:

- 1: The harbour authorities permit quay trials.
- 2: The moorings are sufficient.
- 3: A watch is kept on the bridge.

The engine is now ready to start.

1 Starting

Start the engine as described in Engine Operation.
See description 6645-0250.

In the event that all power including the UPS backup has been removed from the CCU's (e.g. during docking) the engine will have to turn up to 5 full revolutions before fuel is admitted to the cylinders. This is due to a supervision function in the CCU that validates the function of the exhaust valve before fuel injection is allowed. In order to prevent a start failure due to the supervision function, it is suggested that the engine is turned by the turning gear, by Slow Turn or Air Run for 5 full revolutions before attempting to start the engine on fuel in Auto.



If the engine has been out of service for some time, starting-up is usually performed as a quay trial.
Prior to this, it must be ascertained that:

- 1: The harbour authorities permit quay trials.
- 2: The moorings are sufficient.
- 3: A watch is kept on the bridge.

2 Starting Difficulties

Starting Difficulties – See also Item 3, 'Supplementary Comments'. Points marked with * are all monitored by the ECS and an error report will occur.			
Difficulty	Point	Possible Cause	Remedy
Engine fails to turn on starting air after START order has been given	*1	Pressure in starting air receiver too low	Start the compressors. Check that they are working properly
	*2	Shut-off valve for solenoid valves is closed	Open the valve
	*3	Valve on starting air receiver closed	Open the valve
	*4	No pressure in the control air system	Check the pressure (normally 7 bar). If too low, change over to the other reducing valve and clean the filter
	*5	Main starting valve (ball valve) locked in closed position	Lift locking plate to working position
	6	Main starting valve (ball valve) sticking/failing	Check the valve
	7	Spool in solenoid air valves sticking	Overhaul the solenoid
	8	Starting air valves in cylinder covers defective	Pressure test the valves. Replace or overhaul defective valves. See description 6645-0170.
Engine does not reverse when order is given.	9	Propeller blades are not in zeropitch (CPP-plants).	Set pitch to zero position.

Starting Difficulties – <i>See also Item 3, 'Supplementary Comments'.</i> Points marked with * are all monitored by the ECS and an error report will occur.			
Difficulty	Point	Possible Cause	Remedy
Engine turns too slowly (or unevenly) on starting air.	10	Trigger/Marker signal missing.	Check signal.
	11	'Slow-turning' of engine adjusted to low.	Set the 'Slow-turning' adjustment screw so that the engine turns as slowly as possible without faltering.
	12	'Slow-turning' is not cancelled (automatic control).	<i>See the 'Bridge Control' instructions.</i>
	13	Main starting valve is not working properly.	Check valve.
	14	Sticking slow-turning valve (valve not returned).	Check valve.
Engine turns on starting air but stops after receiving order to run on fuel.	15	CCU exhaust valve supervision function prevents fuel injection	Turn the engine 5 full revolutions with turning gear, by Slow Turn or Air Run before attempting to run on fuel.
	*16	Shut-down of engine (no rotation present).	Check pressure and temperature. Reset "shut-down".
	*17	Fuel Oil Pressure Booster, sticking.	Check Fuel Oil Pressure Booster.
	*18	NC valves not functioning.	Check NC valves.
	*19	Fuel pressure missing (an error is reported in the ECS).	Check fuel pressure.
Engine turns on fuel, but runs unevenly (unstable) and will not pickup rpm.	*20	Auxiliary blowers not functioning.	- Stop the engine. - Start the auxiliary blowers for 10 min. - Slow-turn the engine by air. - Start the engine.
	21	Scavenge air limit set at too high or too low level.	Check level of scavenge air limiter. Check the scavenge air pressure and the exhaust gas pressure at the actual load. Compare the pressures with testbed or sea trial observations.
	*22	Fuel filter blocked.	Clean the filter.
	*23	Too low fuel pressure.	Increase the pressure.
	*24	One or more cylinders not firing.	Check suction valves. <i>If fault not found, check/change fuel injection valves.</i>

3 Supplementary Comments

Item 2, 'Starting Difficulties' gives some possible causes of starting failures, on which the following supplementary information and comments can be given.

Point 1

The engine can usually start when the starting air pressure is above 10 bar. The compressors should, however, be started as soon as the pressure in the starting air receiver is below 25 bar.

Point 7

Examine whether there is voltage on the solenoid valve which controls the starting signal.

If the solenoid valve is correctly activated or the engine is being manually controlled, trace the fault by loosening one copper pipe at a time on the route of the signal through the system, until the valve blocking the signal has been found. The failure can be due to a defective valve, or to the causes mentioned under point 16.

Point 8

The testing procedure describing how to determine that all starting valves in the cylinder covers are closed and are not leaking is found in *description 6645-0170*. If a starting valve leaks during running of the engine, the starting air pipe concerned will become very hot. When this occurs, the starting valve must be replaced and overhauled, possibly replacing the spring. If the engine fails to start owing to the causes stated under point 8, this will usually occur in a certain position of the crankshaft.

If this occurs during manoeuvring, reversing must be made as quickly as possible in order to move the crankshaft to another position, after which the engine can be started again in the direction ordered by the telegraph.

Point 15

See the description of the exhaust valve supervision function in item 1 Starting .

Point 16

If the shut-down was caused by over-speed, cancel the shut-down impulse by moving the regulating handle to the STOP position, whereby the cancellation switch closes.

If the shut-down was caused by too low pressures or too high temperatures, bring these back to their normal level. The shut-down impulse can then be cancelled by actuating the appropriate "reset" switch on the alarm panel.

4 Checks during Starting

Make the following checks **immediately after starting**:

NOTICE

The start/stop logic in the ECS has already, before start, checked that the direction of rotation is corresponding to the telegraph order. The ECS monitors whether the exhausts valves are operating correctly or not.
If an error occurs an alarm will occur.

Check 1: Direction of Rotation

Ensure that the direction of propeller rotation corresponds to the telegraph order. The current direction of the propeller can be seen on the MOP.

Check 2: Turbochargers

Ensure that all turbochargers are running.

Check 3: Circulating Oil

Check that the pressure and discharge are in order (main engine and turbochargers).

Check 4: Cylinders

Check that all cylinders are firing.

Check 5: Starting Valves & safety caps

Feel over the pipes. A hot pipe indicates leaking starting valve.

If a bursting disc of the safety cap is damaged due to excessive pressure in the starting air line, overhaul or replace the starting valve which caused the burst, and mount a new disc. If a new disc is not available immediately, turn the cover in relation to the cylinder, in order to reduce the leakage of starting air.

NOTICE

Mount a new bursting disc and return the cover to the open position at the first opportunity.

See work card 3465-0201.

Check 6: Pressures and Temperatures

See that everything is normal for the engine speed. In particular: the circulating oil (bearing lubrication and piston cooling), hydraulic oil pressure, fuel oil, cooling water, scavenge air, and control air.

Check 7: Cylinder Lubrication

Ensure the correct feedrate setting on the MOP. Consult the latest service letter regarding the feedrate.

Starting-up**Description****6645-0120-0004**

1 Loading Sequence

Regarding load restrictions after repairs and during running-in, see check 10.

If there are no restrictions, load the engine according to this programme:

Is the cooling water temperature above 50°C?	
YES	▪ Increase gradually to: - FPP-plants: 90% of MCR speed - CPP-plants: 80% pitch ▪ Increase to 100% speed/pitch over a period of 30 minutes or more. <i>See drawings 6655-0115 and 6655-0120.</i>
NO	▪ See table below.

Is the cooling water temperature between 20°C and 50°C?	
YES	▪ Preferably, preheat to 50°C. ▪ If you start with a cooling water temperature below 50°C, increase gradually to: - FPP-plants: 90% of MCR speed - CPP-plants: 80% pitch. ▪ When the cooling water temperature reaches minimum 50°C, increase to 100% of MCR speed/pitch over a period of 30 minutes or more. ▪ The time it takes to reach 50°C will depend on the amount of water in the system and on the engine load. <i>See drawings 6655-0115 and 6655-0120.</i>
NO	▪ Do not start the engine. ▪ Preheat to minimum 20°C, or preferably to 50°C. When 20°C, or preferably 50°C, has been reached, start and load the engine as described above. <i>See description 6645-0110.</i>

2 Checks during Loading

Check 9: Feel-over Sequence

If the condition of the machinery is uncertain (e.g. after repairs or alterations), the "feel-over sequence" should always be followed, i.e.:

- A. After 15-30 minutes' running on SLOW (depending on the engine size).
- B. Again after 1 hour's running.
- C. At sea, after 1 hour's running at service speed.

Stop the engine, open the crankcase, and feel-over the moving parts listed below (by hand or with a "Thermo-feel") on sliding surfaces where friction may have caused undue heating.



During feeling-over, the turning gear must be **engaged**, and the **main starting valve must be blocked**.
Use of safety harness is recommended.



Feel:

- Main, crankpin and crosshead bearings,
- Piston rods and stuffing boxes,
- Crosshead shoes,
- Telescopic pipes,
- Thrust bearing / guide bearing,
- Gear wheels on hydraulic pump gearbox, and chains (on some ME-engines)
- Axial vibration damper,
- Torsional vibration damper (if mounted).

After the last feel-over, repeat 'check 2.1' as mentioned in *description 6645-0100 'Oil Flow'*: "While the circulating oil pump is still running and the oil is warm, open up the crankcase and check that the oil is flowing freely from all the crossheads, crankpin and main bearings".
See description 6645-0300.

Check 10: Running-in

For a new engine, or after:

- Repair or renewal of the large bearings,
- Renewal or reconditioning of cylinder liners and piston rings, Allowance must be made for a running-in period.

Regarding bearings: increase the load slowly, and apply the feel-over sequence, *see check 9*. Regarding liners/rings: *See description 2245-0100.*

1 Running Difficulties

Difficulty	Point	Possible Cause	Remedy
Exhaust temperature rises *) a) All cylinders.	1	Increased scavenge air temperature owing to inadequate air cooler function.	<i>See description 6345-0310</i> <i>The chapter entitled 'Evaluation of Records', item 4, 'Air Cooler Synopsis'.</i>
	2	Fouled air and gas passages.	Clean the turbine by means of dry cleaning/water washing. Clean the blowers and air coolers. <i>See description 6345-0320.</i> Check the back pressure in the exhaust gas system just after the T/C turbine side.)
	3	Inadequate fuel oil cleaning, or altered combustion characteristics of fuel.	<i>See description 4245-0100 *)</i>
Exhaust temperature rises b) Single cylinder.	4	Defective fuel valves, or fuel nozzles.	*)
	5	Leaking exhaust valve	Replace or overhaul the valve. *)
	6	Blow-by in combustion chamber.	*)
	7	Falling scavenge air temperature.	Check that the seawater system thermostat valve is functioning correctly.
	8	Air/gas/steam in fuel system.	Check the fuel oil supply and circulating pump pressures. Check the function of the de-aerating valve. Check the suction side of the supply pumps for air leakages. Check the fuel oil preheater for steam leakages.
	9	Defective Fuel Oil Pressure Booster (FOPB) suction valve.	Repair the suction valve.
	10	Fuel Oil Pressure Booster (FOPB) plunger sticking or leaking. (an alarm will occur in the ECS)	Replace the fuel oil pressure booster plunger/barrel.
*) <i>See description 6645-0310 in particular the fault diagnosing table.</i>			

Table 1: Running Difficulties – See also Item 2. 'Supplementary Comments'

Running Difficulties (continued)

Difficulty	Point	Possible Cause	Remedy
Engine r/min decrease	11	Exhaust valve sticking in open position. (an alarm will occur in the ECS)	Replace the exhaust valve.
	12	Oil pressure before fuel oil pressure boosters too low.	Raise the supply and circulating pump pressures to the normal level.
	13	Air/gas/steam in the fuel oil.	<i>See point 8.</i>
	14	Defective fuel valve(s) or fuel oil pressure boosters.	Replace and overhaul the defective valve(s) and fuel oil pressure boosters.
	15	Fuel index limited by torque/scavenge air limiters in the ECS due to abnormal engine load.	<i>See description 6345-0300.</i>
	16	Water in fuel oil.	Drain off the water and/or clean the fuel more effectively.
	17	Fire in scavenge air box.	<i>See description 6645-0290.</i>
	18	Slow-down or shut-down.	Check pressure and temperature levels. If these are in order, check for faults in the slow-down equipment.
	19	Combustion characteristics of fuel oil.	When changing from one fuel oil type to another, alterations can appear in the r/min, at the same booster index. Fuel index (MEP%) must be rectified with the fuel quality, so that correct MEP can be obtained.
Smoky exhaust	20	Fouling of hull. Sailing in shallow water.	<i>See description 6345-0300.</i>
	21	Turbocharger revolutions do not correspond with engine r/min.	Some smoke development during acceleration is normal; no measures called for. Heavy smoke during acceleration: Fault in ECS limiters setting.
	22	Air supply not sufficient.	<i>See reference quoted under point 1.</i> Check engine room ventilation.
	23	Defective fuel valves (incl. nozzles).	<i>See point 4, and description 6345-0340.</i>
	24	Fire in scavenge air box.	<i>See description 6645-0290.</i>

Table 2: Running Difficulties (Continued) - See also Item 2. 'Supplementary Comments'

2 Supplementary Comments

The previous paragraph, 'Running Difficulties' gives some possible causes of operational disturbances, on which the following supplementary information and comments can be given.

Point 5

A leaking exhaust valve manifests itself by an exhaust temperature rise, and a drop in the compression and maximum pressures.

In order to limit the damage, if possible, immediately replace the valve concerned, or, as a preliminary measure, cut out the fuel oil pressure booster.

See description 6645-0320.

Point 6

In serious cases, piston ring blow-by manifests itself in the same way as a leaking exhaust valve, but sometimes reveals itself at an earlier stage by a hissing sound. This is clearly heard when the drain cock from the scavenge air box is opened. At the same time, smoke and sparks may appear.

When checking, or when cleaning the drain pipe, keep clear of the line of ejection, as burning oil can be blown out.

With stopped engine, blow-by can be located by inspecting the condition of the piston rings, through the scavenge air ports. Piston and cylinder liner become black in the area of blow-by. Sludge, which has been blown into the scavenge air chamber, can also indicate the defective cylinder.

See description 2245-0100.

Since blow-by can be due to sticking of unbroken piston rings, there is a chance of gradually diminishing it, during running, by reducing the fuel oil pressure booster index for a few minutes and, at the same time, increasing the cylinder oil amount. If this is not effective, the fuel oil pressure booster index and the $p_{\max}$ must be reduced until the blow-by ceases.

The pressure rise $p_{\text{comp}} - p_{\max}$ must not exceed the value measured on testbed at the reduced mean effective pressure or fuel oil pressure booster index. Regarding adjusting of $p_{\max}$: *See MOP description 6645-0250.*

If the blow-by does not stop, the fuel oil pressure booster should be taken out of service (with the engine stopped), or the piston rings changed. The load limit can be reduced and the exhaust valve movement stopped individually on each cylinder, without stopping the engine.

Running with piston ring blow-by, even for a very limited period of time, can cause severe damage to the cylinder liner. This is due to thermal overheating of the liner. Furthermore, there is a risk of fire in the scavenge air boxes and scavenge air receiver.

See description 6645-0290.

In case of several blow-by, there is a general risk of starting troubles owing to too low compression pressure during the starting sequence.

Concerning the causes of blow-by, *See description 2245-0100*, where the regular maintenance is also described.

Points 8 and 13

Air/gas in the fuel oil system can be caused by a sticking fuel valve spindle, or because the spring has broken.

If a defective fuel valve is found, this must be replaced, and it should be checked that no fuel oil has accumulated on the piston crown.

Points 10 and 14

If, to obtain full load, it proves necessary to increase an individual fuel booster index by more than 10% (from sea trial value), then this in most cases indicates that the fuel oil pressure booster is worn out. This can usually be confirmed by inspecting the plunger. If the cut-off edge shows a dark-coloured eroded area, the fuel oil pressure booster plunger/barrel should be replaced.

3 Check during Running

Check 11: Thrust Bearing

Check measuring equipment.

Check 12: Chain Tighteners (if applicable)

Check the chain tighteners for the moment compensators (if applicable). The combined chain tighteners and hydraulic damping arrangements should be re-adjusted, when the red-coloured part of the wear indicators is reached.

See work card 1465-0501.

Check 13: Shut Down and Slow Down

Check measuring equipment.

Check 14: Pressure Alarms (Pressure Switches)

General:

The functioning and setting of the alarms should be checked.

It is **essential** to carefully check the functioning and setting of pressure sensors and temperature sensors.

They must be checked under circumstances for which the sensors are designed to set off alarm.

This means that sensors for low pressure/temperature should be tested with falling pressure/temperature, and sensors for high-pressure/temperature should be tested with rising pressure/temperature.

Checking:

If no special testing equipment is available, the checking can be effected as follows:

- a. The alarm pressure switches in the lubricating and cooling systems may be provided with a test cock, by means of which the pressure at the sensor may be decreased, and the alarm thereby tested.
- b. If there is no such test cock, the alarm point must be displaced until the alarm is given. When the alarm has thus occurred it is checked that the pressure switch scale is in agreement with the actual pressure. (Some types of pressure switches have an adjustable scale).

Then reset the pressure switch to the preselected alarm limit, which should cause the alarm signal to stop.

Check 15: Temperature Alarms (Thermostats)

See also Check 14, 'General'.

Most of the thermostatic valves in the cooling systems can likewise be tested by displacing the alarm point, so that the sensor responds to the actual temperature.

However, in some cases, the setting cannot be reduced sufficiently, and such valves must either be tested when the service temperature has been reached, or by heating the sensing element in a water bath, together with a reference thermometer.

Check 16: Oil Mist Detector

Check the oil mist detector.

Adjustment and testing of the alarm function is effected in accordance with the instructions given on the equipment, or in the separate Oil Mist Detector instruction book.

Check 17: Observations

Make a full set of observations, by means of the PMI-system. Check that pressures and temperatures are in order.

See drawing 6355-0110 'Performance Observations' and description 6345-0330.

Check the load distribution between the cylinders.

See description 6345-0310.

1 General



Scavenge port inspection

See description 2245-0100, regarding scavenge port inspection prior to arrival in port.

1. Decide whether the harbour manoeuvres should be carried out on diesel oil or on heavy fuel oil.
See description 4245-0120.

Change-over should be carried out **one hour** before the first manoeuvres are expected.

See description 4245-0120.

2. Start an additional auxiliary engine to ensure a power reserve for the manoeuvres.
3. Make a reversing test (FPP-plants). *This ensures that the starting valves and reversing mechanism are working.*
4. Blow-off any condensed water from the starting air and control air systems just before the manoeuvres.

1 General

Always perform a stop manoeuvre before entering harbour/taking pilot on board to state that the ECS is functioning as intended.

Stopping

Description
6645-0160-0002

1 General

When the 'FINISHED WITH ENGINE' order is received in the control room:

1. Test the starting valves for leakage:
 - Obtain permission from the bridge.
 - Check that the turning gear is disengaged.

Next step is because a leaky valve can cause the crankshaft to rotate.

- Close the main air valve to the starting air distribution system.
- Open the indicator valves.
- Change-over to manual control from the LOP on the engine side.
- Activate the START button.

This admits starting air, but not control air, to the starting valves.

- Check to see if air blows out from any of the indicator valves.
In this event, the starting valve concerned is leaky.

If the cylinder is in BDC, detection can be difficult, due to air escaping through the scavenge air ducts in the cylinder liner.

- Replace or overhaul any defective starting valves.

2. Lock the main starting valve in its lowest position by means of the locking plate.

Engage the turning gear.

Check the indicator lamp.

Check that the valve to the starting air distribution system is closed.

3. Close and vent the control air and safety air systems.

Do not stop the air supply to the exhaust valve air cylinders, as air draught through an open exhaust valve may cause the turbocharger shaft to rotate, thus causing bearing damage, if the lube oil supply to the turbocharger is stopped.

4. Wait minimum 15 minutes after stopping the engine, then:

Stop the lube oil pumps

Stop the cooling water pumps.

This prevents overheating of cooled surfaces in the combustion chambers, and counteracts the formation of carbon deposits in piston crowns.

5. Fuel oil pumps:

Did the engine run on heavy fuel oil until STOP?	
YES	▪ Stop the fuel oil supply pumps. ▪ Do not stop the circulating pumps. ▪ Keep the fuel oil preheated. <i>The circulating oil temperature may be reduced during engine standstill.</i> <i>See description 4245-0120 'Fuel Preheating when in Port'.</i> <i>Cold heavy fuel oil is difficult or even impossible to pump.</i>
NO	▪ Stop the fuel oil supply and circulating pumps.

6. Freshwater preheating during standstill:

Will harbour stay exceed 4-5 days?	
YES	▪ Keep the engine preheated or unheated. <i>However, see description 6645-0110, item 3 and description 6645-0130, item 1.</i>
NO	▪ Keep the engine preheated to minimum 50°C. <i>This counteracts corrosive attack on the cylinder liners during starting-up.</i> ▪ Use a built-in preheater or the auxiliary engine cooling water for preheating of the engine. <i>See description 5045-0100 'Cooling Water System'.</i>

7. Switch-off other equipment which need not operate during engine standstill.

8. Regarding checks to be carried out during engine standstill.
See description 6645-0100.

**WARNING****Authorised personnel only!**

Please note that access to the areas of the MOP computer behind the user interface screens shown in the appendix of this manual, is restricted to personnel authorised by MAN Diesel & Turbo.

Altering items in the restricted area of the MOP may result in engine failure.

1 General information

The engine control system (ECS) consists of a number of computer-based multi purpose controllers and operating panels.
See drawing 7055-0150.

Below is brief description of the different units, including the related monitoring systems, *see also 6655-0125 figure 1:*

Multi purpose controllers:

ACU	The auxiliary control units control the pumps of the hydraulic system unit and the auxiliary blowers.
CCU	The cylinder control units control the, ELFI/ELVA or FIVA valves, starting air valves, and the cylinder lubricators.
CWCU	The cooling water control unit controls the LDCL/LDHT system (optional).
ECU	The engine control units perform the engine control functions: engine speed, running modes and start sequence.
EICU	The engine interface control units handle the interface to external systems.
LOP	The engines local operating panel.
MOP	The engineers' interface to the ECS.
SCU	The scavenge control unit controls both the exhaust gas bypass (both on/off as well as variable bypass) and VT- variable turbocharging (optional).

Control station and operating panels:

LOP	The engine's local operating panel.
MOP	The main operating panel is the engineer's interface to the ECS.

Monitoring systems:

PMI	Pressure Measuring Instrument. The PMI system is a valuable tool for performance measurements.
CoCoS EDS	Computer Controlled Surveillance, Engine Diagnostics System. CoCoS EDS is an essential tool with regards to troubleshooting and diagnostics.

With reference to drawing 7055-0150 and 6655-0125 figure 1, a more detailed description of the units can be found in the following:

2 Multi purpose controllers

The multi purpose controller (MPC) can be used for several purposes. For further information regarding the MPC, *see description 6645-0270*.

The purposes of the different MPC functions are described in the following:

ACU

The auxiliary control unit (ACU)s control the pressure of the hydraulic power supply system and the electrical start-up pumps using the 'pressure set point' given by the ECUs as a reference. Furthermore the start and stop of the auxiliary blowers are controlled according to the scavenge air pressure.

The control of the auxiliary equipment on the engine is normally divided amongst the ACUs so that, in the event of a failure of one unit, there is sufficient redundancy to permit continuous operation of the engine.

For a complete overview of the signals,
see MOP screen 'Maintenance -> System View I/O Test -> ACU'.

CCU

In appropriate time for the next firing, the cylinder control unit (CCU) ensures that it has received new valid data. The injection profile start crank angle is set up using the tacho function.

On the correct start crank angle the injection is initiated and is controlled according to the fuel amount command and the injection profile command.

When the fuel injection is completed, the exhaust valve opening and closing angles are set up using the tacho function. The exhaust valve control signal is then activated on the appropriate crank angles.

The cylinder lubricator is activated according to the feed rate amount received from the ECU.

All of the CCUs are identical, and in the event of a failure of the CCU for one cylinder, only this cylinder will automatically be put out of operation. This means that fuel injection, exhaust valve operation and cylinder lubrication will stop. A (cancellable) slow down request will be initiated and in case of high load a (non-cancellable) load limit will be set.

See description 6645-0320 Running with Cylinders or Turbochargers out of Operation, Exhaust valve control failure

In the event that the CCU cannot be replaced immediately, a procedure to temporarily restore cylinder lubrication is available. See:

Work card 6665-0101 Special Running, CCU failure

For a complete overview of the signals,
see MOP screen 'Maintenance -> System View I/O Test -> CCU'.

CWCU (optional)

The cooling water control unit (CWCU) is made for controlling all parts of the LDCL or LDHT cooling water system.

For information about the cooling water system, *see description 5045-0100*.

For a complete overview of the signals,
see MOP screen 'Maintenance -> System View I/O Test -> CWCUC'.

ECU

The engine speed control (ECU) requires that the amount of fuel is calculated for each cylinder firing. The calculation made by the speed controller (ECU) is initiated in relation to the crankshaft position, so that the execution is started just in time to make the fuel injection. This is controlled by the tachometer function.

The output from the speed controller is a 'request for fuel amount' to be injected for the next combustion. This request is run through different protective algorithms – the fuel limiters – and the 'resulting amount of fuel command' is produced.

Based on the algorithm of the selected engine running mode, the injection profile is selected, the timing parameters for the fuel injection and exhaust valve are calculated and the pressure set point for the hydraulic power supply derived.

Based on the user input of fuel sulphur content, minimum feed rate etc., the resulting cylinder lubrication feed rate for each individual cylinder unit is calculated.

The resulting amount of fuel command, the requested fuel injection profile, the timing parameters and the resulting cylinder lubrication feed rate amount are all sent to the CCU of the cylinder in question via the control network. Likewise, the hydraulic pressure set point is sent to all ACUs.

For redundancy purposes, the control system comprises two ECUs operating in parallel and performing the same task, one being a hot stand-by for the other. If one of the ECUs fail, the other unit will take over the control without any interruption.

For a complete overview of the signals,
see MOP screen 'Maintenance -> System View I/O Test -> ECU'.

EICU

The engine interface control unit (EICU)s receive navigational inputs from the control stations and selects the active station based on signals given by the 'remote control' system.

The main navigational command is the speed set point (requested speed and direction of engine rotation).

In the EICUs the raw speed set point is processed by a series of protective algorithms. These ensure that the speed set point from which the engine is controlled is never harmful to the engine. An example of such an algorithm is the 'barred speed range'.

Now the processed speed set point and the selected engine running mode request are available via the control network to be used by the ECUs as a reference for the speed control and engine running mode control.

The two redundant EICU units operate in parallel.

For a complete overview of the signals,
see MOP screen 'Maintenance -> System View I/O Test -> EICU'.

SCU (optional)

The scavenge air control unit (SCU) controls either an exhaust gas bypass (EGB) valve or a variable turbocharger (VT). The control of the exhaust gas bypass (EGB) valve can be combined with various waste heat recovery (WHR) system applications (engine dependent). The SCU is connected to the engine control system (ECS) network and receives the estimated engine load and the measured scavenge air pressure from the ECS.

For the majority of engines in service from 1st of November 2013 and onwards, the control of the EGB valve position depends on the estimated engine load. The operation of the EGB valve will therefore be independent of how the ambient conditions (primarily air temperature) changes. This means that with constant load the scavenge air pressure will, to some extent, vary depending on the ambient conditions. Some limitations apply, if the pressure reaches the limits, an alarm will be raised. The upper limit is fixed, the lower limit changes with the engine load. *For more information see description 6645-0260 Scavenge Air, description 5445-0200 VT or 5445-0300 EGB or separate manuals.*

For engines in service before 1st of November 2013 the SCU will put the estimated engine load into a scavenge air pressure table, and send a set point to the P_{scav} controller (the P_{scav} controller is a part of the SCU). The P_{scav} controller will also receive the measured scavenge air pressure from the scavenge air receiver and then calculate a set point (%) to the EGB or VT actuator. This means that with constant load the scavenge air pressure will not vary when the ambient conditions change. Some limitations apply, if the pressure reaches the limits, an alarm will be raised.

For a complete overview of the signals,
see MOP screen 'Maintenance -> System View I/O Test -> SCU'.

3 Control stations and operating panels

During normal operation the engine can be controlled from either the bridge control panel, the engine control room panel or the local operation panel (LOP).

There are two operating panels which are a part of the engine control system:

- Local operation panel (LOP)
- Main operation panel (MOP)

LOP

The LOP is as standard placed on the engine.

From the LOP, the basic functions are available, such as starting, engine speed control, stopping, reversing, and the most important engine data are displayed.

Starting from local operating panel (LOP)

To start and run the engine from the LOP, some conditions have to be fulfilled. Next to the LOP, a nameplate (containing the text, highlighted below) is placed. The name plate comprises the conditions that have to be fulfilled before start.

Main Engine Start from Local Operating Panel

In order to start/stop and operate the main engine from the local operation panel (LOP), local control must be selected as the active control station. This is normally done via the request / acknowledge facility of the remote control system. However, it is possible to override the normal change-over procedure by means of the 'forced take command' push button. Activating this button will force the control to the local control station.

Before start, the hydraulic oil pressure must be higher than 150 or 205 bar, depending of the hydraulic system is at 200 or 300 bar. After shut down, the pressure has to be rebuilt which may take 60 - 120 seconds.

To stop the engine: Activate STOP
(and reset shut down)

To start the engine: Change from STOP to START

If the auxiliary blowers are running, the engine control system will start the main engine automatically without delay.

If the auxiliary blowers are stopped, the engine control system delays the start until the auxiliary blowers are started and running. Then, the engine control system will start the main engine automatically.

MOP

The Main Operating Panel (MOP) is the main information interface for the engineer operating the engine. The MOP communicates with the controllers of the ECS through the control network. However, the running of the engine is not dependant on the MOP, as all the commands from the local control stations (ECR and LOP) are communicated directly to the EICU's/ECS.

The MOP is located in the engine control room. It is a PC with a touch screen as well as a trackball from where the engineer can carry out engine commands, adjust the engine parameters, select the running modes, and observe the status of the control system. A back-up MOP (MOP B) is also placed in the engine control room (*see description 6645-0190 for a detailed MOP-description*).

4 Engine Management Services

EMS (Engine Management Services) is used on MAN B&W engines from MAN Diesel & Turbo for condition monitoring, data logging & data distribution. EMS is integrated with ECS (Engine Control System) to allow for continuous performance tuning.

EMS includes following applications:

PMI System

The PMI (Pressure measurement instrument) system is a valuable tool for performance measurements and is a basic for engine adjustments.
The PMI system comes in one of two versions:
PMI Auto tuning (standard).

PMI "offline" version (alternative).

The PMI software is installed on the same computer which runs the CoCoS EDS software.

A user's manual is included in the software.

See the user's manual for a description of the system.

See description 6645-0250 for Auto tuning and Manual adjustment of process offsets on the MOP.

CoCoS EDS

This software is used for the data logging program that is collecting data from the ECS. It is to be installed on the same PC that is running the PMI software.

Always ensure that this software is running correctly since this will greatly enhance the troubleshooting options.

Since the CoCoS EDS interfaces to the ECS for data logging it is important to ensure that the versions are compatible. For instance in case of an update of the ECS, make sure that CoCoS EDS is also updated.

The program DatGat is included with the CoCoS EDS software. This program is a valuable tool for extracting data from the ECS used during troubleshooting, *see the next item Data logging.*

Data logging

In the case that assistance from external parties is needed, it is essential for troubleshooting that following data is delivered to external parties:

- A clear description of the case
- ECS Alarm/Event Log
- ECS parameter file (Spaf)
- ECS HCU data logger files
- ECS HPS data logger files
- EDS data logger files

This information can be gathered automatically with a program called "datgat.exe" which is located on the CoCoS-EDS/PMI computer or on the EMS-MOP (where applicable, see below). On the CoCoS-EDS/PMI computer the datgat.exe program is located in the CoCoS-EDS installation folder called "EDS".

In order to find the datgat.exe program in the EDS folder:

Right-click on the CoCoS-EDS shortcut and select the "Open File Location".

Alternatively the path to the EDS folder can be found in CoCoS-EDS in Help->About->System Information ->WorkingDir: (see figure 1, next page)

A description on how to use the datgat.exe program can also be found in the EDS folder.

The output from the datgat.exe program is a ZIP file which can be stored on a USB memory stick and sent to external parties.

On the EMS-MOP (where applicable):

The DatGat program is started from the EMS user interface, the EMS users guide (3094328-0) describes how to launch DatGat.

NOTICE

Troubleshooting process

The above mentioned data and log files will contribute to speed up the troubleshooting process, and are for that reason very important for external parties.

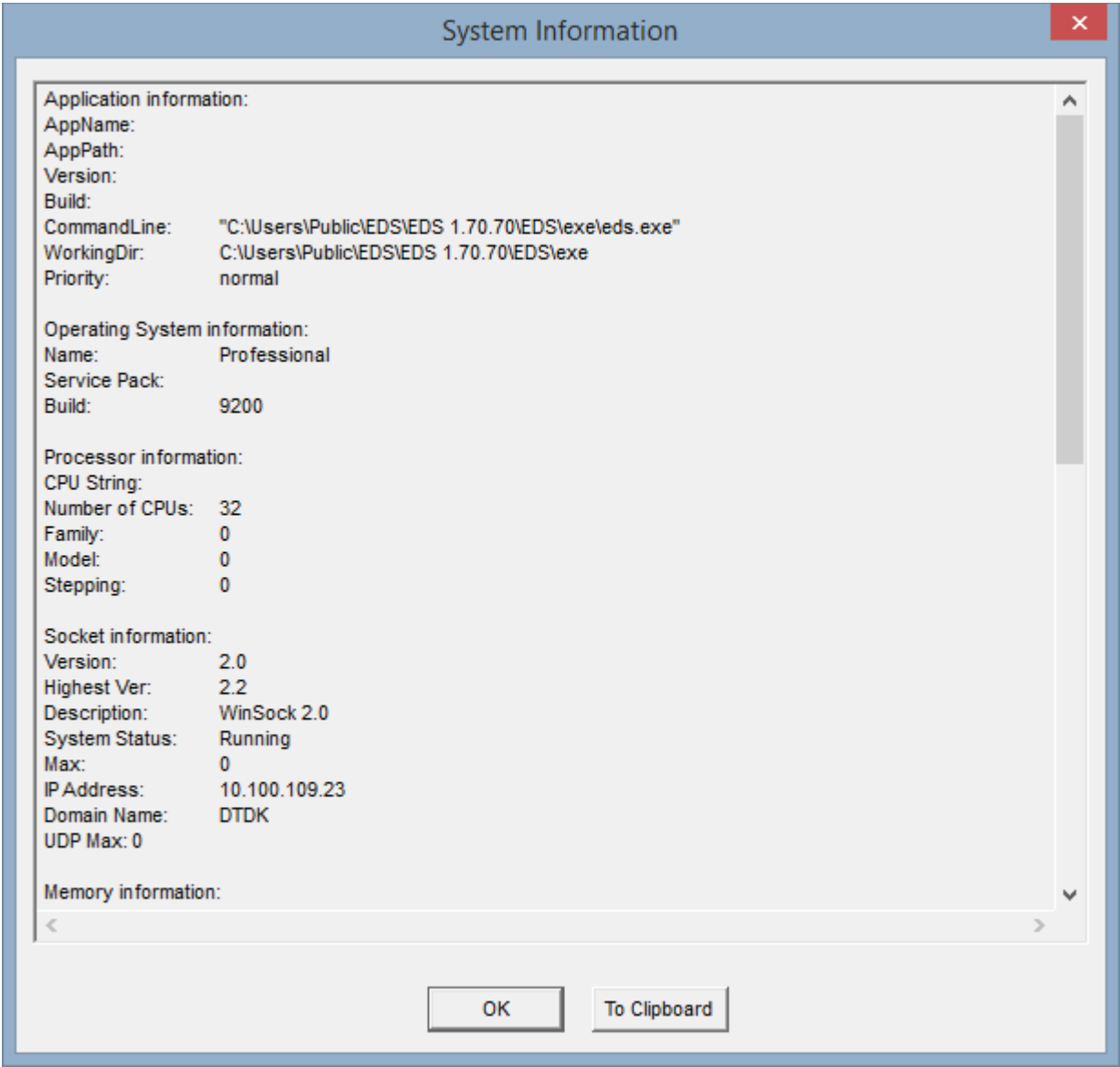


Figure 1: The path to the EDS folder is shown at the "WorkingDir:" in the System Information dialogue.

1 General

If you encounter difficulties while operating the ME-engine, this guide can be useful in solving the problems.

The information in this chapter will help you with:

1. Cylinder Components, Tests and Evaluation.
2. Test for Earth Failure in the ECS System.

1.1 Cylinder Components, Tests and Evaluation

This document describes the usage of troubleshooting diagrams and procedures. The procedures only focus on cylinder components (excluding cylinder lubricating components).

Cylinder Fault Diagram

The Cylinder Fault Diagram (CFD – pages 2 and 3 this section) describes the correlation between system failures and symptoms (alarms and other known symptoms). The crosses in the diagram indicate the symptoms that **can** be generated from a certain failure/ cause.

Cylinder Loop Test (flowchart)

The Cylinder Loop Test (CLT – pages 4 and 5 this section) is a description of a test procedure. The CLT can isolate failures on cylinders where it is known that there is an error.

The test categorises failures in: FIVA valve, FIVA sensor, cabling, MPC, exhaust valve system, exhaust valve sensor, fuel plunger system, fuel plunger sensor and hydraulics.

This makes reference to the below mentioned tests.

Please note that there are separate tests for different FIVA valve types.

Amplifier Test (flowchart)

The Amplifier Test (AT – page 6 this section) is a description of a test procedure. The AT should be used to isolate failures in the amplifier loop if it is known that there is an error.

The test categorises failures in: amplifier, power cabling, cabling to amplifier, FIVA and MPC.

The test is only applicable on systems with Curtiss Wright FIVA valves.

Sensor Chain Test (flowchart)

The Sensor Chain Test (SCT - page 7 this section) is a description of a test procedure. The SCT should be used to isolate failures in sensor chains where there is a supervision alarm or another error.

The test categorises failures in: sensor, cabling, MPC.

Possible Failures

FIVA Alarms

- FIVA position feedback signal failure
 - FIVA Amplifier current Supervision (I = Current)
 - FIVA Amplifier reports internal faults (Too high current)
 - Illegal position (FIVA pilot spool, window function)
 - Fuel Plunger and Exhaust Valve Alarms
 - Exhaust Valve open stroke low
 - Illegal plunger position (Window function)
 - Supervision Alarms
 - Superv. Ch30, 4102 Proportional Valve position
 - Superv. Ch31, 4114, Plunger position M
 - Superv. Ch34, 4111, Exhaust Valve position
 - Superv. Ch33, 4106, Valve Amplifier Ac
 - Misc. Alarms
 - Frozen IO detected (Ch 30)
 - Other Symptoms
 - No fuel injection
 - Low Pmax
 - Low MIP
 - Increased fuel index
 - Plunger sticking in top
 - Exhaust Valve noise
 - Exhaust Valve knocking
 - Exhaust Valve not moving

Legend:

- x This failure can generate this alarm
- o This failure can only generate this alarm

Note: To further separate between these failures: Perform "Cylinder Loop test".

- ✕ This failure can generate this alarm
- This failure can only generate this alarm if it also generates other alarms

Additional Information

Symptoms

Possible Failures

FIVA Alarms

- FIVA position feedback signal failure
- FIVA Amplifier reports internal faults (Too high current)
- Illegal position (FIVA pilot spool, window function)
- Fuel Plunger and Exhaust Valve Alarms
- Exhaust Valve open stroke low
- Illegal plunger position (Window function)

Supervision Alarms

- Superv. Ch30, 4102 Proportional Valve position
- Superv. Ch31, 4114, Plunger position M
- Superv. Ch34, 4111, Exhaust Valve position

Misc. Alarms

- Frozen IO detected (Ch 30)
- Other Symptoms
- No fuel injection
- Low P_{max}
- Low MIP
- Increased fuel index
- Plunger sticking in top
- Exhaust Valve noise
- Exhaust Valve knocking
- Exhaust Valve not moving

Accumulators (One CCU) or Hydraulic Power Supply (Many CCUs)

If failure occurs on many cylinders - root cause can be extreme ambient conditions or water in oil

To further separate between these failures:
Perform "Cylinder Loop Failure Test".

FIVA failures

- FIVA failure
- Exhaust Valve failures
- Non-return valves
- High-Pressure pipes
- Lack of pressure oil
- Air Spring vented hole failure

Electronics failure

- MPC failures
- Sensor failures
- Exhaust Valve position feedback failure
- Fuel Plunger position feedback failure
- FIVA feedback failure
- Cabling failure

Fuel Plunger failure (Suction Valve)

- Low fuel oil pressure

Hydraulic failure

To further identify the failure in these single alarm cases:
perform sensor chain test

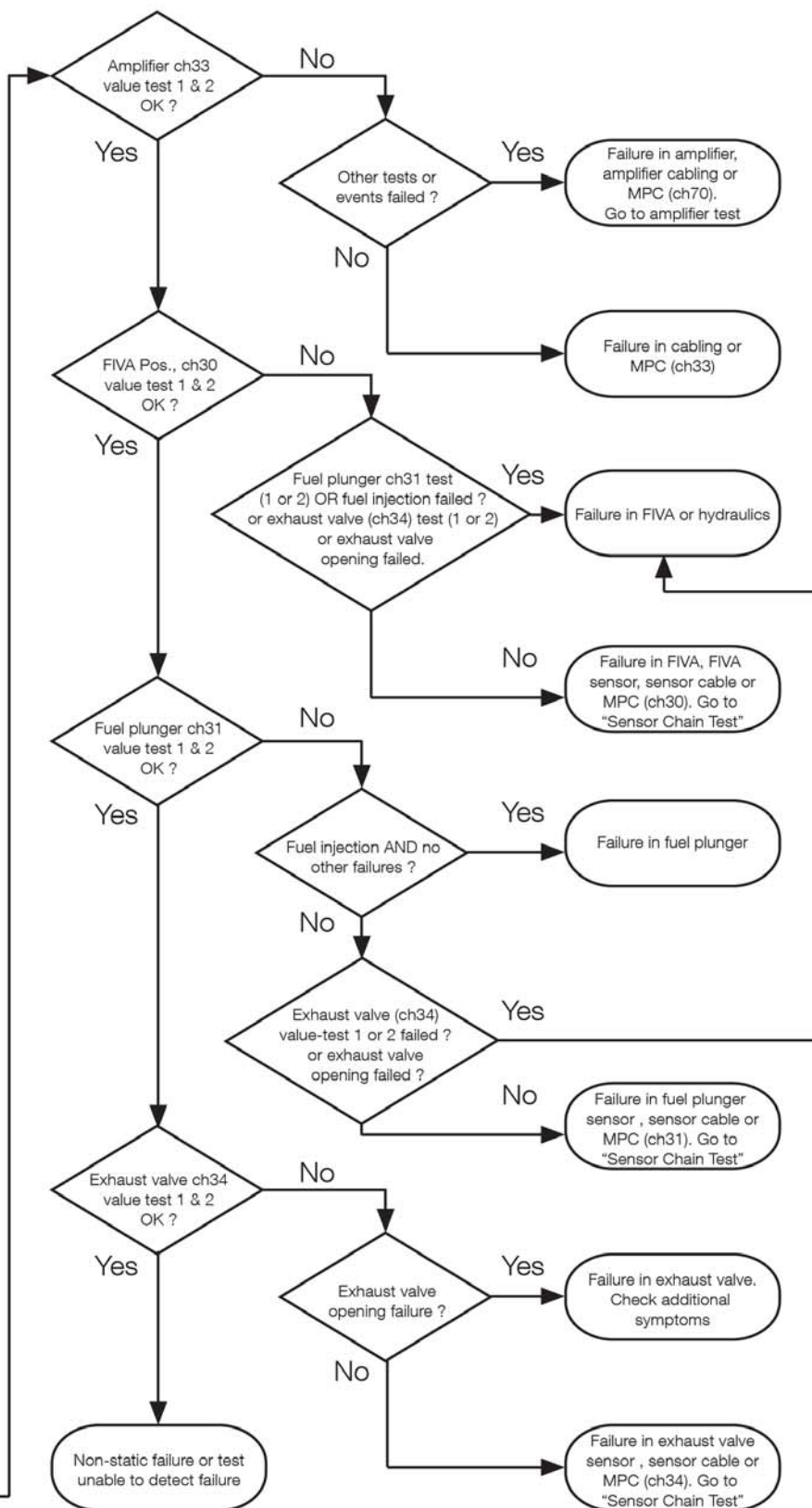
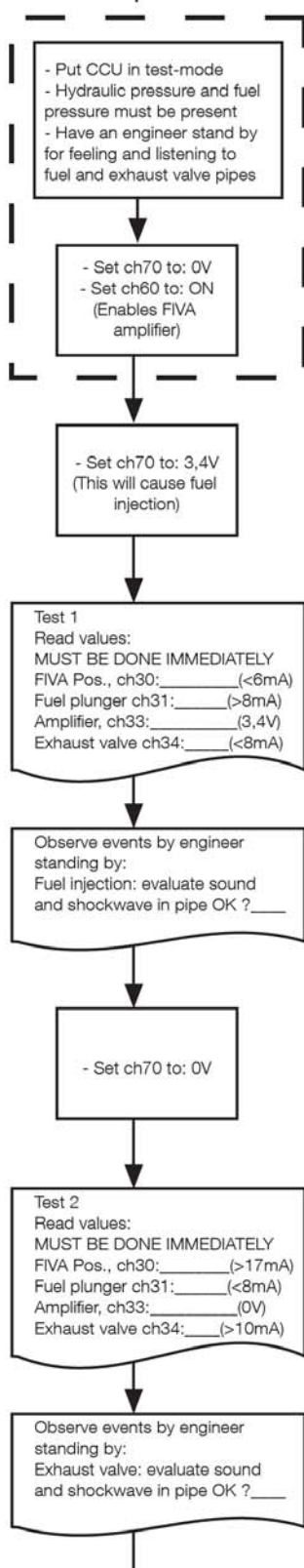
- ☒ This failure can generate this alarm
- ☐ This failure can only generate this alarm if it also generates other alarms

Additional Information

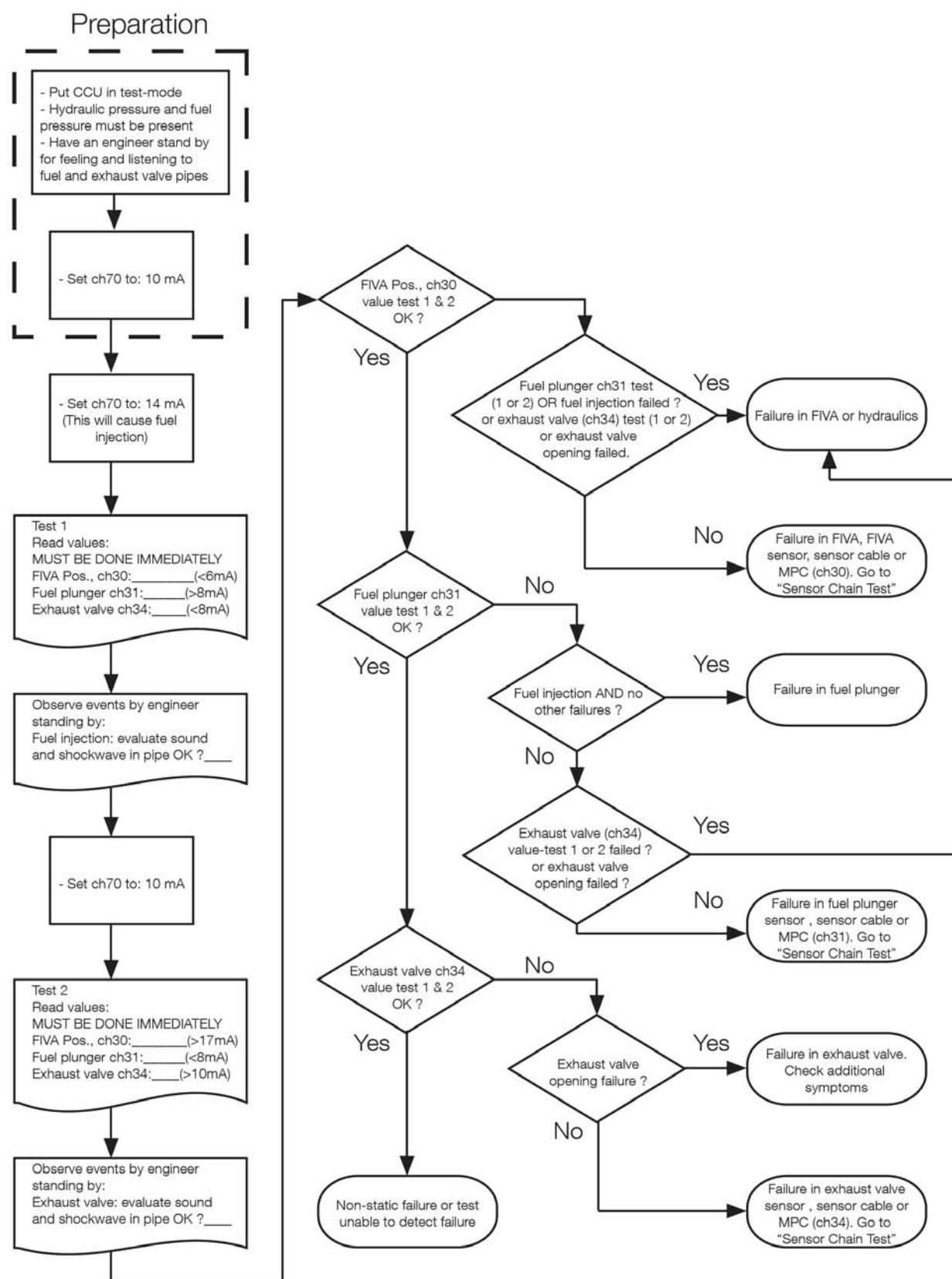
Description

6645-0182-0001

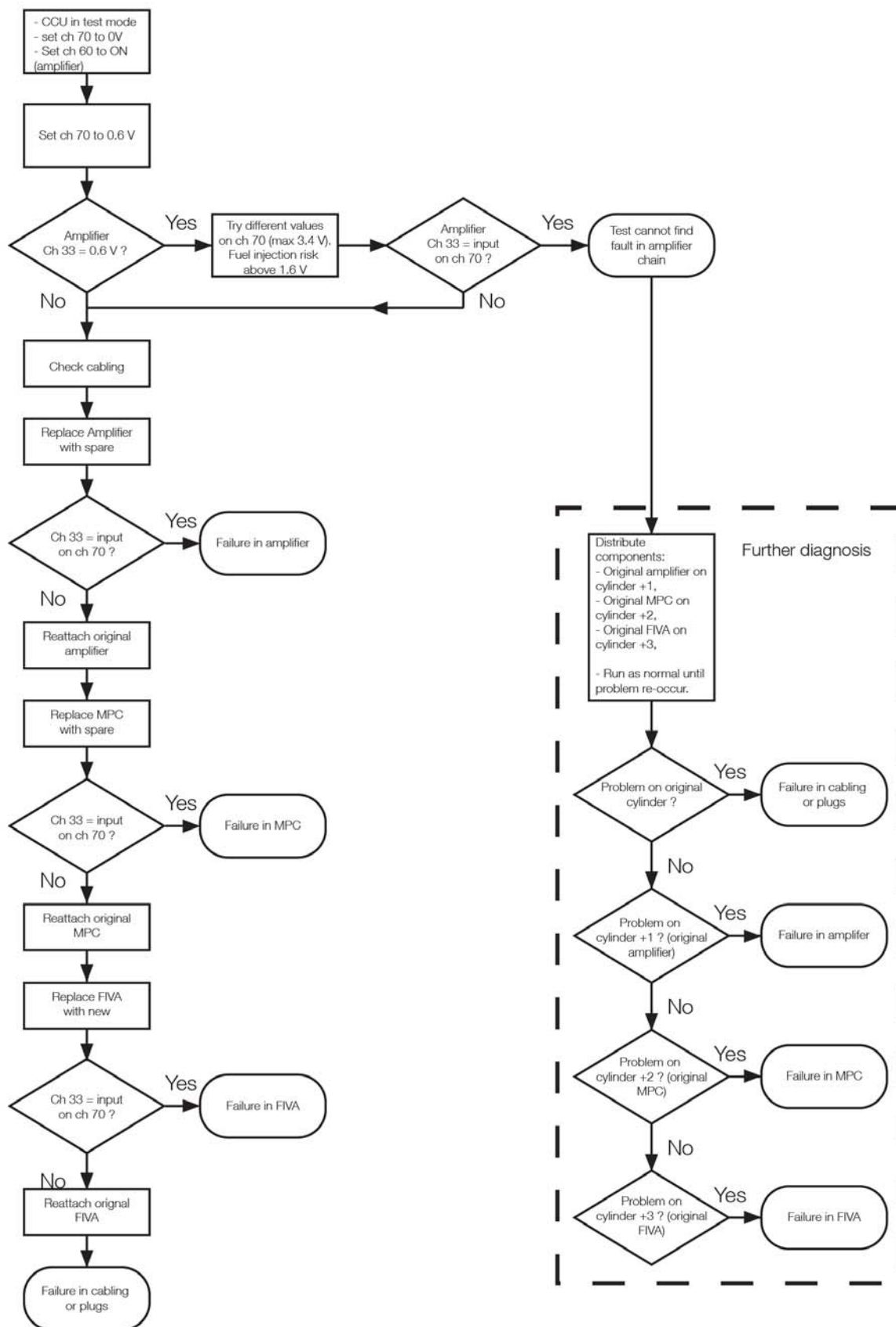
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1.1.3 Cylinder Loop Test (CW - FIVA)**Preparation**

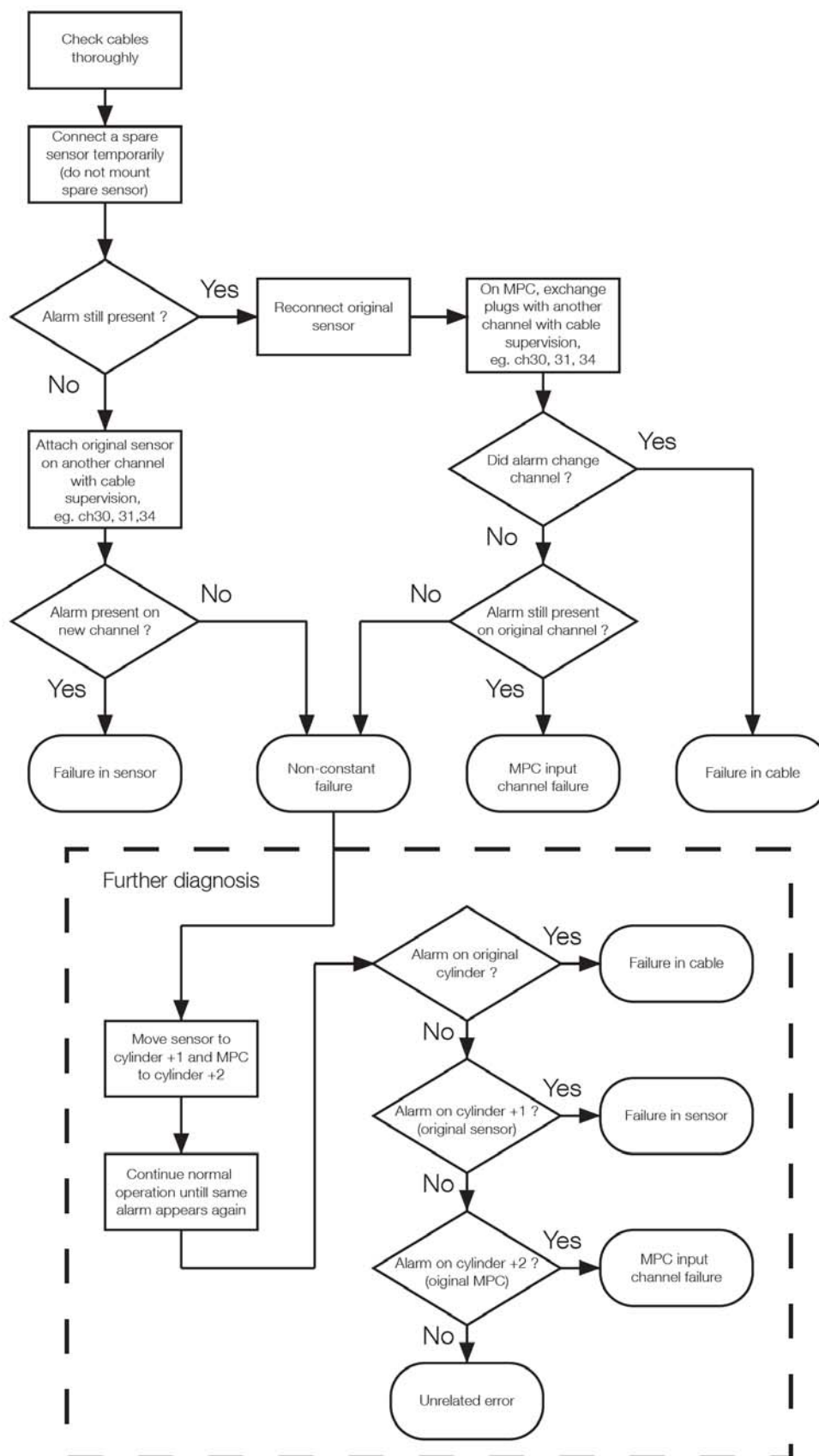
1.1.4 Cylinder Loop Test (MD – FIVA)



1.1.5 Amplifier Test (CW – FIVA)



1.1.6 Sensor Chain Test



1.2 Test for Earth Failure in the ECS System

1.2.1 Method 1

Fault isolation of an earth ground failure.

A certain and fast method (compared to method 2 below).

Precondition: The engine must be stopped and in FWE.

1. Disconnect the isolation monitor unit (e.g. Bender xxx) from the power supply.
2. Measure the current between ground (a non-isolated point of the engine or ship steel structure) and 0 Volt, and ground and 24 Volt, respectively, by means of an ampere meter (a multimeter in current mode) in serial with a 2 kOhm resistor. The measurement can practically be done either in the power supply of the ECS or in the power distribution box on the engine. If any of the currents are higher than 0.2 mA, the isolation to ground is too low. In a properly isolated system, the current will be lower than 0.2 mA.
3. Disconnect the power plugs (J1) (which disconnects both 0 Volt and 24 Volt) for one MPC at a time until the MPC containing the isolation fault is found, i.e. when the current drops below 0.2 mA.
4. The power plug to the MPC causing the isolation failure is connected again, and the connectors for sensors and external signals are disconnected one at a time, until either a sensor is found that causes the isolation failure, or all connectors have been disconnected. Ground current must be checked as described in Item 2 between 0 Volt and 24 Volt, respectively, while each connector is disconnected.
5. If the isolation failure is located to a sensor, its cabling must be checked and perhaps the sensor must be exchanged.
6. If the isolation failure is still present after all connectors to external signals are disconnected, while the power connector is still connected to the MPC, the failure is probably in the MPC, which must then be exchanged.

When the problem has been rectified, all connectors and plugs are reinstalled, and the isolation monitor is reconnected. Check that the isolation monitor no longer initiates an alarm (note that failures might be present in more than one unit (MPC) at a time).

1.2.2 Method 2

A certain but slow method.

Precondition: The engine must be stopped and in FWE. 1.

1. Disconnect the power plug (J1) (which disconnects both 0 Volt and 24 Volt) in one of the MPCs .

2. Wait one minute - check the isolation value on the isolation monitor (e.g. Bender xxxx) in power supply A. If the isolation value is still lower than 24 kOhm (the alarm level), then repeat point 1 in the next MPC. In a properly isolated system the isolation is higher than 100 kOhm.
3. Repeat point 1 and 2 for each MPC until the MPC containing the isolation fault is found, i.e. when the isolation comes above 100 kOhm.
4. The power plug to the MPC causing the isolation failure is connected again.
5. One of the connectors (J2 - J85) for the sensors and external signals is disconnected.
6. Wait one minute - check the isolation value on the isolation monitor as in point 2.
7. Repeat point 5 and 6 for each of the connectors for external signals until either a sensor is found that causes the isolation failure (the isolation comes above 100 kOhm), or all connectors have been disconnected.
8. As method 1 point 5 or point 6.

When the problem has been rectified, all connectors and plugs are reinstalled. Check that the isolation monitor no longer initiates an alarm (note that failures might be present in more than one unit (MPC) at a time).

1.2.3 Method 3

A faster, but uncertain method.

Precondition: The engine must be stopped and in FWE.

1. Disconnect the isolation monitor unit (e.g. Bender xxxx) from the power supply.
2. Connect a voltmeter between the 0 Volt and ground (a non-isolated point of the engine or ship steel structure) and, if possible, another voltmeter between 24 Volt and ground. Alternatively one voltmeter must be connected alternately between 0 Volt and 24 Volt. The measurement can practically be done either in the power supply of the ECS or in the power distribution box on the engine. When using this method both measured values should be within 10 - 16 V (+ or -) if the system has normal isolation to ground, while an isolation failure normally causes one of the measurement to be below 5 V and the other above 20 V.
3. The further procedure is similar to method 1 above, except that pin pointing of the isolation fault is based on the voltage measurements being in the isolation fault or normal range as specified in previous point 2.

When the problem has been rectified, all connectors and plugs are reinstalled, and the isolation monitor is reconnected. Check that the isolation monitor no longer initiates an alarm (note that failures might be present in more than one unit (MPC) at a time).

1 Main Operation Panel (MOP)

The MOP is the Human Machine Interface (HMI), through which the Engine Control System (ECS) and thus the engine is operated. The HMI is described in descriptions 6645-0240 through 6645-0280.

The MOP is basically a marine approved and certified PC with 24V - DC supply and a touch screen.

An actual installation comprises of two MOPs where both are placed in the engine control room (ECR). Typically MOP A is placed in a console by the manoeuvring handle (the normal operation position) and MOP B on a desk.

Normally MOP A is equipped with a trackball mouse. MOP B has a mouse and a keyboard connected. Both may be optionally equipped.

1.1 Using the MOP

The two MOPs are operationally fully redundant to each other. Though some of the more advanced troubleshooting facilities are only available on MOP B.

Instead of traditional use of a mouse, the operator touches the graphic elements on the screen in order to interact with the ECS.

A keyboard is essentially not required during normal engine operation and a virtual keyboard is displayed in case textual input (e.g. password) is needed.

1.2 Service kit

The MOP comes with a service kit. The kit comprises of a CD-ROM drive (if not built-in), a keyboard and a CD with the operating system, and is setup specifically for this PC type.

1.3 MOP Issues

1.3.1 Ethernet connections

Only MOP B may be connected with an ethernet connection to other systems such as CoCoS-EDS. Special care must be taken when connecting to networks of any kind to avoid virus and worms on the MOP. Connections to other systems are illustrated on drawing 6655-0125 figure 1.

1.3.2 Unauthorised software

DISCLAIMER: MAN Diesel disclaim responsibility for any event or condition that originates from installation of unauthorised software. This includes, but is not limited to, virus.

To emphasize the disclaimer, yellow stickers are placed at suitable places on the MOPs.

1.3.3 Control network

Each MOP is connected to the ECS by means of the control network which interconnects the controllers in the ECS. The control network is implemented as two independent networks for redundancy reasons as shown on drawing 6655-0190.

1.3.4 Maintenance

Normal PC maintenance tools and cleaning detergents apply.

1.4 Software scope of supply

There are three different standard types of software and one optional type supplied with the ECS:

- 1.4.1 Operating system
- 1.4.2 Engine control system
- 1.4.3 Service parameters
- 1.4.4 Language change (optional)

This software is either stored on a set of CD-ROMs or on a pair of USB memory sticks. In either case it is important that the software is stored in a proper place where it is accessible and can be found on request. The recommended storage place is together with the engine's instruction manual.

In case the software is stored on USB memory sticks these might be equipped with a Read/Write selector. This switch should normally always be set to Read.

In addition to the above there will also be the following two types of software as a part of the software supply:

- 1.4.6 CoCoS EDS
- 1.4.7 PMI software

These last two types of software are not to be installed on the MOPs, but instead on a separate PC (see drawing 6655-0125 figure 1). However having these programmes running correctly is essential to achieving optimal performance of the engine and ECS. Both of these programmes include user manuals and instructions together with their installation.

1.4.1 Operating system

The operating system is the software that is used for the MOPs. This is an embedded version of Windows XP. This is normally pre-installed by the MOP supplier and delivered with the MOP hardware.

1.4.2 Engine control system

The engine control system (ECS) is a set of applications installed on the MOPs that enables them to perform their main function, i.e. it turns them into the MOPs.

A very important aspect of the engine control system is the software version (e.g. "1312-1.9" or "1205-3.8"). It is critical that the software version stored on USB/CD-ROMs is the same version that is currently installed. The currently installed version can be seen on the Admin > Version Screen on the MOPs (this screen is described in more detail in description 6645-0280).

NOTICE

Always ensure that the software version of the installed ECS matches the version stored onboard.

1.4.3 Service parameters

The service parameters software functions as a backup in case of major system failure. Normally it should not be used as the MOPs automatically stores backup versions of the service parameters from the MPCs.

1.4.4 Language change (optional)

On the "Operator" tab it is possible to change the language on the MOP. The flag indicates which country's language it is possible to change to. This function is optional.

See drawing 6655-0211



1.4.5 Situations in which stored software can be applied

Normally there are two situations in which stored software can be applied

A. During replacement of a MOP (by crew)

B. During a service visit including update of parameters and/or ECS version

In **case A** (a new MOP) the operating system is normally pre-installed on the MOP, so when the MOP powers up it will seem identical to a standard Windows PC. The task is then to install the engine control system.

To install the engine control system insert the software medium (USB or CD-ROM) into the PC and locate the correct setup file. There will normally be two optional setup files on the CD-ROM/USB: "install_mopA_XPE.bat" and

“install_mopB_XPE.bat”. It is important to select the file name which matches the MOP being installed, either MOP A or MOP B. Double click on the file and follow the on-screen instructions.

After a successful completion of the installation the MOP main application can be started using the “Start MOP” option in the Windows Start menu.

After starting this application the MOP will automatically acquire configuration information and service parameter backup from the MPCs.

In **case B** (during a service visit where parameters and/or ECS version is changed) it is important that the visiting service engineer ensures that the ECS version and service parameters stored onboard are correct. This either means supplying a new set of CD-ROMs or updating the data on the USB memory stick (momentarily changing the Read/Write selector to Write).

1 HMI (Human Machine Interface)

The HMI consists of four fixed areas always shown.
See Drawing 6655-0125 Fig. 2.

1. An Alarm Status Bar showing the oldest unacknowledged alarm and Alarm status at the top of the screen.
2. A Navigation Bar at the right side of the screen.
3. A Toolbar at the bottom of the screen.
4. A Screen area (rest of the Screen)

On the screen, the displays which can be activated (i.e. pushed like a button) are shown in 3-D graphic and the inactive displays are in 2-D graphic. Once activated, the display is highlighted with a blue line at the outer circumference

The HMI operates with two password levels, which are Operator level and Chief level.

Operator level:

From the Operator level it is not possible to set any parameters. It is for normal operation and monitoring only.

Chief level:

In addition to the Operator level, this user level has privileges to set parameters (setpoints, engine states and engine modes). A password must be supplied in order to access Chief level.

There is no limit in the number of unsuccessful attempts to enter the correct password. The password is hard coded in the system and can therefore not be changed.

2 Alarm System

The alarms on the MOP are all related to the Engine Control System.

On Drawing 6655-0125 fig. 1 is shown the ECS and the possibilities to communicate with the ordinary alarm system, and the safety system. These three systems are able to interact with each other i.e. in case of a slow down and a shut down.

The shut down and slow down can be divided into two kinds – cancellable and non-cancellable.

If a cancellable shut or slow down occur the safety system will release an alarm pre-warning and after timeout of the pre-warning period activate the shut/slow down.

If a non-cancellable shut or slow down occur the safety system must release the shut or slow down immediately.

3 Alarm Handling

Alarm handling is carried out from one of the following four screens

3.1 Alarm list

3.2 Event Log

3.3 Manual Cut-Out List

3.4 Channel List

These four Alarm Handling screens can be accessed via the secondary navigator by pressing the "Alarms" button in the main navigator. When pressing this button, the latest selected alarm screen will be shown on the screen. If no screen has previously been selected, the "Alarm List" is shown. The screen can then be changed via the secondary navigator.

3.1 Alarm List (See Drawing 6655-0130)

The Alarm List contains the central facility of the Alarm Handling, allowing for display, acknowledgement and cut-out of raised alarms. Detailed alarm explanation can be accessed for each of the alarm occurrences.

The alarms are displayed in chronological order, with the latest alarm at the top.

The Alarms might be grouped by the ECS if they are related to the same cause in order to simplify the overview of the alarm list. The group can be expanded by selecting a group and pressing the -/+ button on the toolbar. Not all alarms are grouped.

If there are too many alarms to be displayed at the same time on the screen, the remaining alarms can be accessed by pressing the Page-up/Page-down buttons on the Toolbar.

Alarms presented in the alarm list can be found in three states:

1. Alarm unacknowledged
2. Alarm acknowledged
3. Normal unacknowledged

An alarm can only appear as "one line" in the alarm list. An acknowledged alarm going into normal or an alarm in the normal state being acknowledged, is immediately removed from the list.

Acknowledgement of a single alarm or all alarms is allowed on both levels (operator or chief) from the “Ack”/“All” buttons on the toolbar at the bottom of the screen. (When pressing “Ack”/“All” only the alarms visible on the screen are acknowledged).

To see a detailed alarm explanation, press the relevant alarm line. The alarm line is then surrounded by a thick blue line showing that it has been selected. By pressing the button “Info” on the Toolbar, a window will appear just above the Toolbar. This window contains:

- Description
- Cause
- Effect
- Action

So the engineer is able to start troubleshooting on this particular alarm (The detailed alarm explanation is removed by pressing the same “Info” button).

3.1.1 Alarm Line Fields, Colours and Symbols (See Drawing 6655-0130)

Each alarm line is divided into the following fields:

Ack. The acknowledgement status field of unacknowledged alarms contains an icon toggling between two states, alerting the operator of a unacknowledged alarm.

The status of the alarm can also be identified by the background colour as well as the graphical identification in the Acknowledgement field on the Screen as shown below.

	Unacknowledged alarm in alarm state
	Unacknowledged alarm in normal state
	Transition from unacknowledged to acknowledge of an alarm in alarm state
	Acknowledged alarm in alarm state
	Unacknowledged alarm is cut out
	Alarm was previously unacknowledged in normal state. Now the state is not available
	Alarm was previously unacknowledged in alarm state. Now the state is not available

	Transition from unacknowledged to acknowledge of an alarm in normal state
	Alarm is acknowledged in normal state, and in the process of being removed from the alarm list

At the upper right corner of the screen four small icons are shown which are (from left to right):

	Number of unacknowledged alarms
	Number of active alarms
	Number of Manual Cut-out alarms
	Number of invalidated channels

From the toolbar at the bottom of the Alarm List screen, alarms can be cut-out. This feature is described in details in Section 3.3.

Description. This field contains the alarm text (e.g. »Tacho set A failure«)

Status. This field shows the status of the alarm as one of the following:

- Normal
- Alarm
- Low
- High
- Not Available
- Auto Cut-out
- Manual cut-out

ID. This field contains a unique alarm identity. (e.g. CCU1_01010328). This ID must always be used for reference and reporting.

Time. This field shows the time of the first occurrence of the alarm, no matter the status changes. The time is shown in hours, minutes, seconds and 1/100 sec. (e.g.13:47:02.56)

3.2 Event Log (See Drawing 6655-0135)

The event log can be used for viewing the history of events and to support the operator in troubleshooting. Events stay in the log even after they have been acknowledged and are no longer active. Alarms are logged with three events in the Event Log. The events are Alarm, Normal and Acknowledged. There can be up to 1 million events logged in the event log.

The events are stored in a database on the MOP's hard disc with both local and UTC time stamps. If more than 1 million events are logged, the oldest events are discarded.

Each event (with the most recent event on top) is shown as a single line and each event line is divided into the following fields:

ID Unit Tag. This field contains a unique event identity.

Date. This field contains the date of the event.

Time. This field shows the time of the event. The time is shown in hours, minutes, seconds and 1/100 sec.

Description. This field contains the alarm text (e.g. »HCU oil leakage«).

Status. This field shows either Normal or Alarm.

MCo. Shows whether the alarm is Manual Cut-Out or not.

ACo. Automatic Cut-Out.

Ack. The alarm is acknowledged.

3.2.1 Searching for an Event From a Specific Date and Time or by Tag Number.

This feature can be helpful when extracting information to external parties or when investigating an event.

When scrolling up or down on the Event Log screen is not sufficient, it is possible to search for a specific event by tag number by pressing the button "Unit/Tag Filter". When an alarm occurs, it is given a tag number that is stored together with the alarm event. By entering this number in the dialogue box and pressing "Apply" the alarm event is shown on the screen.

Similarly, the button "Time Span Filter" sorting can be selected.

Enter the from/to date and time in the toolbar by using the popped up keyboard. Press "Apply" to execute. Note that the entered time has to be in UTC time. As a result the events, inside the selected time span to the specified date and time, will be selected and shown on the screen.

If an event log is exported (*see next item*) only the selected time span events are exported. This is useful in order to highlight relevant events and to reduce the file size.

From the button "Go to Time/Date", events which took place at/on a specific time/date can be displayed. Note that the entered time has to be in UTC time.

When a filter is no longer needed, remember to remove it (by pressing the button again), otherwise it might seem like the event log is frozen and does not receive new events.

3.2.2 Exporting the Event Log

From the toolbar “Export Event Log”, displayed when the “Export” button is pressed, it is possible to print a copy of the Event Log or make a back-up Dump used for information to external parties or the engine crew themselves.

Should external parties ask for an Event Log record (for trouble shooting purposes), the Event Log record can be saved on a USB memory stick (or Hard Disc Drive if no USB memory stick is available) as a zip file. Be aware of the risk of using USB-sticks generally.

If an event log is exported and a time span filter is active, the only the selected time span events are exported (*see previous item*). This is useful in order to highlight relevant events and to reduce the file size.

In order to save the event log on a USB memory stick, insert the clean (free of malware) USB memory stick *before* pressing the Export button.

The file name will be: **EventLog<DateTime>.zip** when the file is saved on a USB memory stick or hard disk drive.

In both cases the **DateTime** is the UTC time when the file was saved.

The USB memory stick (containing the zip file) can then be hand carried to the ships mail PC and the zip file mailed to external parties for evaluation.

3.3 Manual Cut-Out List (See Drawing 6655-0140)

Manual Cut-Out of alarms may be used, for instance, if the engineer has observed a failure of a sensor that is not detected automatically (see below) or if, for instance, a Tacho pick-up is failing (the engine running on the redundant Tacho system) and is continuously giving an alarm and cannot be replaced immediately.

Alarms are sometimes cut-out automatically. Automatic cut-out may be used by the system to suppress alarms which are unimportant in specific states, e.g. when a sensor is invalidated by the operator.

The manually cut-out alarms are shown in a separate list, which can be accessed from the navigation bar. The number of Manual Cut-Out of alarms are also shown in the upper right hand of the alarm line fields.

See description 6645-0240 Alarm Line Fields, Colours and Symbols

The manual cut-out screen is in functionality equivalent to the channel list screen. An alarm can be cut-out manually from the screens Alarm List, Manual cut-out List or Channel list.

All alarm channels that have the status “Manual cut-out” are shown in the Manual cut-out List screen.

Removing ("Re-activating") an entry from the Manual cut-out List is done by highlighting the alarm(s) involved on the screen and thereafter pressing the button "Reactivate" in the toolbar.

NOTICE

A Manual Cut-Out of an alarm should only be used as a temporary solution and never as a permanent solution to a problem.

3.4 Channel List (See Drawing 6655-0145)

The channel list screen contains status information of all alarm channels within the ECS, no matter the status of the individual alarm channel. As default, the alarm channels are listed in tag-name alphabetic order. From the channel list screen, it is possible to cut out (and re-activate) alarm channels.

1 Engine

Engine operation and adjustment is carried out from one of the following five screens:

1.1 Operation

1.2 Status

1.3 Process Information

1.4 Process Adjustment

1.5 Chief Limiters

Screens 1.1, 1.2 and 1.3 are related to engine start-up preparations and daily running, 1.4 and 1.5 are related to engine adjustments.

The operator can access these five operation and adjustment screens via the secondary navigator by pressing the Engine button in the main navigator.

1.1 Operation (See Drawing 6655-0150)

Operation is the main screen for control of the engine during operation.

On this screen, "prepare start" can be performed and "slow turn" can be enabled before start of the engine.

Drawing 6655-0150 shows the full screen. In the following, a detailed description of the individual fields will be given.

1.1.1 Main State (See drawing 6655-0150 Fig. 1+2)

The main state field contains 3 status fields indicating the current sub-telegraph command states and the states of the engine.

The background colours on the graphics are specified as:

- Blue = Normal state
- Yellow = Warning state
- Red = Alarm state
- Grey/dimmed = Not in use

The top field indicates the current sub-telegraph command state, which can be one of the following:

- FWE (Finished With Engine)
- Standby
- At Sea

The middle field indicates the states of the engine:

- (Blank)
 - (engine is operative or blocked according to the sub-telegraph command)
- Engine Not Blocked (with yellow background): if top field is in FWE condition, and not all conditions are fulfilled.
- Engine Not Ready (with yellow background): if top field is Standby or At Sea, and not all conditions are fulfilled.

The cause of the states “Engine Not Blocked” or “Engine Not Ready” can be seen in the Status screen, drawing 6655-0155, in the field Start Conditions.

The bottom field indicates, via yellow or red warnings, why the engine is not ready:

- (Blank) (engine is ready and Increased Limitation inactive)
- Increased Limitation (yellow) is shown when active, (and engine status is not FWE, and neither Start blocked or Shut Down status is active). Increased Limitation is a warning condition.
- Start blocked (red) is shown when active, (and engine status is not FWE, and Shut Down status is not active). Start blocked is an alarm condition.
- Shut Down (red) is shown when active. Shut Down is an alarm condition.

1.1.2 Command [RPM]

The command indicator button contains six or eight status fields. Two fields highlighted, indicating the current active control station (Bridge, ECR or LOP) and the actual speed command setting for each of the control stations. The actual selected control station is indicated by dark blue (normal selection) or yellow (take command) see below.

The Bridge Control and ECR stations are parts of the RCS (Remote Control System). Only one control station at a time is active.

The active control station is normally selected via the RCS request acknowledge system. However, the selection may be overridden from either the ECR or LOP by the “take command” buttons, which are wired directly to the ECS (Engine Control System) and situated on the control station panels.

If the active control station selection is inconsistent, the ECS keeps the last valid active control station as the active station, until a new valid selection is available (possibly a “take command”).

In the event the “take command” signals from both the ECR and the LOP are selected simultaneously, the LOP has first priority and is selected.

1.1.3 RPM Fine Adjust

By pressing the Command [RPM] button (not shown), a RPM Fine Adjust toolbar is displayed. It allows the RPM setpoint to be adjusted in operator level. E.g. if the

speed command setpoint is 83.8 RPM, it can be fine adjusted to 84 RPM. Moving the manoeuvring handle will disable the fine adjustment mode.

NOTICE

RPM fine adjustment can only be performed in ECR Command mode.

1.1.4 Running Mode button (See drawing 6655-0150 Fig. 2)

The engine Running Mode button contains a status field indicating the current active running mode.

Changing the running mode is done by pressing the Running Mode button. This brings up a toolbar. On the toolbar, the current running mode is selected.

For the ME engine, several running modes may exist, e.g. Economy, Emission or TC Cut Out. These contain different algorithms, and provide various fuel efficiency and emission characteristics. The running modes are commissioned during test bed running. If only Economy mode is available, the mode selection is not usable (dimmed).

1.1.5 Governor Mode button (See drawing 6655-0150 Fig. 3)

The engine Governor Mode button contains a status field indicating the current active governor mode.

Changing the governor mode is done by pressing the Governor Mode button. This brings up a toolbar. On the toolbar, the current governor mode is selected.

The speed controller can be requested to calculate the fuel index according to various methods. Each method is referred to as a 'Governor Mode', and they represent various tolerances for maintaining the engine speed equal to the set point during load and/or set point variations.

For normal operation the following two modes are available:

- **RPM control:**
'Speed' mode - provides the most rigid speed control, leading to large fuel index variations. **Use this mode when making performance measurements and adjustments.**
- **Torque control:**
'Torque' mode – the speed control is dampened when the speed is close to the required speed, providing speed control without large index variations, but allowing larger speed variations.

1.1.6 Pressure Indicators

The pressure indicators consists of a bar graph and a status field.

Both the bar graph and the status field indicate the actual pressure of the actual-medium.

1.1.7 Auxiliary System Status Indicators (See drawing 6655-0150 Fig. 4)

The system status indicators display information of the operation mode of the auxiliary systems controlled by the ME ECS. These are all indicators and do not allow changing mode or status. Possible control is made on the screens for the actual systems. The indicators are:

- HPS (Hydraulic Power Supply): Manual, Auto.
- Lubricator: Running Stopped, Prelube, LCD (Load Change Dependent) On.
- Auxiliary Blowers represented by two status fields, one indicates the operation mode, which can be Auto or Manual. The other indicates the current status of the blowers, which can be Stopped, Starting, Running or Failed.

The following indicators are **optional** (engine dependent):

- PTO (Power Take Off): Off, Request, Permit, Request (yellow and warning if a parameter for switching on the PTO is not fulfilled).
- WHR (Waste Heat Recovery): Off, Allowed, Request, Request (with yellow and warning) and Permission.
The WHR is ready for use when »Allowed« is shown.
(See separate manual or description 5445-0300)
- Var. XBP (Variable Exhaust Gas Bypass): percentage open.
(See separate manual or description 5445-0300)
- On/Off XBP (Exhaust Gas Bypass): Open or Closed.
(See separate manual or description 5445-0300)
- VTI Valve (Variable Turbocharger Inlet Valve): Open or Closed.
- VT (Variable Turbocharging system) (Not shown)
(See separate manual or description 5445-0200 Variable Turbocharging System).

1.1.8 Start Status

The start status indicator consists of a single display, showing information on the status of a start attempt.

The status shown can be one of the following:

- Stopped
- Running
- Repeated Start (yellow)
- Slow Turn Failed (red)
- Start Failed (red)

1.1.9 Speed [RPM] (See drawing 6655-0150 Fig. 4+5)

The speed indicator consists of a bar graph.

The set point and the actual running speed of the engine are shown in the two displays above the graph.

The uppermost display is the speed command modifier. The speed modifier is a function that may override the actual speed command and control the speed system set point for the engine speed. When the function is active, the control mode is shown in the Speed Indicator.

The available modes are:

Stabilizing	The stabilizing modifier defines a speed set point that ensures the starting of the engine.
Stop	The stopped modifier sets the speed set point to zero.
Minimum Speed	The minimum speed command modifier defines a minimum speed set point during operation of the engine.
Maximum Speed	The maximum speed command modifier defines a maximum speed set point during operation of the engine.
Fixed Speed Set	Fixed speed set is activated when running in pitch backup mode from bridge (option for CPP systems).
Shut Down	The shut down modifier sets the speed set point to zero.
Slow Down	The slow down modifier sets the speed set point to a predetermined slow down level.
PTO	The speed is kept higher than ordered to keep the shaft generator connected during start up of the auxiliary engines.
Speed Ramp	Increase and decrease of speed is limited by the ramp.
Load Program	The load control modifier defines a maximum speed set point that ensures the maximum fuel oil index limit is not exceeded.
Barred Speed range *	Indicates that the modifier has changed the preset from inside a barred range to either lower or upper limit of the ramp. The engine may have 0-2 barred speed range(s).
RPM Fine Adjust	The speed is being modified according to the setting entered in the RPM Fine Adjustment toolbar on the Operation screen.
Run Up/Down Prog.	When the chief increases or decreases the speed set significantly, the engine speed follows predefined curves. (Optional).
Chief Max Speed	If the user is at Chief level, it is possible to define a Maximum Engine Speed on the Chief limiter screen. See section 1.5
TC Cut Out	If the TC Cut Out option is installed, the speed will be limited, when the engine is running in TC Cut Out Mode.
WHR	The speed is kept higher than ordered to keep the shaft generator connected during start up of the auxiliary engines.

* Barred Speed Range

If the function is used, the barred speed range(s) is marked on the side of the bar

graph. Most engines have two barred ranges and the ranges are identical in the ahead and astern directions (FPP systems). When operating from ECR and Bridge, the speed set is automatically kept outside these range(s).

1.1.10 Pitch [%] (See drawing 6655-0150 Fig. 6)

The pitch indicator is only shown on ships with CPP systems.

The pitch indicator consists of a label and a bar graph, indicating the current pitch setting. The label uses + (plus) or – (minus) to indicate positive (forward) or negative (backwards) pitch. The bar graph is centred at 0 and positive and negative is up and down, respectively.

The pitch indicator bar graph uses a pointed graph to underline the direction (sign) of the current pitch.

1.1.11 Fuel Index [%] (See drawing 6655-0150 Fig. 5+6)

The fuel Index indicator consists of a bar graph and a set of status fields. The top status field indicates the current effective or nearest limiter. The electronic governor will limit the fuel index command according to the actual engine operating conditions. If no limiter is currently active the nearest limiter is displayed on a light blue background. When a limiter is active it is displayed on a dark blue background.

Available limiters are:

Start	The start limiter defines a fixed amount of fuel to be used for the first injections during start.
Chief Index	The chief limiter defines a maximum amount of fuel to be injected according to the settings done by the operator at the screen Chief limiters.
Scavenge Air Pressure	The scavenge air pressure limiter defines a maximum amount of fuel to be injected based on the actual scavenge air pressure, in order not to overfuel the engine.
Torque	The torque limiter defines a maximum amount of fuel to be injected according to actual engine speed. This is to ensure that the engine torque does not exceed recommended levels.
Hydraulic Power Supply	The hydraulic power supply pressure limiter defines a maximum amount of fuel oil to be injected according to actual hydraulic power supply requirements, in order to ensure that the hydraulic pressure does not drop below a minimum operation limit.
Running Mode	The running mode limiter is a limitation of the current selected running mode, and can not be increased by "Increase Limitation".
Chief Load	The chief load limiter defines the maximum allowed engine load set by the chief on the Main Operating Panel. This limiter can not be increased by "Increase Limitation".
Compression pres. *	The compression pressure limiter defines the maximum scavenge air pressure (0.9 bar) when running with stopped (closed) exhaust valve operation.

* See description 6645-0320 for further information.

Below the limiter status field is a set of dynamic labels displaying the actual fuel index and the current fuel index limit.

1.1.12 Prepare Start button

The prepare start function is normally to be activated before start if the engine has been stopped for some time. Pressing the button will start the cylinder pre-lubrication and the auxiliary blowers (if stopped).

When pressed, the button will stay down until the procedure is completed. If the engine has not been started within a certain time, the auxiliary blowers will automatically stop.

The command is available only when the engine is stopped and the prepare start-procedure is not running.

1.1.13 Slow Turn button

Slow Turn is used during preparations before start of the engine, and is normally to be used with the indicator cocks open. Slow turn is used for visual inspection of the blow out.

Slow Turn, Air Run or the turning gear can also be used for exhaust valve operation verification, if one or more CCU's have been rebooted.

See 6645-0120 item 1 Starting, regarding exhaust valve supervision function in CCU's

When the button is selected, the engine is operated on starting air through the slow turn valve as long as the manoeuvring handle is activated. If a manual prepared start has not been executed, the system will automatically perform one.

1.1.14 Auto button

The auto button is pressed when start preparations are completed, and the engine has to be started. When selected the engine will perform a normal automatic start. If a manual prepared start has not been executed, the system will automatically perform one.

1.1.15 Air Run button

The Air Run button function is only available in Chief operating level.

The Air Run function can be used in the following situations:

When checking the Tacho system (test), starting air valve test and after maintenance (and after check with the turning gear) to check the function and movement.

Air Run, Slow Turn or the turning gear can also be used for exhaust valve operation verification, if one or more CCU's have been rebooted.

See 6645-0120 item 1 Starting, regarding exhaust valve supervision function in CCU's

Air Run function is similar to Slow Turn, except that the main starting valve is open and the engine is running faster (still without fuel injection).

Air Run is activated when the manoeuvring handle is in "run" position (as with Slow Turn). This will rotate the engine until the manoeuvring handle is set to »stop« (or the engine is started by selecting the Auto button).

1.2 Status (See Drawing 6655-0155)

The engine status screen provides extended engine information specifically for use when changing the status of the engine, i.e. in the process from FWE to standby state or vice versa.

1.2.1 Main State

The main state field shows exactly the same information as the main state field in the operation screen view, drawing 6655-0150. For a detailed explanation, see 1.1.1 Main State Field, in this description.

1.2.2 Start Conditions

The Start Conditions field is a status list, showing if the engine is in the intended state (FWE or st.by/at sea). The conditions shown in bold must be fulfilled before the intended state can be obtained.

If a condition is shown with a green check mark, the condition is in accordance with the intended state.

If a condition is shown with a red background and a white exclamation mark the engine is not ready for starting.

If the condition is not relevant the background is dimmed, but a check mark or exclamation mark will still indicate the status of the condition.

The possible status indications of each field are listed below:

- Main Starting Valve in service position (Standby or At Sea)
Yellow, when main starting valve is not in service position.
Green, when main starting valve is in service position.
- Main Starting Valve Blocked (FWE)
Yellow, when main starting valve is not blocked.
Green, when main starting valve is blocked.
- Starting Air Distribution System in service (Standby or At Sea)
Red, when Starting Air Distribution system is blocked.
Yellow, when Starting Air Distribution system is not in service.
Green, when Starting Air Distribution system is in service.
- Starting Air Distribution System blocked (FWE)
Yellow, when Start Air Distribution system is not blocked.
Green, when Start Air Distribution system is blocked.
- Starting Air Pressure (Standby or At Sea)
Red, when starting air pressure is below level for bridge start.
Green, when OK.
- Control Air Pressure (Standby or At Sea)
Red, when control air is vented.
Yellow, when control air pressure is low.
Green, when control air pressure is OK.

- Control Air vented (FWE)
Yellow, when control air is not vented.
Green, when control air is vented.
- Turning Gear disengaged (Standby or At Sea)
Red, when turning gear is not disengaged.
Green, when turning gear is disengaged.
- Auxiliary Blowers (Standby or At Sea)
Red, when blowers are not operational.
Green, when blowers are operational.
- Hydraulic Power Supply (Standby or At Sea) (Start-up pumps)
Yellow, when HPS is not OK. (e.g. in manual mode)
Green, when HPS is OK.
- Hydraulic Pressure (Standby or At Sea)
Red, if pressure is too low.
Green, if pressure is OK.
- Zero Pitch before starting (Standby or At Sea) (CPP systems only)
Red, if pitch is not zero before starting.
Green, if pitch is zero before starting.

1.2.3 Start Air

The starting air pressure indicator displays the system starting air pressure continuously.

1.2.4 Turning Gear

The field shows either Engaged or Disengaged.

1.2.5 Control Air Pressure

The control air pressure indicator displays the system control air pressure continuously.

1.2.6 Blowers

Shows the status of the auxiliary blowers, which is either:

- Stopped
- Running
- Starting
- Failed

1.2.7 Hydraulic Oil

The hydraulic oil pressure indicator displays the system hydraulic oil pressure continuously.

1.2.8 Crankshaft

Shows the current position of the crankshaft when turning the engine (for maintenance purposes) with the turning gear, and allows checking of the position in case of malfunction of starting air valves.

1.2.9 Pitch Start Blocking Indicator (CPP Systems Only)

On the pitch start blocking indicator, it is possible to cancel the start blocking. (This could be relevant if the engine is stopped with the pitch in ahead or astern position, and return to zero is not possible due to failure).

Cancel of start blocking can only be performed from Chief Level. When blocking is cancelled this is shown with the text "Blocking Cancelled" on a red background.

1.2.10 Start Status

The start status indicator consists of a single field containing information on the current start status.

Three successive start attempt failures or a slow turn failure will cause Start – Blocked. The below conditions are indicated in the start status indicator:

- Stopped
- Running
- Repeated Start (warning)
- Slow Turn Failed (alarm)
- Start Failed (alarm)

1.2.11 Details

Pressing this button will display the individual readings of the Start Air, Control Air and Crank Shaft sensors.

1.2.12 Pneumatic Diagram

In addition to the information described above the screen contains a schematic diagram of the pneumatic starting and control air system. The diagram is intended to indicate the functionality of the system. For a specific engine, further details can be found in the plant installation drawings supplied by the engine builder.

The pilot valves A, B and Slow Turning, can and must be activated to test that the main starting valve and the slow turning valve open and the tightness of the starting air valves in the cylinders. (This test is performed regularly with stopped engine, see description 6645-0100).

Pressing the field, encircling the pilot valves, opens a tool bar from which activation of the pilot valves is possible.

1.3 Process Information (See Drawing 6655-0160)

Process Information has some tabs which are described in the following.

1.3.1 Running Mode tab

The displayed values on a light blue background (e.g. Pcomp/ Pscav ratio or Estimated Engine Load) are set points or estimates, where as those on a dark blue background (e.g. Speed Actual or Hyd. Oil Actual) are actual measurements. Due to the inherent difficulties of estimating process values there will often be some deviations between the set points and the values that can be measured using e.g. PMI equipment.

Running Mode. This button is the same as described in 1.1.4 - Running Mode.

1.3.2 Speed Control tab

This screen gives the user an overview of the possible Speed Modifiers and Governor/Index limiters. Arrows indicates if a modifier or limiter is active, or if it is a near limiter. The same information will be shown on the Speed indicator and Fuel Index indicator on the Operation screen.

The Speed Modifiers are described in section 1.1.9 Speed [RPM].

The Index Limiters are described in section 1.1.11 Fuel Index [%].

1.3.3 LDCL tab (engine dependent)

This screen gives the user an overview of the LDCL, temperature Load Dependent Cylinder Liner cooling water system.

By pressing the details button it is possible to see set points and other detailed information in order to evaluate performance of the control system.

During normal operation the system should be in Automatic mode. Stop mode can be used to force the LDCL pump to stop and set the 3-way valve to 100% position. This is regarded as an error in the system and an alarm for LDCL stopped will be raised. In order to stop the Automatic mode, press the LDCL State button and select Stop.

See description 5045-0100 Cooling Water Systems for a description of the LDCL system.

1.4 Process Adjustment (See Drawing 6655-0161)

ECS offers two methods for adjustment of the combustion process:

- Auto Tuning for easy tuning of the cylinder pressures for best engine performance
- Manual adjustment of process offsets for cylinder pressures and FO quality

Auto-tuning is described in section 1.4.1. For detailed information and use of auto-tuning is referred to the "PMI Auto-tuning, Operation, User's Reference Guide", included in the PMI installation.

NOTICE

Auto-tuning functions are available only for engines for which the PMI Auto-tuning option has been selected.

Manual adjustment of process offsets is described in section 1.4.2 and is intended for engines equipped with PMI Offline or for adjusting cylinder pressures during operating conditions that do not allow for auto-tuning.

1.4.1 Auto Tuning (Optional)

Auto-tuning reduces the workload required for operating the engine continuously at the design conditions, according to the actual running mode and engine load ordered by ECS. Auto-tuning covers adjustment of maximum, compression and mean indicated pressures and is made available as “continuous auto-tuning” (fully automatic) and as “user-controlled auto-tuning” (each auto-adjustment session commanded by the operator).

Auto-tuning Status

With following conditions fulfilled:

- **Index is stable:** Engine is in steady state operation, indicated by a stable governor index
- **Index is sufficient:** Index is above minimum required level (app. 25% load, can be plant dependent)
- **Sensor values:** Valid sensor values are available from the PMI auto-tuning system and deviation between cylinders as well as towards the reference are not too large

The functions for auto-tuning are available, informed in the status bar as “Tuning allowed” (green).

If one or more conditions are not met, the status bar will display “Tuning not available”, and indicate the reason why (yellow or red).

Continuous Auto-tuning

With continuous auto-tuning selected by the operator, the mean pressure level will automatically be adjusted in order to minimise the deviation between ordered and measured mean value. The continuous function is only active if the above conditions are fulfilled and will adjust only within narrower limits than available to manual adjustment. The adjustment offsets applied by the continuous function are displayed in the lower right corner of the “Mean” field.

Continuous P-Comp

The mean pressure level will automatically be adjusted in order to minimise the deviation between ordered and measured mean value. The continuous function is only active if the above conditions are fulfilled and will adjust only within narrower limits than available to manual adjustment. The adjustment offsets applied by the continuous function are displayed in the lower right corner of the “Mean” field.

User-controlled Auto-tuning

The cylinder pressures are automatically adjusted once, each time the operator presses the command button in the toolbar. This is available for adjusting either the engine balance or the mean pressure level:

- **Balancing**

By pressing the “Deviation” field, the operator can command an auto-balancing, that will balance the engine in respect to one or all of the key parameters Pmax, Pcomp or Pi.

- **Mean Deviation**

The operator can command an auto-mean deviation adjustment. The result will be a minimised deviation between the ordered and the actual mean pressure. This function should be used when deviation is larger than allowed to be adjusted automatically by the continuous auto-tuning function.

NOTICE

The user-controlled mean deviation function is intended only for adjustments in relation to fuel property changes, and only when engine is running above Pmax Break Point. Executed at lower loads, it is required for safe engine operation to check the maximum pressures and re-adjust if necessary when engine load is increased.

CAUTION

Applying an offset in Pmax at low load (<BP), may lead to too high Pmax at high engine loads.

1.4.2 Manual Adjustment of Process Offsets

The cylinder pressures can be adjusted by manually setting the corresponding process offsets for control of fuel injection timing and exhaust valve closing time.

Before making any performance measurements and adjustments select RPM Control governor mode. *See 1.1.5 Governor Mode.* Performance measurements and adjustments should always take place during calm weather/sea conditions.

Cylinder load

On the “Cylinder load” tab, the operator (Chief level) can adjust the load balance.

Cylinder pressure

On the “Cylinder pressure” tab, the operator (Chief level) can manually adjust Pmax level and balance, Pcomp/Pscav ratio and Exhaust Valve Open Timing Offset.

NOTICE

The “Pmax offset all” function is intended used when engine is running above Pmax Break Point. Executed at lower loads, it is required for safe engine operation to check the maximum pressures and re-adjust if necessary when engine load is increased.

**CAUTION**

Applying an offset in Pmax at low load (<BP), may lead to too high Pmax at high engine loads.

1.4.3 Fuel Quality

On this screen a function for in- or decreased fuel oil index for all cylinders (FQA = Fuel Quality Adjustment) is available, e.g. in case of changed fuel quality. The specific calorific value and fuel oil density must be checked in the actual fuel oil specification delivered with the fuel samples at bunkering.

When entering new bunker values the ME system will suggest a new value for Fuel Quality Offset. The 'Suggested Fuel Quality Offset' does not influence the engine in any way. In order to change the actual running conditions it is necessary to change the 'Applied Fuel Quality Offset'. Adjusting the 'Applied Fuel Quality Offset' is required in order to make sure that the internally calculated ME-ECS load (as displayed on the process information screen, see drawing 6655-0160) corresponds to actual engine load (as estimated by e.g. PMI equipment).

Ensuring this match in internal and external power estimation is an important aspect of getting correct functioning of the ME system.

The 'Suggested Fuel Quality Offset' is a good starting point for finding the correct 'Applied Fuel Quality Offset' however the final value must be found in an iterative process where internal load estimation and external load estimation are compared and 'Applied Fuel Quality Offset' is adjusted.

NOTICE

Mismatch between internal and external load estimation can give rise to a wide range of problems. Including, but not limited to, too restrictive fuel index limiters, wrong cylinder pressures and wrong cylinder lube oil usage.

1.5 Chief Limiters (See Drawing 6655-0162)

This screen gives the operator the opportunity to:

- Limit the maximum engine speed
- Manually limit the fuel index at all cylinders
- Manually limit the fuel index or cut out one or more cylinders
- Stop or enable the exhaust valve operation on one or more cylinders
- Observe the HCU Status and reset HCU related failure if needed

The buttons are described more in details in the following.

1.5.1 Chief Max Speed

When this button is selected the operator can limit the engine's maximum speed by entering a new value in the toolbar. The ECS will use the new value when Apply is selected.

1.5.2 Chief Max Load

When this button is selected the operator can limit the maximum load by entering a new value in the toolbar. The ECS will use the new value when Apply is selected.

1.5.3 Chief Index Limit [%]

When Chief Index Limit for All cylinders is selected the operator can limit the maximum fuel index by entering a new value in the toolbar. The ECS will use the new value when Apply is selected.

When Chief Index Limit for individual cylinders is selected the operator can limit the maximum fuel index on the selected cylinder by entering a new value in the toolbar followed by [Apply].

In order to completely cut out the fuel injection on a cylinder unit then the new value should be 0 followed by [Apply].

Before putting a cylinder out of operation the restrictions in description 6645-0320 must be taken into consideration.

To reenale fuel injection on a cylinder unit then the new value should be more than zero; in order to get the same limit on all units then the values should be identical. The ECS will use the new value when Apply is selected.

1.5.4 Exhaust Valve operation

On this button the current status on each unit can be observed, the current status can be either Enabled or Stopped.

In order to stop exhaust valve operation on a given cylinder unit then press the Enabled button and select Stopped. The exhaust valve will during normal circumstances remain closed and the fuel injections on the cylinder unit will stop.

Before stopping the exhaust valve operation follow the advise in the Warning text in the toolbar. The restrictions in description 6645-0320 must also be taken into consideration.

NOTICE

Stopping an exhaust valve operation is only possible when the scavenge air pressure is below the critical limit (**0.9 bar**), in order to protect the engine against cylinder cover lift.

To re-enable the exhaust valve operation press the Stopped button and select Enabled.

1.5.5 HCU status and reset

On this button the current HCU status on each unit can be observed, the current status can be either Normal or Fault.

A Faulty HCU unit can be selected and reset in the toolbar. HCU Fault reset should only be done after proper investigation according to the Alarm text. HCU Fault can only be reset when the engine speed is reduced to a certain level (engine dependent), e.g. below 50 rpm.

If a HCU Failure has occurred then the system will create a HCU event on MOP B.
See description 6645-0270 HCU and HPS Events.

1 Auxiliaries

The Hydraulic System, Scavenge Air and Cylinder Lubrication are monitored in the Auxiliaries main navigator.

From each menu, the operator can control and monitor these systems.
The screens are:

1.1 Hydraulic System

1.2 Scavenge Air has one or more tabs (engine dependent):

- 1.2.1 Main tab
- 1.2.2 Main tab with Exhaust Gas Bypass and VT System (engine dependent)
- 1.2.3 Main tab with Variable Turbocharger Inlet (VTI) (engine dependent)
- 1.2.4 Process Values tab (engine dependent)
- 1.2.5 TC Speed Balancing tab (engine dependent)
- 1.2.6 WHR (Waste Heat Recovery) tab (engine dependent)

1.3 Cylinder Lubrication

1.1 Hydraulic System (See Drawing 6655-0175)

This screen shows a simple schematic drawing of the HPS (Hydraulic Power Supply). The screen shows from three to five engine-driven pumps (depending on engine layout) and two electrically driven start-up pumps. A bypass valve from pump pressure side to suction side is also shown.

EL-HPS: On some plants the main HPS pumps are not engine-driven but instead electrically driven (EL-HPS). In this case there will be no start-up pumps or bypass valve. Apart from that the following description is valid also for EL-HPS, just ignore the word 'engine-driven'.

If, for some reason, control signal to an engine-driven pump is lost, the pump swash plate is deflected to 100% in ahead direction. Thereby ensuring adequate hydraulic power for running ahead.

NOTICE

On engines with 4 or 5 engine-driven pumps, pump 4 is controlled from ECUA and pump 5 is controlled from ECUB
See drawing 7055-0150.

On Chief level the following buttons are available:

- HPS Mode
- Pump Torque Limiter

- Set Point
- Bypass

1.1.1 HPS Mode

Pressing the HPS Mode button activates a toolbar at the bottom of the screen. At Chief level, it is possible to switch between Auto and Manual mode.

In Auto mode it is possible to perform the following commands (both Operator and Chief level)

1. Select one of the electrically driven pumps as master.
2. Select one of the engine-driven pumps as pressure controlling pump.

In **Manual mode** (Chief level) the additional command features are:

1. Adjustment of the current hydraulic pressure set point (see Section 1.1.3 in this Chapter).
2. Operate engine-driven pumps bypass valve using either ACU1 or ACU3 (Bypass valve to be tested for movement every 6 months, at stopped engine, see 1.1.5 in this Chapter).
3. Start/stop of the electric start-up pumps.

1.1.2 Pump Torque Limiter

In this field, it is possible to cancel the Pump Torque Limiter. (Chief-Level)

The torque limiter has two functions:

1. The total torque to the engine-driven pumps must not exceed a level that can harm gear and chain. Hence, to protect gear and chain, the sum of the swash plate positions must not exceed a predefined value. (Engine specific).
2. To protect the individual pumps from breakdown or damage.

By pressing the Pump Torque Limiter field, a toolbar will appear, where the limiter can be either activated or cancelled. (Cancellation of the limiter will raise an alarm on the MOP).

When the limiter is cancelled, the electrically controlled swash plates in the pumps are allowed to deflect to the mechanical limitation, if the need is there. (When the limiter is active, they are only allowed to deflect to an electrically controlled maximum position).

1.1.3 Set Point and Hydraulic Oil

Adjustment of the oil pressure set point can be done from the Set Point display, where the actual set point is always shown. The engine must be running. The actual oil pressure is shown at the display as Hydraulic oil

NOTICE

Adjustment of the Set Point (Chief level and manual mode) is only intended as an option in test or failure situations.

As default, the normal operating pressure is in the 200-300 bar range and is set at commissioning. The engine shutdown level is approximately 140 - 180 bars, also set at engine commissioning. Both the operating pressure and the shutdown pressure is engine dependent.

The pressure set point is only relevant for the engine-driven swash plate pumps, as the pressure of the start-up pumps is limited via mechanical adjusted pressure limiting valves. The start-up pumps are automatically stopped or started as needed.

1.1.4 Double Pipe (Not shown) (Engine dependent)

If equipped with a double pipe system a display shows the pressure in the outer pipes of the high pressure double pipes. Normally, this pressure should be in the 0-10 bar range, depending on the specific engine layout.

See description 4545-0150 for more details of the hydraulic system.

1.1.5 Bypass Valve

On the main pressure line from the engine-driven pumps, a bypass valve is installed.

At normal running with HPS mode in "Auto", the bypass will open in the event of shutdown of the engine (wind milling can occur). This ensures oil return to the suction side of the pumps and thereby avoids cavitation and unintended wear on the pump parts.

Also, if the shutdown is due to a leakage at the high pressure side, and the engine keeps turning due to wind milling, the amount of oil spilled can be reduced by leading the oil back to the suction side.

By checking the valve manually, it is ensured that the valve is working properly. (The valve is to be checked manually every 6 months.) See description 6645-0100.

The bypass valve is tested at engine still stand, in Chief level and the HPS mode in manual. For redundancy reasons the bypass valve is controlled both via ACU1 and ACU3.

1.2 Scavenge Air (See Drawing 6655-0180)

Scavenge Air has one or more tabs (engine dependent) described in the following.

1.2.1 Main tab (See drawing 6655-0180 Fig. 1-4)

The scavenge air main tab contains information and controls for monitoring and operating the auxiliary blowers. If equipped (engine dependent), the main tab displays Exhaust Gas Bypass (EGB) system or Variable Turbocharger (VT) system. See the next paragraph.

By pressing the “Details” button, indication of the current scavenge air pressure is shown for each individual scavenge air sensor.

The blowers are normally operating in Auto mode. Operating conditions are:

The blowers are started when :

- “Prepare start” button is pressed (Operation Screen)
- Manoeuvring handle is moved to start position, prompting the system to perform an automatic prepare start (engine start is delayed until blowers are running and pressure is correct)
- Engine is running but the scavenge air pressure is below a certain value (e.g. during manoeuvring)

The blowers are stopped when

- Engine is shut down
- The current sub-telegraph command state is moved to FWE position
- 10 minutes after engine has been stopped (adjustable)
- Engine is running and the scavenge air pressure is above a specified level
- After prepare start if no start has occurred within the pre-determined time

If a switch to manual operation is required, this is done by pressing the “Blowers Mode” push button (see drawing 6655-0180). By pressing the individual blower 3D display at chief level and manual mode, it is possible to start or stop the individual blower.

The screen contains 2 to 5 blowers, depending on the engine layout. The state of each blower is shown. Status is either stopped, starting, running or failed.

NOTICE

Manual operation of the blower is mainly intended for use during fault-finding and test situations. Selecting Manual Mode will therefore also raise an alarm on the MOP.

1.2.2 Main tab with Exhaust Gas Bypass and VT System (engine dependent) (See drawing 6655-0180 Fig. 5-7)

Monitoring of the Exhaust Gas bypass Systems (EGB) and Variable Turbocharger (VT) system is performed from the Scavenge Air Main tab.

The actual positions and settings of the on/off bypass, the variable controlled bypass valves and VT System are shown on the screen.

By pressing the "Bypass Mode" button (Chief level), the bypass valve modes can be changed between automatic and manual.

In manual mode (Chief level), the variable controlled bypass valve can be opened / closed or set to the angle desired.

In manual mode (Chief level), the on/off bypass can be opened or closed.

For a detailed description of the Variable Turbocharger system see description 5445-0200 or a separate manual, for Exhaust Gas bypass system see description 5445-0300 or a separate manual.

1.2.3 Main tab with Variable Turbocharger Inlet (VTI) (engine dependent) (See drawing 6655-0180 Fig. 8-10)

Monitoring of the Variable Turbocharger Inlet (VTI) system is performed from the Scavenge Air Main tab.

The Set Point and Actual position of the VTI valve is shown on the screen.

By pressing the "VTI Valve Mode" button (Chief level), the VTI Valve Mode mode can be switched between Automatic and Manual.

In manual mode (Chief level), the VTI valve can be opened or closed.

1.2.4 Process Values tab (engine dependent) (See drawing 6655-0180 Fig. 11)

This screen displays the different values in either the Exhaust Gas Bypass (EGB) system or Variable Turbocharger (VT) system. It is not possible to change any values or set points on the screen.

The estimated engine load from the ECS goes into a scavenge air pressure set point table. This set point is displayed in the Pscav Set Point field and is sent to the scavenge air controller (Pscav Control field). The scavenge air controller also receives the actual scavenge air pressure measurement indicated in the Actual Pscav field.

The scavenge air controller calculates the necessary relative flow area for either the Exhaust Gas Bypass valve or Variable Turbocharger, displayed as Rel. Flow Area. Depending on engine layout, there may be a minimum or a maximum limit allowed of the flow area, this will be indicated in the Min Limit or Max Limit fields respectively.

See description 5445-0200 or a separate manual for a more detailed description of the system.

1.2.5 TC Speed Balancing tab (engine dependent) (See drawing 6655-0180 Fig. 12)

This screen is for speed balancing of multiple VT's (Variable Turbochargers). The actual speed of the turbo chargers is displayed in the Speed (RPM) field. Any deviation is displayed in the Speed Deviation (RPM) field. The optimum condition is achieved if both TC's runs with the same speed, then the efficiency is highest.

In case the speed deviation is too large, it is possible to offset the set point to the variable nozzle ring to minimize the deviation. Select either TC1 or TC2 and enter a new value in the toolbar followed by [Apply].

1.2.6 WHR (Waste Heat Recovery) tab (engine dependent) (See drawing 6655-0180 Fig. 13)

This screen displays the different values in the WHR system. It is not possible to change any values or set points on the screen.

Common for the values on the valves is that the value either is expressed in percent of the valve position (angle) or in percent of the effective flow area.

The individual fields on the screen are described in details below.

Failure Handling

In case of failure in the EGB control, the EGB valve is opened (fail safe position). If equipped with Power Turbine Control this is disabled by setting the maximum allowed position (Max Allowed Pos.) for the Power Turbine Control Valve to zero. If equipped with TC PTO this is disabled by setting the maximum allowed power to zero.

Main Engine Interface to Power Management System (PMS)

In case that the WHR system will supply an essential part of the electrical power supply, meaning that sudden loss of engine power would lead to a black-out, then a handshake interface to the main engine is used. This interface ensures exhaust power for the WHR system until the PMS system has started an auxiliary engine, within a timeout period.

In case the WHR system is non-essential for the power generation, meaning that there is no risk of black-out when reducing engine power, then the "WHR allowed" signal may be utilised by the PMS system.

In both cases speed ramps adjusted suitable for WHR operation is enabled in the entire working range of the WHR.

See description 5445-0300 or a separate manual for a more detailed description of the WHR system.

1.2.6.1 Nom. Max. Area

Nominal Maximum allowed area.

The total maximum bypass area allowed at the current engine load.

The value may be decreased by the scavenge air pressure "L" (Low) limiter.

See also "Total BP Area".

1.2.6.2 Pscav

Scavenge Air Pressure.

The current measured scavenge air pressure is indicated in numbers and in a bar graph. The "H" (High) arrow indicates the upper scavenge air pressure limit; the "L" (Low) arrow indicates the lower limit. The upper limit is fixed, the lower limit changes with the engine load. If the pressure reaches the limits, an alarm will be raised.

1.2.6.3 Nom. Min. Area

Nominal Minimal allowed area.

The total minimum bypass area allowed at the current engine load.

This value may be increased by the scavenge air pressure "H" (High) limiter.

See also "Total BP Area".

1.2.6.4 Dec. BP Limiters

Decrease Bypass Limiters.

In case of low Pscav, the maximum allowed bypass area is gradually decreased until pressure is within limits or until EGB is closed.

1.2.6.5 Inc. BP Limiters

Increase Bypass Limiters.

In case of high Pscav, the minimum allowed bypass area is gradually increased until pressure is within limits or until EGB is fully open.

1.2.6.6 Max. Alowd. Pos.

Maximum allowed position for the Power Turbine Control Valve.

1.2.6.7 Max Alowd. Area

Maximum allowed flow area for the Power Turbine Control Valve.

1.2.6.8 Actual Position

Actual position of the Power Turbine Control Valve.

1.2.6.9 Actual Area

Actual flow area of the Power Turbine Control Valve.

1.2.6.10 Max. Area

Max allowed area for exhaust gas bypass "EGB Set point" calculation.

See "EGB SetPoint".

1.2.6.11 Min. Area

Minimum allowed area for exhaust gas bypass "EGB Set point" calculation.

See "EGB SetPoint".

1.2.6.12 Incr. Exh. Energy

Increase Exhaust Energy.

The steam system (boiler or economizer) can request the "EGB SetPoint" calculation to increase or decrease the exhaust gas bypass valve area set point in order to optimize steam production.

See "EGB SetPoint"

1.2.6.13 EGB SetPoint

Exhaust gas bypass valve set point calculation.

Depending on the input values from the steam system "Incr. Exh. Energy" and the Max. and Min. allowed area the controller calculates a set point for the exhaust gas bypass valve.

If "Incr. Exh. Energy" signal is 100 % the "EGB Set point" = Max. Area.

If "Incr. Exh. Energy" signal is 0 % the "EGB Set point" = Min. Area.

1.2.6.14 Total BP Area

Total Combined Bypass area.

This is the total sum of the exhaust gas bypass "Set Point; Area" added to the Power Turbine Control Valve "Actual Area".

The "Total BP Area" is normally expected to be between the allowed limits of the "Nom. Max. Area" and "Nom. Min. Area".

1.2.6.15 EGB Values

This field displays the values of the exhaust gas bypass valve:

- Set Point
 - Area

Flow area set point value for the exhaust gas bypass valve. This is the output from the "EGB SetPoint" calculation.
 - Position

Position set point (angle) value for the exhaust gas bypass valve. This is the output from the "EGB SetPoint" calculation.
- Actual

Actual values for the exhaust gas bypass valve. Values are expressed in position and flow area.

1.3 Cylinder Lubrication (see Drawing 6655-0185) ME Lube

The ME lube Control System provides the operational monitoring and control of the ME cylinder lubrication plant which lubricates the cylinders in the ME type engine.

The following displays can be **monitored**:

1.3.1 Flow (l/h)

1.3.2 Basic Feed Rate (g/kwh)

1.3.3 Actual Feed Rate (g/kWh)

The following displays can be **operated** at Chief level.

1.3.4 Total

1.3.5 Prelube

1.3.6 LCD (Load Change Dependent)

1.3.7 S% (Sulphur Content)

1.3.8 Brk. Pnt (Brake Point)

1.3.9 Feed Rate Factor

1.3.10 Min. Feed Rate (g/kWh)

1.3.11 Feed Rate Adjust Factor

1.3.12 Running In (g/kWh)

1.3.13 Lubricator Test Sequence

NOTICE

The latest Service Letter from MAN Diesel & Turbo should be consulted with regards to feedrate and brake point adjustments and settings.

1.3.1 Flow

The Flow display shows the ordered lube oil amount in litres/hour.

NOTICE

If one or more lubricators are malfunctioning (e.g. Feedback Failure) the actual amount applied will differ.

1.3.2 Basic Feed Rate

The Basic Feed Rate is a calculated rate for the complete lubricator system in g/kWh shown with two (2) decimals. The formula for calculating the Basic Feed Rate is $\text{Rate} = S\% \times (\text{Feed Rate Factor})$.

1.3.3 Actual Feed Rate (each cylinder)

The bar graphs for each individual LCD shows the actual feed rate per cylinder. When running at low load the full bar is barred and the upper display on the bar graph shows "Low Load".

1.3.4 Total

The Total display shows the total ordered amount of lubricating oil used since last power up of the ECU involved. Pressing this display opens a toolbar with the option to reset the total amount of lubricating oil.

Both of the values Flow and Total are based on the ordered numbers of lubrication strokes and the displaced amount per stroke.

1.3.5 Prelube (for test purpose)

As stated above this button is mainly used for test purposes, since the prepare start will cause the system to automatically perform a prelube.

When the "Prelube" button is pressed a toolbar is shown on the screen. Pressing the button "ON" triggers a prelubrication on all cylinders and evaluates feedback from the lubricators.

NOTICE

Prelubrication can only be activated if hydraulic pressure is present. This demands that the engine (Sub-telegraph) is put in the state "Standby" or that the Hydraulic start-up pumps are set to manual operation and started.

1.3.6 LCD (Load Change Dependent)

The LCD display shows whether the LCD (Load Change Dependent) lubrication is on or off. When the LCD button is pressed, a toolbar will be displayed which will allow the operator to disable the LCD.

1.3.7 S % (Sulphur content)

Activating the display S % enables adjustment of the Sulphur content equal to the sulphur content in the HFO used. The range is between 0.00 to 5.00 S % and is not adjustable outside this range.

1.3.8 Brk. Pnt (Brake Point)

The Break Point button is used to set the desired changeover point between the "RPM" and "Power" lubrication algorithms. A change between the two algorithms is determined by the engines current fuel index. If the fuel index is below the break-point then the "RPM" lubrication algorithm is used and Low Load will be displayed in the Actual Feed Rate field. If the fuel index is above the breakpoint then the "Power" lubrication algorithm is used and the current feed rate will be displayed in the Actual Feed Rate field. The break point is set in Fuel Index %.

Always refer to the latest Service Letter from MAN Diesel & Turbo regarding cylinder oil lubrication for the correct setting.

1.3.9 Feed Rate Factor

Activating the display Feed Rate Factor enables adjustment of the feed rate for all cylinders. The display shows the feed rate with 2 decimals and is "g/kWh%S".

1.3.10 Min. Feed Rate

The display Min. Feed Rate enables adjustment of the minimum feed rate for all cylinders. The value is displayed in g/kWh and is normally set to 60% of the basic recommended feed rate.

1.3.11 Feed Rate Adjust Factor

Activating the display Feed Rate Adjust Factor enables adjustment of the feed rate for each cylinder separately.

1.3.12 Running In [g/kWh]

When a cylinder is being run-in, the feed rate can be entered by this display. Running-in of a single cylinder is described in chapter 2245-0100. The latest service letter from MAN Diesel & Turbo should be consulted as mentioned earlier.

1.3.13 Lubricator Test Sequence

Pressing the Lubricator Test Sequence starts a continuous activation of the lubricator at predefined injection rate (different from "Prelube" 1.3.5 where the injection of oil is done at the fastest possible speed.)

This feature is used after repairs, etc. on the lubricator(s), enabling the engineer to manually check the lubricator for leaks and injection.

If a single button (cylinder 1, 2, 3, etc.) is pressed, a toolbar is shown on the screen. The toolbar enables the engineer to start test of the lubrication on the particular cylinder concerned or on all lubricators.

In case of CCU failure (and the CCU can not be replaced immediately) please see description 6645-0321 for how to obtain the back-up signal for lubrication.

NOTICE

The lubricator test can only be activated if hydraulic pressure is present. This requires that the engine (Sub-telegraph) is put in state "Standby" or that the Hydraulic start-up pumps are set to manual operation and started.

1 Maintenance

The maintenance screens give an overall view of the status of the ECS. In order to understand the use of the screens, an explanation of the layout of the Multi Purpose Controller (MPC) is appropriate and is placed in item 1.1.

The five maintenance screens are described from item 1.2 and onwards. They can be accessed via the secondary navigator by pressing the "Maintenance" button in the main navigator. They are mainly used at engine commissioning, during fault finding on I/O cabling / channels and external connections to sensors and during engine operation. The use of these screens is therefore relevant for engine crew as well.

1.1 MPC description

1.2 System View I/O Test

1.3 Invalidated Inputs

1.4 Network Status

1.5 Function Test

1.6 Troubleshooting

1.1 MPC description

To understand the use of the maintenance screens, an explanation of the layout of the multi purpose controller (MPC) is appropriate.

The MPC is a computer unit which has no user interface such as a display or a keyboard, but has a wide variety of inputs/outputs (I/O) for interfacing to sensors and actuators of the engine, e.g.: (*see figure 1*).

- Inputs for e.g. tacho signals, standard (0)4-20mA transducers, $\pm 10V$ signals, switches and 24V binary signals.
- Outputs such as (0)4-20mA and $\pm 10V$ signals, contacts and high-speed semiconductor switches.
- Duplicated control network for security.
- Serial communication controller for either a remote I/O network or point-to-point serial communication.
- Service channel to be connected to a laptop PC for service purposes.

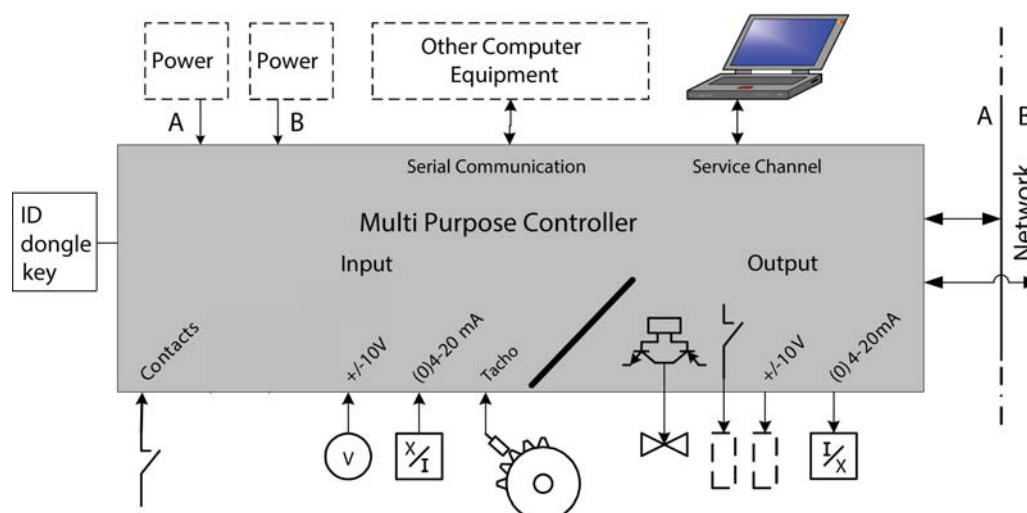


Figure 1: The MPC Mk.2's wide variety of inputs/outputs (I/O) for interfacing to sensors and actuators of the engine.

The main processor of the multi purpose controller is a Motorola 68332, which is a 32-bit processor »borrowed« from the automotive industry. It includes an on-chip timing co-processor for synchronisation with the crankshaft rotation and speed measurement.

To ease the production of the multi purpose controller, all programmable components are in-circuit programmable, which also allows field update of the controller by means of relatively simple tools. The MPC contains no hard drive or other sensitive mechanical components, and the software is stored in a non-volatile Flash-PROM memory, i.e. the application software may be sent to and programmed into the multi purpose controller through the network, and thereby restore the functionality after the multi purpose controller has been exchanged with a spare unit from stock.

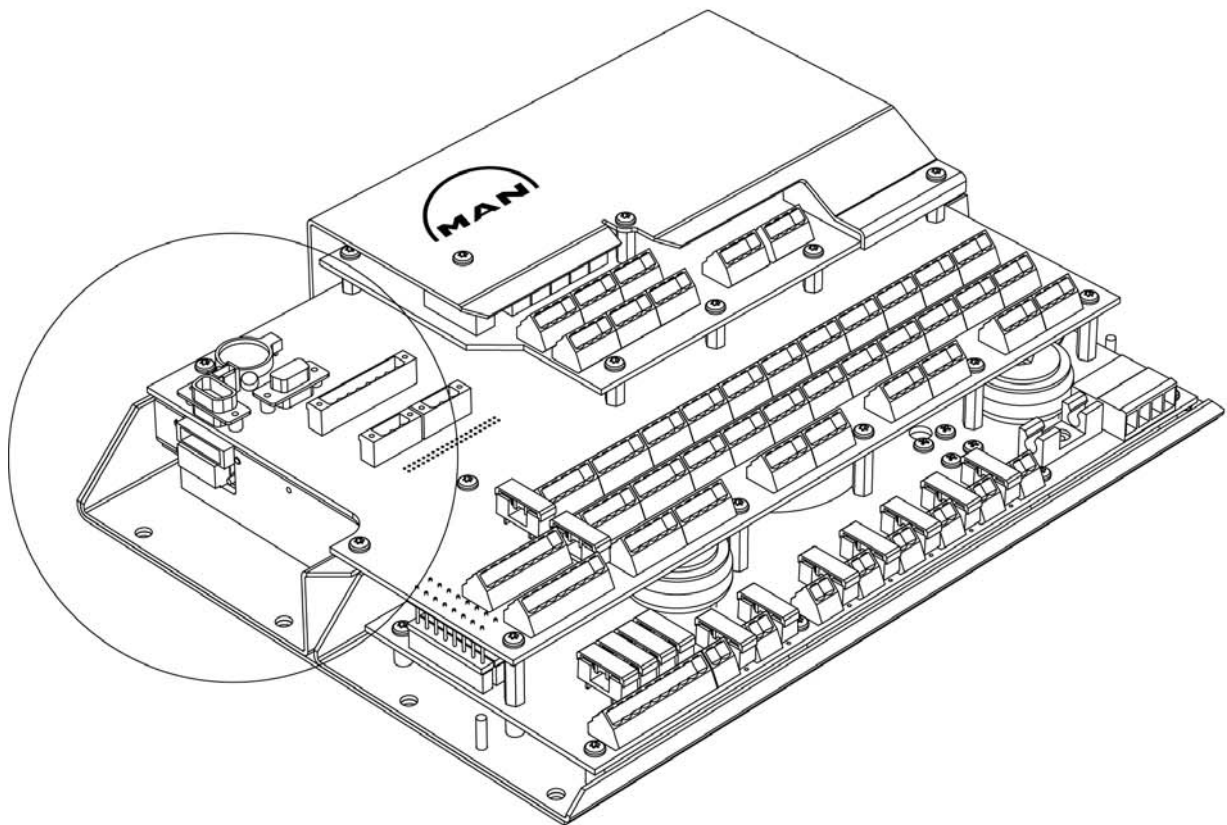
There are two types of MPCs, MPC Mk.2 (see figure 2) and MPC10 (see figure 3). The MPC Mk.2 is equipped with a battery. This battery is used for back-up power to the clock function of the MPC in the event that the 24 V power supply is turned-off. All clocks of all MPC's are synchronised via the network. Synchronisation is done regularly and always after power is on after a possible power off. *Regarding battery in MPC Mk.2: See work card 4765-1901.* The MPC10 can only be used as CCU.

When a new MPC is mounted in the cabinet, the ID dongle key in the cabinet is mounted in the ID dongle key plug-in, after reconnecting of all wires. The ID dongle key tells the "new" MPC in which cabinet it is mounted and, in that way, which software and parameters it should upload from the MOP hard drive (e.g. CCU1, or EICU).

The MPC is also equipped with a light emitting diode (LED), capable of showing green, yellow or red light. The LED indicates the current status of the MPC.

During normal running the LED is green. If the LED is yellow, the MPC is rebooting or is in test or configuration mode. If the LED is red, the MPC is unavailable.

The MPC is equipped with a reset button. A reset of the MPC will reboot the MPC, but will not erase or renew the software stored in the memory. If resetting does not solve the problem with a red LED then a replacement of the MPC might be necessary.

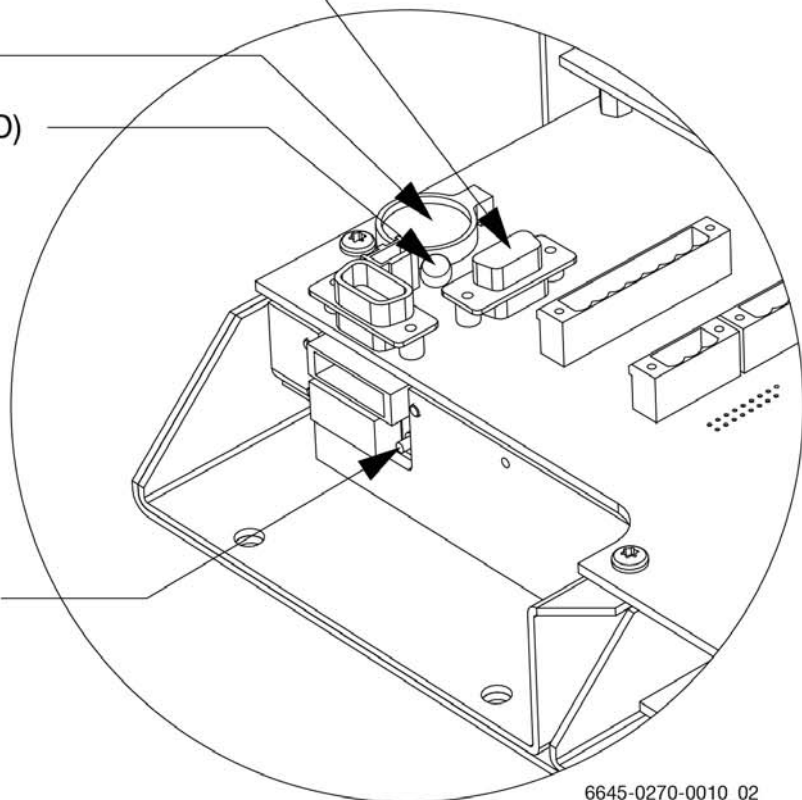


Socket for ID dongle key

Socket for battery

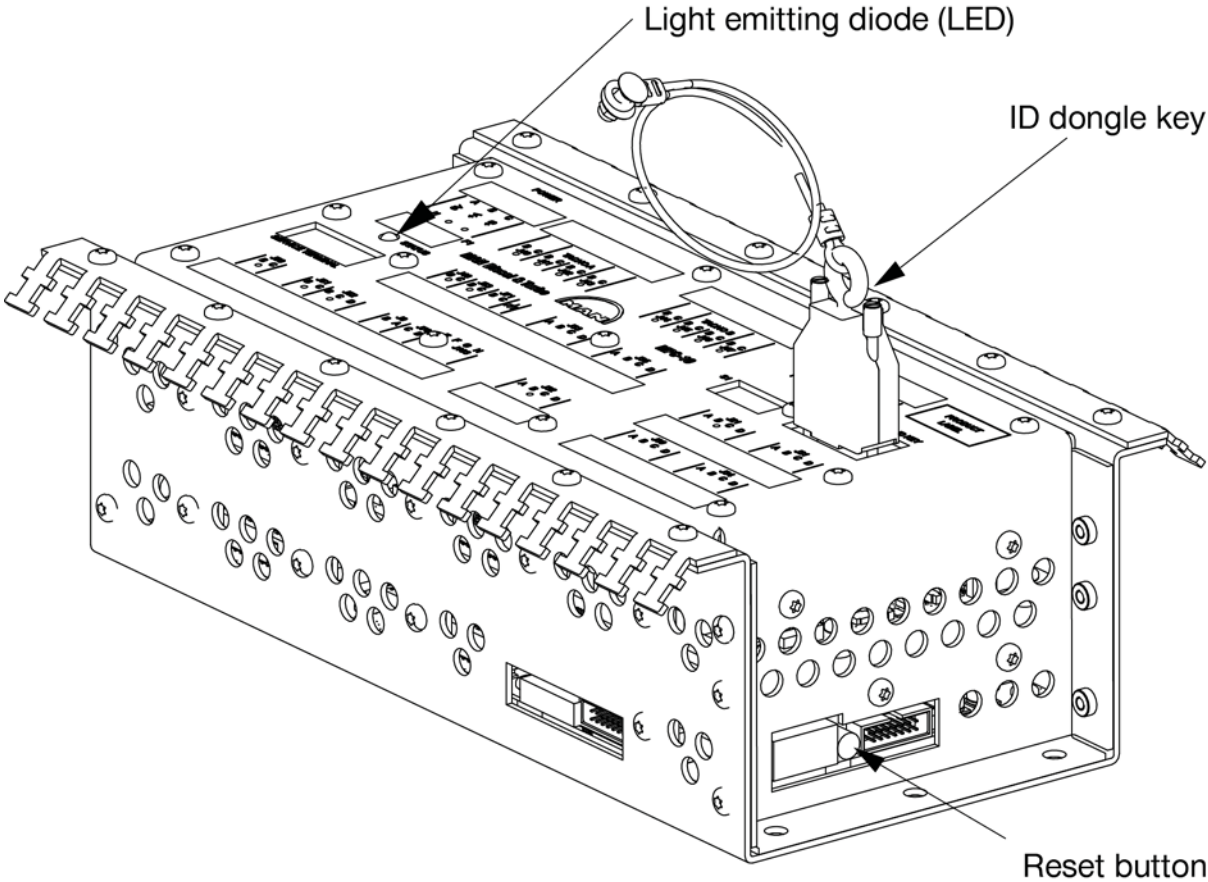
Light emitting diode (LED)

Reset button



6645-0270-0010_02

Figure 2: The MPC Mk.2.



6645-0270-0010_03

Figure 3: The MPC 10.

1.2 System View I/O (See drawing 6655-0190)

The icons (see drawing 6655-0190 Fig. 1) shown on the controllers, show the status of each single controller, e.g. whether it is in mode:

Active	
Controlling	
Test	
Configuration	
Blocked	
Not accessible	

By pressing a single controller on this screen (in this case ACU1 is pressed and shown on drawing 6655-0190 Fig. 2), the actual inputs/outputs on the selected controller are shown.

The screen shows # (Number), Info, ID, Description and Process Value of each single channel on the MPC.

It is possible to see each single channel in both Normal and Test Mode, but to set an output channel manually, Test Mode has to be chosen (Chief Level).



Changing to TEST Mode will STOP the MPC from controlling the system.



If all CCUs have been turned off and then on or switched to TEST mode, is it necessary to turn the engine 5 revolutions in order to bring the "Exhaust valve activation status" back to "OK" internal in the ECS software. The engine can be turned by using the turning gear, Slow Turn or Air Run.

By pressing the channel number, as for instance shown drawing 6655-0190 Fig. 3, a single channel is shown (in this case, channel 37 on ACU1). The status and values of this channel are listed on this screen.

On this screen, input channels can be invalidated and re-validated by pressing Process Value, see drawing 6655-0190 Fig. 4+5 (Chief Level).



Changing the status of a channel may cause the system to malfunction.

The reason for alarm on an input could for instance be a defective sensor or loose wiring from the sensor to the MPC.

If a channel is invalidated, the ECS will continue to operate in the best possible way, without the invalidated input sensor value.

1.3 Invalidated Inputs (See drawing 6655-0195)

If an input channel is invalidated (as described in item 1.2 above), it is listed on the screen "Invalidated Inputs". ID number, signal ID and a short description to easily overview and recognise the channel(s) involved are shown on this screen.

The reason for alarm on an input could for instance be a defective sensor or loose wiring from the sensor to the MPC. If a channel is invalidated, the ECS will continue to operate in the best possible way, without the invalidated input sensor value.

Invalidated input channels can be re-validated from this screen. Select the channel and press "Set Valid" (Chief Level).



Changing the status of a channel may cause the system to malfunction.

1.4 Network Status (See drawing 6655-0200)

This screen gives the engineer an overall view and exact status of the Control Network of the ECS

From this screen, it is possible to see the status of the Network using the icons named below: (Icons are visible at drawing 6655-0200, bottom)

- | | |
|------------------------------|--|
| • OK | |
| • This MOP | |
| • No Reply Single Channel | |
| • No Communication | |
| • Not Accessible | |
| • On-line But No Information | |
| • Not Relevant | |
| • Reference | |
| • Cross Connection | |

When all fields are shown with a green √ (check mark) everything is okay.

1.5 Function Test (See drawing 6655-0203)

The Function Test tab consists of 4 items (sub tabs).

1.5.1 HCU for each cylinder

1.5.2 Tacho equipment



1.5.3 HPS for each pump

1.5.4 Speed Handles

The main purpose of these tests is to provide the engine personnel with a tool to test the function of the HCU, Tacho equipment, HPS and the speed handles and their related components. The function test screens are also used to calibrate replaced components, e.g. in case of replacement of a fuel plunger sensor.

The function test screens are made as a step-by-step procedure, guiding the engine personnel through the tests. Each test begins with a few preparation steps in order to ensure the right conditions before commencing the actual test. **Chief access level** is required and if not otherwise stated, the engine must be stopped before commencing the test.

NOTICE

When rebooting an MPC in test mode, multiple alarms irrelevant to the test may occur.

1.5.1 HCU (See drawing 6655-0203 Fig. 2-10)

The HCU tab focuses on the FIVA valve or the ELFI/ELVA valves. Depending on the configuration, the list contains two or three function tests. Only FIVA valves with external amplifier have the option of an Amplifier Test. In the following all three function tests are explained.

NOTICE

As the HCU function test list is longer than the height of the screen a scrollbar is placed to the right.

Preparation of HCU Test

To begin the function test press the button START and follow the steps on the screen.

NOTICE

In order to verify that the fuel booster or exhaust valve are functioning as expected, an assistant must be stationed on the engine top at the unit in question during the test. For this test fuel pressure must be present.

Test of FIVA or ELFI/ELVA valve and calibration of Fuel Plunger

If the CCU MPC is not in test mode when the START button is pressed, the engineer is prompted to switch to test mode and reboot the MPC. Once the MPC has been rebooted, the function test will continue.



For testing of the fuel injection components, the FIVA/ELFI will make one fuel injection.

The fuel injection is verified by the assistant on the engine top by feeling the shock-wave on the respective fuel injection pipe, and feeling on the high pressure pipes.

For testing the exhaust valve components, the FIVA will activate the respective exhaust valve once. This is verified by the assistant, by listening for the "thump" sound of the exhaust valve opening and closing.

The test values listed on blue background in the far right column when the function test is finished and will under normal circumstances be within the default reference range listed next to the test value column.

If for some reason the test value differs from the reference value, this will be shown in one of the following ways:



Signal and value ok.



Signal not present. (check if the MPC is connected to the network)



Signal value outside reference range. (Value electrically out of range or wire-break)



Signal value outside reference range. (Signal ok, unit mechanically out of range)

If the test is successfully completed then the user has the option to use the SAVE button to upload the new calibration set points to the MPCs. Should this operation fail then another attempt should be made after approximately 30 seconds.

Amplifier test (only applicable to Curtis Wright FIVA valves)

This amplifier test enables the engineer to test the FIVA amplifier. When the START button is pressed a set of adjustment buttons will appear on the toolbar.

The adjustable voltage range for channel 70 is between -3.6V to +3.6V. If signal value field for ch. 70 turns red, this normally indicates that something is wrong with the MPC.



The signal value field for ch. 33 has the same different types of error indications as shown above. If any of these are triggered then this most likely indicates that something is wrong with either the amplifier or the connections to the amplifier.

Cyclic Test of Exhaust Valve and / or fuel injections

When START button is pressed, a set of buttons will appear on the toolbar, which enables the engineer to start a repeated cyclic test of the exhaust valve, in other words, the exhaust valve will continue opening and closing until the STOP button is pressed. Also for the fuel booster a single injection test is possible (both during the cyclic test and independent of this).

**CAUTION**

Activation of "single injection" will lead to one full MCR fuel Injection in the cylinder. Several activation will lead to filling of the combustion chamber with fuel oil.

Reboot of CCU

Reboot the CCU MPC to test mode in order to continue with tests or reboot to set the CCU MPC to normal operating mode (finished with function tests).

1.5.2 Tacho (See drawing 6655-0203 Fig. 11-12)

The Tacho Test allows for the verification of the angles of the Tacho Pick-Ups and angle encoder fine adjustment of certain parameters.

Test of Tacho Signals

Press Start and follow the instructions on the screen. Make sure that an assistant is standing by to activate the Turning Gear, and verify the crankshaft position.

During the test the following is displayed on the screen:

A: xx B: xx (blue background):

If the crank has been turned to the prescribed angle when the background is blue, then the value is correct. Continue to next step.

A: xx B: xx (yellow background):

If the crank has been turned to the prescribed angle and the background is still yellow, then the test has failed. Continuation of the test is not possible. By pressing the details button, specific information regarding the failure is displayed. Check and adjust the Tacho arrangement.

The x in the test can be either T or F

Setting of Fine Adjustment Parameters

As indicated on the screen a certain minimum engine speed is required in order for the ME system to measure a correct 'delta Tacho-B' value.

The 'Trigg Offset AH' value that is to be entered must be taken from the PMI equipment (see PMI manual). The 'Trigg Offset AH' value is not measured by the ME system, that is why a PMI-O diagram is required as part of the setting of the final Tacho parameters.

1.5.3 HPS (See drawing 6655-0203 Fig. 13)

The HPS function Test allows for the test and calibration of the hydraulic pumps. Up to 5 pumps can be present depending on system configuration, each tab corresponds to a pump.

Preparation

To start the test press " Start " and make sure that a start-up pump is in local control on the starter cabinet, and running so that the necessary hydraulic pressure can be maintained.

Test

Press " Start " and follow the instructions on the screen. Make sure an assistant is standing by at the pump to check the swash plate angle.

During the test the following is shown on the screen:

Icons with background colours can be seen in chapter 1.5.1.

x.x mA (blue background):- Value ok - go to next step.

x.x mA (red background):- Value is outside the measurement interval (4-20mA) continuation of the test not possible - check the sensor and cables.

x.x mA (yellow background):- Value differentiates from the reference value. Continuation of the test not possible. Check the sensor.

If all of the steps are satisfactory calibration of the specific pump is carried out by pressing " Save ". The test is concluded by rebooting the MPC back to Normal Mode.

1.5.4 Speed Handles

The Speed Handles tabs is typically used to calibrate a replaced speed handle or pitch handle.

The following tests are possible:

- Calibrate Bridge/ECR/LOP handle position and RPM set point
- Calibrate Bridge/ECR/LOP handle RPM set point only
- Calibrate Pitch Actual handle
- Calibrate Pitch Set Point

In Operator level, the current values can be monitored. In order to do calibration, Chief level access is required.

Calibrate Bridge/ECR/LOP handle position and RPM set point (See drawing 6655-0203 Fig. 14 to 20)

1. Select the handle which is to be calibrated by selecting the relevant "Command" tab: Bridge, ECR or LOP. The last calibrated values will be displayed. In the following example Bridge is selected, but the same procedure is applicable for ECR and LOP handles.

2. Press "Set Number of Positions" button.

3. Enter the number of "Ahead" and "Astern" positions using "Up/Down" buttons and press "Apply" button.

4. Press "Start". Position the handle as indicated on the screen (e.g. Max Astern). Enter the New Rpm value using the "Up/Down" buttons and then press "Next" button to proceed to next step.

5. Position the handle as indicated on the screen (e.g. -1). Enter the New Rpm value using the "Up/Down" buttons and then press "Next" button to proceed to next step.

6. Repeat step 5 until the next handle position is "Stop" level or "0 rpm".

7. Position the handle at "Stop" level or "0 rpm" and press "Next" button to continue.

8. Position the handle as indicated on the screen (e.g. +1). Enter the New Rpm value using the "Up/Down" buttons and then press "Next" button to proceed to next step.

9. Repeat step 8 until the next handle position is "Max Ahead".

10. Position the handle at "Max Ahead". Enter the New Rpm value using the "Up/Down" buttons and then press "Next" button. The "Next and Up/Down" buttons will now be disabled and Apply button will be enabled.

11. Click on "Apply" button for calibration. The calibration may take up to a minute.

Calibrate Bridge/ECR/LOP handle RPM set point only (See drawing 6655-0203 Fig. 21 to 25)

In order to do this, the handle positions must already be calibrated with valid values.

1. Select the handle which is to be calibrated by selecting the relevant "Command" tab: Bridge, ECR or LOP. The last calibrated values will be displayed. In the following example Bridge is selected, but the same procedure is applicable for ECR and LOP handles.
2. Click on "Set RPM Only" button.
3. If the Current RPM needs to be adjusted, enter a New RPM value using the Up/Down button. Click on "Next" button. If no adjustment is needed click on "Next" button.
4. Repeat step 3 for all the steps as necessary.
5. When all necessary steps are adjusted, click on "Apply". The calibration may take up to a minute.

Calibrate Pitch Actual handle (See drawing 6655-0203 Fig. 26 to 31)

1. Select "Pitch Actual" tab. The latest calibrated values will be displayed.
2. Press "Set Number of Positions" button.
3. Enter the number of "Ahead" and "Astern" positions using "Up/Down" buttons and press "Apply" button.
4. Press "Start". Position the handle as indicated on the screen (e.g. Max Astern). Enter the New Pitch value using the "Up/Down" buttons and then press "Next" button to proceed to next step.
5. Position the handle as indicated on the screen (e.g. -1). Enter the New Pitch value using the "Up/Down" buttons and then press "Next" button to proceed to next step.
6. Repeat step 5 until the next handle position is "Stop" level or "0 Pitch".
7. Position the handle at "Stop" level or "0 Pitch" and press "Next" button to continue.
8. Position the handle as indicated on the screen (e.g. +1). Enter the New Pitch value using the "Up/Down" buttons and then press "Next" button to proceed to next step.
9. Repeat step 8 until the next handle position is "Max Ahead".
10. Position the handle at "Max Ahead". Enter the New Pitch value using the "Up/Down" buttons and then press "Next" button. The "Next and Up/Down" buttons will now be disabled and Apply button will be enabled.
11. Click on "Apply" button for calibration. The calibration may take up to a minute.

Calibrate Pitch Set Point

The Pitch Set Point is calibrated in the same way as the previously described Pitch Actual handle. The Pitch Set Point tab is selected instead.

1.6 Troubleshooting (See drawing 6655-0204)

These screens are used for performing troubleshooting on the Hydraulic Cylinder Unit (HCU), the Hydraulic Power Supply (HPS) or insulation problems. The HCU Events and HPS Events are used to show the actual movements of FIVA or ELFI/ELVA valve, plunger positions, exhaust valve movements and swash plate positions as trend graphs.

1.6.1 HCU (See drawing 6655-0204 Fig. 1-9)

On this screen FIVA or ELFI/ELVA activation can be performed to execute fuel plunger and exhaust valve movement to check whether the system is working correctly.

Activation of the FIVA or ELFI/ELVA is performed by changing MPC Mode to Test Mode and activating the buttons displayed in the toolbar.

The cyclic test is only a cyclic activation of the exhaust valve.

NOTICE

Activation must only be performed with stopped engine. Each activation of the fuel plunger results in a fuel injection into the cylinder.

1.6.2 HPS (See drawing 6655-0204 Fig 10+11)

On this screen the swash plate position for each pump can be regulated to check whether the system is working correctly.

Activation of the swash plate position is performed by changing MPC Mode into Test Mode and activating the buttons displayed in the toolbar.

The swash plate position can be seen on input ch 34 and compared with the desired set point.

When the test is finished put the MPC back to normal mode.

1.6.3 HCU and HPS Events (See drawing 6655-0204 Fig. 12+13) (Only available on MOP B)

These screens are an aid for the engineer and are used to monitor the actual movements of the HCU and HPS related signal. E.g. used to identify trouble in case of a malfunction of the electrical and mechanical components.

The HCU and HPS Events include a lot of very useful information for e.g. troubleshooting.

It can however in certain cases be difficult to make quantitative conclusions based on HCU and/or HPS Events logs taken during a situation where problems are present (e.g. deviating cylinder pressures, hunting hydraulic pressure, etc.).

In those cases it is very helpful to have HCU and HPS Events logs from periods where there were no problems or irregularities. By comparing these logs with logs from situations where problems are present it is often possible to make qualitative conclusions regarding the current problems.

Therefore it is recommended to take manual HCU and HPS Events logs from time to time when no problems or malfunctions are present.

A suggested procedure is to make a note regarding the current speed, index and internal estimated power together with the names of the HCU and HPS Event logs and then save these on either a USB stick or some other computer (so the logs are still available even if MOP-B is later replaced).

NOTICE

Always ensure that any USB memory stick inserted into the MOP is scanned and cleaned of any malware.

A list of available dumps can be found in the upper left part of the list - newest on top. To display the contents mark an element in the list and press "Show Sequence".

Both manual dumps (Log Manually) and automatic dumps can be performed for special failures / alarms. The event which caused the dump is described in the text above the graph area. The time of alarm is shown as a vertical dashed line. The display of measured values can be turned on and off by pressing the buttons on the left side of the screen.

By clicking and holding (the cursor turns into a hand) in the area left of the Y- axis or in the area below the X - axis, the graph can be moved vertically or horizontally.

Zooming can be carried out by drawing a square in the graph area while "default view" can be recalled by pressing "Zoom to fit"

Storing both PMI diagrams and HCU Events logs from days with no problems, will greatly improve the options available for later troubleshooting. Therefore it is a good idea to take the HCU Events logs together with Performance Measurements and then save it all together.

1.6.4 Insulation (See drawing 6655-0204 Fig. 14)

When the MPC is connected to a insulation monitor and / or a noise pulse counter equipment the status is showed on this screen. This screen can be used to troubleshoot insulation problems, or monitor the insulation condition.

The insulation level shows slow variations in the insulations level (measured in kOhm). The insulation level is supervised and two alarms can be generated : "ECS Insulation level below normal" "Too low ECS Insulation level".

The noise pulse counter, counts the number of fast variations observed in the insulation level on the MPC. When electrical noise is detected by the "Noise Detect" functionality, an alarm is generated: "Electrical noise detected".

For further information on Insulation level and noise pulse detection please refer to Ident. No.: 5318818-2, "Troubleshooting Electrical Noise".

1.6.5 CoCoS EDS

As described on drawing 6655-0125 MOP B is connected to the CoCoS EDS PC (which also runs the PMI software).

CoCoS EDS is not a part of the ECS, however it is an essential tool with regards to troubleshooting and diagnostics.

Therefore it is important that CoCoS EDS is running correctly and that the connection is functioning. All the time.

The CoCoS EDS installation includes guidance on how to evaluate and troubleshoot the connection.

1.6.6 Data logging

In the case that assistance from external parties is needed, it is essential for troubleshooting that following data is delivered to external parties:

- A clear description of the case
- ECS Alarm/Event Log
- ECS parameter file (Spaf)
- ECS HCU data logger files
- ECS HPS data logger files
- EDS data logger files

This information can be gathered automatically with a program called "datgat.exe" which is located on the CoCoS-EDS/PMI computer or on the EMS-MOP (where applicable).

See description 6645-0180 Data logging for a description of how to use "datgat.exe".

NOTICE

The above mentioned data and log files will contribute to speed up the troubleshooting process, and are for that reason very important for external parties.

1 Admin and Power Off

The screens and button explained in the following are:

1.1 Set Time

1.2 Version (software and IMO Check Sum)

1.3 Power Off

1.1 Set Time (See Drawing 6655-0205)

At the Set Time screen, the operator is able to set the time/date for UTC (Chief Level required) or to set the time offset for Local Time in intervals down to 5 minutes (Operator Level).

Pressing on either button "UTC Date/Time" or button "Local Date/Time" will display toolbars (shown on drawing 6655-0205). From these toolbars, Date and Time can be set.

Pressing the buttons "UTC Time displayed" or "Local Time Displayed" enables the operator to choose between the time to be displayed at the MOP (upper right corner) and in the lists (alarm list, event log etc.)

Alarms and logs are recorded with both Local Time/Date and UTC Time/Date regardless of which time/date is selected for displayed .

NOTICE

Always ensure a correct setting of UTC. The ECS has no connections to the ship's master clock

1.2 Version (See Drawing 6655-0210)

1.2.1 Background

This screen displays the version type of the Engine Control System (ECS) controlling the engine. It is used to obtain the configuration information of the ECS. It displays, in table format, all the controllers that comprise the system, including specific information related to each controller.

1.2.2 Screen Items

In the upper system information line, general information of the ECS for this particular engine is shown. The fields are: (See drawing 6655-0210)

Product Name & Version	The name and version of the ECS software
Engine Group No.	The Engine number of the engine builder
IMO No.	Engine IMO number (former Lloyds number)
Engine Builder	Name of engine builder
Eng. No.	Engine Serial number

1.2.3 Controller information

In the controller information panel, data for each controller in the system is displayed. The pane contains the following:

1.2.4 Controller unit

ID	Name of MPC (controller)
Addr.	Network Address of MPC
Type	Application group the MPC belongs to (ACU, CCU, CWCU, ECU, EICU, ETU or SCU)

1.2.5 Parameters Check Sums

The Parameter Check Sums are indications of the current parameter values in the ECS. They are used as a method for determining if parameters have been changed. Especially the IMO Design parameters must not be changed compared to shop trial values, since they reflect emission and performance relevant parameters.

No changes made on the MOP will change the IMO Design Parameters Check Sums.

NOTICE

It is not possible to recreate the parameters of the ECS from the Check Sums, therefore sending a screen dump of this screen is not sufficient for external parties who inquire about specific parameter values.

1.2.6 Using the Screen

When the screen is first displayed (after power up of a MOP), no information appears in the table. Press the “Refresh” button to retrieve the latest system information and parameter checksums of all controllers connected to the ECS. (See drawing 6655-0210.)

If the information stored in one or more controller(s) is not consistent with the other controllers, a warning message is displayed in yellow by the specific controller and at the toolbar.

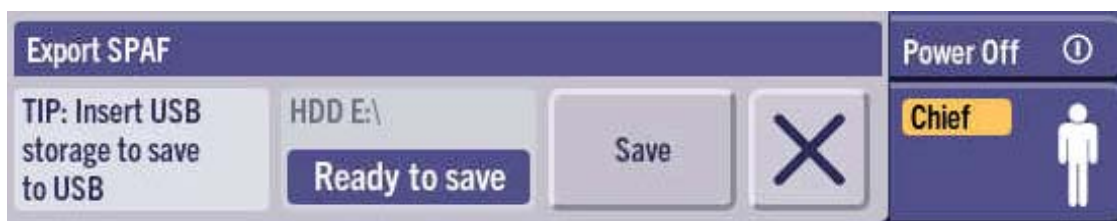


Pressing the Export Version button generates a copy of the information displayed in the table. This can be saved to a hard drive or USB memory stick. In order to export to USB, insert a scanned and cleaned USB memory stick in the MOP *before* pressing the Export Version button. The exported file is compressed in Zip format and must be unpacked to be readable. The file format is: SWVersNParam-Checksums on <Date & Time> for <MOP> <SW-version> on IMO <IMO number> Engine no <Engine number>.zip

When unpacked, the .html file can be opened in a normal internet browser and printed (and signed) if desired.

Export the System Parameter File (SPAF)

You may be requested by external parties like MAN Diesel & Turbo to send a SPAF file. The SPAF is a copy of the current parameter values in the ECS.



In order to export directly to USB, insert a scanned and cleaned USB memory stick in the MOP. Press the Export SPAF button, and then Save. The exported file is compressed in Zip format.

If a USB is not inserted before pressing Export, then the SPAF will be saved on the hard drive of the MOP.

NOTICE

Always ensure that any USB memory stick inserted into the MOP is scanned and cleaned of any malware.

1.3 Power Off

The Power Off button acts the same way as the "Shut Down" button in Windows Operating Systems on PCs. The Power Off button will only power off the MOP computer, not the rest of the ECS.

In order to start a MOP which is shut down, switch the power for the MOP computer "off" and then "on".



1 Cause

If flakes of burning or glowing carbon deposits drop into the oil sludge at the bottom of the scavenge air box, this sludge can be ignited and serious damage can be done to the piston rod and the scavenge air box walls, possibly reducing the tension of the staybolts.

Ignition of carbon deposits in the scavenge air box can be caused by:

- prolonged blow-by,
- “slow combustion” in the cylinder, owing to incorrect atomization, incorrect type of fuel valve nozzle, or “misaligned” fuel jets.
- “blow-back” through the scavenge air ports, due to an incorrectly adjusted exhaust cam disc or large resistance in the exhaust system (back pressure).

To keep the exhaust resistance low, heavy deposits must not be allowed to collect on protective gratings, nozzle rings and turbine blades, in addition the back pressure after the turbocharger must not exceed 350 mm WC.

2 Warning of Fire



WARNING

If the auxiliary blowers do not start during low-load running, on account of a fault, or the switch for the blowers not being in “Auto”-position, unburned fuel oil may accumulate on top of the pistons. This will involve the risk of a scavenge air box fire.

In order to avoid such fires:

- obtain permission to stop the engine
- stop the engine
- remove any unburned fuel oil from the top of the pistons
- re-instate the supply of scavenge air
- start the engine



CAUTION

The switch for the auxiliary blowers should be in “**AUTO**”-position during all modes of engine control, i.e.:

- remote control
- control from engine side control console

A fire in the scavenge box is indicated by:

- an increase in the exhaust temperature of the affected cylinder,
- the turbocharger may surge,
- smoke from the turbocharger air inlet filters when the surging occurs,
- the scavenge air box being noticeably hotter.

 CAUTION

If the engine stops on shut-down or if the operator performs a safety stop, the auxiliary blowers are stopped independently of the operating mode (automatic or manual).

If the fire is violent, smoky exhaust and decreasing engine revolutions will occur.

Violent blow-by will cause smoke, sparks and even flames to be blown out when the corresponding scavenge box drain cock is opened – therefore keep clear of the line of ejection.

Monitoring devices, in the scavenge air space give alarm and slow-down at abnormal temperature increase.

See description 7045-0100,

For CPP-plants with shaft generator engaged, an auxiliary engine will be started automatically and coupled to the grid before the shaft generator is disengaged and the engine speed reduced.

See drawing 6655-0120.

3 Measures to be taken

Owing to the possible risk of a crankcase explosion, do not stand near the relief valves – violent flames can suddenly be emitted.

1. Reduce speed/pitch to SLOW, if not already carried out automatically, see above, and ask bridge for permission to stop.
2. When the engine STOP order is received, stop the engine and switch-off the auxiliary blowers.
3. Stop the fuel oil supply.
4. Stop the lub. oil supply.
5. Put the scavenge air box fire extinguishing equipment into function. To prevent the fire from spreading to adjacent cylinder(s), the ball valve of the neighbouring cylinder(s) should be opened in case of fire in one cylinder.

See drawing 5455-0105.

 WARNING

Keep clear of possible fresh spurts of flame.

Do not open the scavenge air box or crankcase before the site of the fire has cooled down to under 100°C.

When opening, keep clear of possible fresh spurts of flame.

Ventilate the scavenge air receiver thoroughly before entering.

6. Remove dry deposits and sludge from all the scavenge air boxes.
See description 0545-0100.
7. Clean the respective piston rods and cylinder liners, and inspect their surface condition, alignment, and whether distorted. If in order, coat with oil.

Continue checking and concentrate on piston crown and skirt, while the engine is being turned (cooling oil and water on). Inspect the stuffing box and bottom of scavenge box for possible cracks.

8. If a piston caused the fire, and this piston cannot be overhauled at once, take the precautions referred to in *description 6645-0120*.

If the scavenge air box walls have been heated considerably, the staybolts should be retightened at the first opportunity.

Before retightening, all engine parts must be returned to normal operating temperature.

4 Scavenge Air Drain Pipes

See drawing 5455-0100.

To ensure proper draining of oil sludge from the scavenge air boxes, thereby reducing the risk of fire in the scavenge air boxes, we recommend:

- Daily check with the engine running
- Cleaning of drain pipes at regular intervals

4.1 Daily checks with the engine running:

1. Open the valve between the drain tank and the sludge tank.
2. Close the valve when the drain tank is empty.
3. Check the pipes from flange **AV** to the drain tank venting pipe:

Does air escape from the drain-tank venting pipe?

- **YES:**
This indicates free passage from flange **AV** to the drain tank venting pipe.
- **NO:**
Clean the pipes as described below, at the first opportunity.

4. Check the pipes from the test-cocks to flange **AV**:

Open the test cocks, one by one, between the main drain pipe and the scavenge air boxes and between the main drain pipe and the scavenge air receiver/ auxiliary blowers.

Begin at flange **AV**, and proceed towards flange **BV**.

See Item 4.2 in order to locate any blockages.

Does air or oil blow-out from the individual test-cock?

- **AIR:**
The scavenge air space is being drained correctly.
This indicates free passage from the actual test cock to flange **AV**.
- **OIL:**
The scavenge air space is not being drained correctly.
This indicates that the main drain pipe is blocked between the test cock which blows-out oil, and the neighbouring test cock near the flange AV.
Clean the drain pipe as described below, at the first opportunity.

4.2 Cleaning of drain pipes at regular intervals:

The intervals should be determined for the actual plant, so as to prevent block-ingup of the drain system.

Clean the main drain pipe and the drain-tank discharge pipe by applying air, hot water or steam during engine standstill.

NOTICE

If leaking valves are suspected, dismantle and clean the main drain pipe manually.

If hot water or steam is used, the risk of corrosion on the piston rods must be considered, if a valve is leaking.

1. Check that the valve between flange **AV** and the main drain pipe is open.
2. Close **all** valves between the main drain pipe and the scavenge air boxes, and between the main drain pipe and the scavenge air receiver/auxiliary blowers.

If hot water or steam is used, it is **very important** to close all valves, to prevent corrosion on the piston rods.

3. Open the valve at flange **BV** on the main drain pipe.

This channels the cleaning medium to the main drain pipe.

4. When the main drain pipe is sufficiently clean, open the valve between the drain-tank and the sludge tank.

This will clean the drain tank discharge pipe.

5. When the drain tank discharge pipe is sufficiently clean, close the valve between the drain tank and the sludge tank.
6. Close the valve at flange **BV**.
7. Finally, open all valves between the main drain pipe and the scavenge air boxes, and between the main drain pipe and the scavenge air receiver/auxiliary blowers.

1 Cause

When the engine is running, the air in the crankcase contains the same types of gas (N_2 - O_2 - CO_2) in the same proportions as the ambient air, but there is also a heavy shower of coarse oil droplets that are flung around everywhere in the crankcase.

If abnormal friction occurs between the sliding surfaces, or heat is otherwise transmitted to the crankcase (for instance from a scavenge air fire via the piston rod/stuffing box, or through the intermediate bottom), "Hot spots" can occur on the heated surfaces which in turn will cause the oil droplets falling on them to evaporate.

When the oil vapour condenses again, countless minute droplets are formed which are suspended in the air, i.e. a *milky-white* oil mist develops, which is able to feed and propagate a flame if ignition occurs. The ignition can be caused by the same "hot spot" which caused the oil mist.

If a large amount of oil mist has developed before ignition, the burning can cause a tremendous rise of pressure in the crankcase (explosion), which forces a momentary opening of the relief valves. In isolated cases, when the entire crankcase has presumably been filled with oil mist, the resulting explosion blows off the crankcase doors and sets fire to the engine room.



In the event that a crankcase explosion has occurred, the complete flame arrester of the relief valves must be replaced.

- Similar explosions can also occur in the chain casing and scavenge air box or gearbox (if applied).

Every precaution should therefore be taken to:

- avoid "hot spots" - (A)
- detect the oil mist in time. - (B)

1.1 "Hot Spots" in Crankcase - (A)

Well-maintained bearings only overheat if the oil supply fails, or if the bearing journal surfaces become too rough (owing to the lubricating oil becoming corrosive or being polluted by abrasive particles).

For these reasons, it is very important to:

- purify the lubricating oil correctly,
- make frequent control analyses (*see description 2245-0100 and 3045-0100*),
- ensure that the filter gauze is maintained intact.

Due to the high frictional speed of the thrust bearing, special care has been taken to ensure the oil supply to this bearing.

Monitoring equipment is included to give an alarm in the event of low circulating oil pressure and/or high temperature of thrust bearing segments. Keep this equipment in tip-top condition.

See description 7045-0100.

Feel over moving parts (by hand or with a "thermo-feel") at suitable intervals (15-30 minutes after starting, one hour later, and again at full load. *See description 6645-0130.*

The checks in description 6645-0100 are still the best safeguard against "hot spots" when starting up after repairs or alterations affecting the moving parts, and should never be neglected. *If in doubt, stop and feel over.*

1.2 Oil Mist in Crankcase - (B)

In order to ensure a fast and reliable warning of oil mist formation in the crankcase, constant monitoring is provided using an "Oil Mist Detector", which samples air from each crankcase compartment.

The detector gives alarm and slow-down, *see description 7045-0100*, at a mist concentration which is less than the lower explosion limit, LEL, to gain time for stopping the engine before ignition of the oil mist can take place.

For adjustment of oil mist detectors:

Oil mist detector sensors will over time be slightly polluted on the measuring device, and must be cleaned on the photocell and light source, carry out this cleaning before adjustment.

Generally the alarm set point should be as low as possible - without generating false alarms. Before deciding the actual alarm level, the normal oil mist level at MCR must be measured.

Pre-alarm and shutdown alarm must be set according to the MCR level eg.

- Pre-alarm level = 1,5 – 3 x MCR level,
- Shut down alarm level = 2 – 5 x MCR level but preferably not exceeding 2.0mg/l.



MAN Diesel & Turbo recommend the set point to be adjusted according to makers instruction.

For CPP-plants with shaft generator engaged, an auxiliary engine will be started automatically and coupled to the grid, before the shaft generator is disengaged and the engine speed reduced.

See drawing 6655-0120.

2 Measures to be taken when Oil Mist has Occured



Do not stand near crankcase doors or relief valves, nor in corridors near doors to the engine room, in the event of an **alarm for:**

- a. oil mist
- b. high lube oil temperature
- c. no piston cooling oil flow, or
- d. scavenge box fire

Alarms b, c and d should be considered as pre-warnings of a possible increasing oil mist level.

See also our Service Letters SL97-348/ERO and SL00-377/CEE

1. Reduce speed/pitch to slow-down level, if not already carried out automatically, see above.
See description 7045-0100.
2. Contact the bridge for permission to stop.
3. When the engine STOP order is received:
 - stop the engine
 - close the fuel oil supply.
4. Switch-off the auxiliary blowers and engine room ventilation.
5. Open the skylight(s) and/or “stores hatch”.
6. Leave the engine room.
7. Lock the engine room doors and keep away from them.
8. Prepare the fire-fighting equipment.

Do not open the crankcase until at least 20 minutes after stopping the engine. When opening up, keep clear of possible spurts of flame. Do not use naked lights and do not smoke.

9. Stop the circulating oil pump. Take off/open all the lowermost doors on one side of the crankcase. Cut off the starting air, and engage the turning gear.
10. Locate the “hot spot”. Use powerful lamps from the start.
Feel over, by hand or with a “thermo-feel”, all the sliding surfaces (bearings, thrust bearing, piston rods, stuffing boxes, crossheads, telescopic pipes, vibration dampers, moment compensators, etc.).
See point 14.
Look for signs of squeezed-out bearing metal and discolouration caused by heat (blistered paint, burnt oil, oxidized steel). Keep possible bearing metal found at bottom of oil tray for later analyzing.
11. Prevent further “hot spots” by preferably making a permanent repair. In case of bearings running hot.
See description 2545-0100 and description 0545-0100.
Ensure that the respective sliding surfaces are in good condition. Take special care to check that the circulating oil supply is in order.

12. Start the circulating oil pump and turn the engine by means of the turning gear.

Check the oil flow from all bearings, spray pipes and spray nozzles in the crankcase, chaincase and thrust bearing.

See description 6645-0100.

Check for possible leakages from pistons or piston rods.

13. Start the engine.

After:

- 15-30 minutes,
- one hour later,
- when full load is reached:
- Stop and feel over.
- Look for oil mist.

Especially feel over (by hand or with a “thermo-feel”) the sliding surfaces which caused the overheating.

See description 6645-0130.

14. In cases where it has not been possible to locate the “hot spot”, the procedure according to Point 10 above should be repeated and intensified until the cause of the oil mist has been found and remedied.

There is a possibility that the oil mist is due to “atomization” of the circulating oil, caused by a jet of air/gas, e.g. by a combination of the following:

- Stuffing box leakages (not air tight).
- Blow-by through a cracked piston crown or piston rod (with direct connection to crankcase via the cooling oil outlet pipe).
- An oil mist could also develop as a result of heat from a scavenge fire being transmitted down the piston rod or via the stuffing box. Hot air jets or flames could also have passed through the stuffing box into the crankcase.

1 General

During normal operation, a few sporadic surges will often occur, e.g. at crash stop or other abrupt manoeuvrings. Such surges are normally harmless, provided the turbocharger bearings are in a good service condition.

However, continuous surges must be avoided, as there is a risk of damaging the rotor, especially the compressor blades.

All cases of turbocharger surging can be divided into three main categories:

1. Restriction and fouling in the air/gas system.
2. Malfunction in the fuel system.
3. Rapid variations in engine load.



Avoid standing close to the turbo charger in case of surging or use safety goggles to prevent dust and air blowing into the eyes.

However, for convenience, the points in the “check lists” below are grouped according to specific engine systems.
See drawing 6655-0225.

2 Causes

2.1 Fuel Oil System

- Low circulating or supply pump pressure.
- Air in fuel oil.
- Water in fuel oil.
- Low preheating temperature.
- Malfunctioning of deaerating valve on top of venting tank.
- Defective suction valve.
- Defective puncture valve.
- Sticking fuel pump plunger.
- Sticking fuel valve spindle.
- Damaged fuel valve nozzle.
- Defect in overflow valve in fuel return pipe.
- Faulty load distribution (this will be monitored in the ECS).

2.2 Exhaust System

- Exhaust valve not opening correctly.
- Damaged or blocked protective grating before turbocharger.
- Increased back pressure after T.C.
- Pressure pulsations after T.C.
- Pressure pulsations in exhaust receiver.
- Damaged compensator before T.C.

2.3 Turbocharger

- Fouled or damaged turbine side.
- Fouled or damaged compressor side.
- Fouled air filter boxes.
- Damaged silencer.
- Bearing failure.

2.4 Scavenge Air System

- Fouled air cooler, water mist catcher, and/or ducts.
- Stopped water circulation to cooler.
- Coke in scavenge ports.
- Too high receiver temperature.

2.5 Miscellaneous

- Rapid changes in engine load.
- Too rapid rpm change:
 - when running on high load.
 - during manoeuvring.
 - at shut downs/slow downs.
 - when running ASTERN.
 - due to “propeller racing” in bad weather.

3 Countermeasure

Continuous surging can be temporarily counteracted by “blowing-off” from the valve at the top of the air receiver. However, when doing this the exhaust temperatures will increase and must not be allowed to exceed the limiting values.
See description 7045-0100.

1 General

The engine is designed and balanced to run with all cylinders as well as all turbochargers working. If a breakdown occurs which disables one or more cylinders, or turbochargers, repair should preferably be carried out immediately.

If this is not possible, the engine can be operated with one or more cylinders or turbochargers out of operation, but with reduced speed owing to the following:

1. As, in such cases, the air supply is no longer optimal, the thermal load will be higher.

Therefore, depending upon the actual circumstances, the engine will have to be operated according to the restrictions mentioned in Items 4 and 5 further on in this description.

NOTICE

Sometimes high exhaust temperatures can occur at about 30-40% load, corresponding to 67 to 73% of MCR speed. It may be necessary to avoid operating in this range.

2. Pressure pulsations may occur in the scavenge and exhaust receivers, which can give a reduced air supply to any one of the cylinders, consequently causing the respective exhaust temperatures to increase.

The load limit for these cylinders must therefore be reduced to keep the exhaust temperatures (after valves) below the value stated in *description 7045-0100*. However, see "Note" under point 1 above.

3. Since the turbochargers will be working outside their normal range, surging may occur.

This can generally be remedied by "blowing off" from the scavenge air receiver. The increased temperature level caused by this must be compensated for by reducing the engine revolutions, until the exhaust temperatures are in accordance with the values stated in *description 7045-0100*.

If more than one cylinder must be cut out of operation, and the engine has two or more turbochargers, it may be advantageous to cut out one of the turbochargers. However, see "Note" in point 1 above.

4. When cylinders are out of operation, hunting may occur. When this happens, the load limit must be limited on the MOP.
5. With one or more cylinders out of operation, torsional vibrations, as well as other mechanical vibrations, may occur at certain engine speeds.

The standard torsional vibration calculations cover the following conditions:

- normal running
- misfiring of one cylinder

The latter leads to load limitations, see *Item 4* further on, which in most cases are irrespective of the torsional vibration conditions; additional restrictions may occur depending on the specific conditions.

The above-mentioned calculations do not deal with the situation where reciprocating masses are removed from the engine or where the exhaust valve remains open. In such specific cases the engine maker has to be contacted.

Should unusual noise or extreme vibrations occur at the chosen speed, the speed must be further reduced.

Because the engine is no longer in balance, increased stresses occur in crankshaft and chain (*If applicable*). However, if no abnormal vibrations occur, the engine can usually be run for a short period (for instance some days) without suffering damage.

If the engine is to be run for a prolonged period with cylinders out of operation, the engine builder should always be contacted in order to obtain advice concerning possible recommended barred speed ranges.

When only the fuel for the respective cylinders is cut off, and the starting air connections remain intact, the engine is fully manoeuvrable.

In cases where the starting air supply has to be cut off to some cylinders, starting in all crankshaft positions cannot always be expected.

If the engine does not turn on starting air in a certain crankshaft position, it must be immediately started for a short period in the opposite direction, after which reversal is to be made to the required direction of rotation.

Should this not give the desired result, it will be necessary to turn the engine to a better starting position, by means of the turning gear. Remember to cut off the starting air before turning and to open the indicator cocks.

2 How to put Cylinders out of Operation

See description 6645-0250.

The following points: **(Case A - E)** describe five different “methods” of putting a single cylinder out of operation.

The extent of the work to be carried out depends, of course, on the nature of the trouble.

NOTICE

In cases where the crosshead and crankpin bearings are operative, the oil inlet to the crosshead must not be blanked-off, as the bearings are lubricated through the crosshead.

A summary of the various cases is given on drawing 6655-0215.

Component list ME-C engines.

See drawings 6655-0235 and 6655-0240.

304	Check valve - cartridge Pump pressure side, separate pump from P1 line
305	Check valve - cartridge ACC-bloc. inlet from start-up pumps, separate start-up pumps from P2 line
309	Check valve - cartridge High pressure depart ACC-bloc., separate P1 from P2
310	Pressure relief valve Short cutting valve used in case of "black-out" on board, release pressure in P1
311	Pressure relief valve System pressure relief
315	Plug valve Drain valve
316	Plug valve Connection between P1 and P2, used for pressure adjustment at Pos. 310
339	Mini-mess Pressure in P1
340	Mini-mess System pressure in P2
420	Plug valve Inlet valve high pressure supply, block valve
421	Plug valve Drain valve from high pressure supply line, block valve
455	Mini-mess Oil pressure supply at FIVA inlet
560	Plug valve Oil supply to cylinder lubricator (currently blanked)
565	Mini-mess Oil pressure in cylinder lubricator (actuator)
702	Drain pipe

2.1 Combustion cut out. Piston and exhaust actuator still working. Compression on. (Case A)**Reasons:**

Preliminary measure in the event of, for instance: blow-by at piston rings or exhaust valve; bearing failures which necessitate reduction of bearing load; faults in the injection system.

Procedure:

Cut out the fuel oil pressure booster.

See description 6645-0250.

NOTICE

**Piston cooling oil and cylinder cooling water must not be cut off.
See Item 4.**

2.2 Combustion and compression cut out. Piston still working in cylinder. (Case B)**Reasons:**

This measure is permitted in the event of, for instance, water is leaking into the cylinder from the cooling jacket/liner or cylinder cover.

Running in this way must as soon as possible be superseded by the precautions mentioned under (Case D or E).

See Item 3.

Procedure:

1. Cut out the fuel oil pressure booster.
See description 6645-0250.
2. Put the exhaust valve out of action and lock it in **open** position.
See work card 6665-0101.
3. Close the cooling water inlet and outlet valves for the cylinder. If necessary, drain the cooling water spaces completely.
4. Dismantle the starting air pipe, and blank off the main pipe and the control air pipe for the pertaining cylinder.
5. When operating in this manner, the speed should not exceed 55% of MCR speed.
See 'Notice' below.

NOTICE

The joints in the crosshead and crankpin bearings have a strength that, for a short time, will accept the loads at full speed without compression in the cylinder.

However, to avoid unnecessary wear and pitting at the joint faces, it is recommended that, when running a unit continuously with the compression cut-out, the engine speed is reduced to 55% of MCR speed, which is normally sufficient to manoeuvre the vessel.

During manoeuvres, if found necessary, the engine speed can be raised to 80% of MCR speed for a short period, for example 15 minutes.

Under these circumstances, in order to ensure that the engine speed is kept within a safe upper limit, the over-speed level of the engine must be lowered to 83% of MCR speed.

2.3 Combustion cut out. Exhaust valve closed. Piston still working in cylinder. (Case C)**Reasons:**

This measure may be used if, for instance, the exhaust valve or the actuator is defective.

See Item 4.

Procedure:

1. Cut out the fuel oil pressure booster.
See description 6645-0250.
2. Put the exhaust valve out of action so that the valve remains closed. (Stop the oil supply and remove the hydraulic pipe).
See work card 6665-0101.
3. Engines entering service in 2012 or later can have high compression pressure when running with one closed exhaust valve. The compression pressure can be significantly higher than the normal maximum cylinder pressure. The maximum allowable load in this condition is 35% load, corresponding to 70% of MCR speed for a fixed pitch propeller.
See "Notice" concerning shut down and exhaust valve control failure.

NOTICE

• Shutdown:

Due to a risk of a cover lift when the engine is running at high load and a shut down of the engine occur, the engine control system (ECS) will force the exhaust valves to open after two seconds of normal operation.

• Exhaust valve control failure:

In case the ECS control of the exhaust valve is lost, e.g. due to a wiring defect, other electric defect or controller (CCU) defect, the FIVA will move to its mechanical fail safe position, ordering the exhaust valve to open immediately, thus avoiding excessive compression pressure and risk of cylinder cover lift, but because the exhaust valve is closing after some seconds, the ECS will force a load down of the engine in order to reduce the scavenge air pressure below the critical limit before the exhaust valve is closing. If the scavenge air pressure is already below the critical limit when the control failure is detected, a non-cancellable load limiter will be set to ensure that the engine load, and thereby the scavenging air pressure, is not increased above the critical limit. When the control has been reestablished the ECS will turn back to normal settings.

In order to obtain hand-shaking with the ship's power management system, the engine control system is awaiting the signal from the power management system. If the circumstances for load-down of the main engine is acceptable for the power management system, the ECS will conduct the forced load-down. But if the reaction time of the power management system for starting up a genset is too long (more than 40 seconds), the forced load-down of the main engine will still take place, in order to protect the main engine against damage.

NOTICE

Do not cut out the cylinder cooling water and piston cooling oil.

2.4 Piston, piston rod, and crosshead suspended in the engine. Connecting rod out. (Case D)**Reasons:**

For instance, serious defects in piston, piston rod, connecting rod, cylinder cover, cylinder liner and crosshead.

See Item 3.

Procedure:

1. Cut out the fuel oil pressure booster.
See description 6645-0250.
2. Put the exhaust valve out of action so that the valve remains closed. (Stop the oil supply and remove the hydraulic pipe)
See work card 6665-0101.
3. Dismantle the starting air pipe and blank off the main pipe and the control air pipe for the pertaining cylinder.

NOTICE

In this case the blanking-off of the starting air supply is particularly important, as otherwise the supply of starting air will blow down the suspended engine components.

4. Suspend the piston, piston rod and crosshead, and remove the connecting rod out of the crankcase, in accordance with the directions in *work card 1465-0301*.
5. Blank off the oil inlet to the crosshead.
6. Set the cylinder lubricator for the pertaining cylinder, to "zero" delivery.

2.5 Piston, piston rod, crosshead, connecting rod, and telescopic pipe out (Case E)**Reasons:**

This method is only used if lack of spare parts makes it necessary to repair the defective parts during the voyage.

See Item 3.

Procedure:

1. Cut out the fuel oil pressure booster.
See description 6645-0250.
2. Put the exhaust valve out of action so that the valve remains closed. (Stop the oil supply and remove the hydraulic pipe)
See work card 6665-0101.
3. Dismantle the starting air pipe, and blank off the main pipe and the control air pipe for the pertaining cylinder.

NOTICE

In this case the blanking-off of the starting air supply is particularly important, as otherwise the supply of starting air will blow down the suspended engine components.

4. Dismantle piston with piston rod and stuffing box, crosshead, connecting rod and crankpin bearing.
Blank off the stuffing box opening with two plates (towards scavenge air box and crankcase).
Minimum plate thickness 5 mm.
5. Blank off the oil inlet hole from the telescopic pipe.
6. Set the cylinder lubricator for the pertaining cylinder to "zero" delivery.

3 Starting after putting Cylinders out of Operation

After carrying out any of the procedures described under points B, C, D, and E, it is, before starting, absolutely necessary to check the oil flow through the bearings, and the tightness of blanked-off openings.

After 10 minutes' running, and again after one hour, the crankcase must be opened for checking:

- the bearings
- the temporarily secured parts
- the oil flow through bearings
- the tightness of blanked-off openings

Load Restrictions:

Cases A and C, see Item 4 below. Cases B, D and E, always contact the engine builder for calculation of allowable output and possible barred speed range.

4 Running with one (1) Cylinder Misfiring (Cases A and C)

Misfiring is defined as:

- no injection and
- compression present.

If only **one** cylinder is misfiring, it **may** be possible to run the engine with the remaining and working cylinders, under two restrictions:

1. The thermal load of the cylinders.
2. The torsional vibration in the propeller shaft system.

Ad 1) Thermal load restriction:

The following r/min and shaft powers may be obtained with a fixed pitch propeller given by the thermal load of the cylinders:

Total No. of Cylinders	% r/min (of MCR)	% Load (of MCR)
4	83	57
5	86	63
6	88	67
7	89	71
8	90	73
9	91	75
10	91	77
11	92	78
12	92	78
14	93	80

Ad 2) Torsional vibration restrictions:

These restrictions, given as barred speed range, may be found from the class-approved report on the torsional vibration of the actual propeller shaft system.

NOTICE

Only valid for misfiring, i.e. Item 2, cases A and C.
See drawing 6655-0215.

With a CP-propeller, the same restrictions apply when running according to the design pitch. During the misfire operation keep the CP-propeller pitch fixed at the design pitch.

If more than one cylinder is misfiring, the engine builder must be contacted.

Running limitations in Cases B, D and E

In cases B, D and E, the engine builder must always be contacted for calculation of allowable output and possible barred speed range.

5 How to put Turbochargers out of Operation

See special instruction book for turbochargers.

If heavy vibrations, bearing failure, or other troubles occur in a turbocharger, preliminary measures can be taken in one of the following ways:

5.1 If the ship must be instantly manoeuvrable: (Case W)

Reduce the load until the vibrations cease.

5.2 If the ship must be instantly manoeuvrable, but the damaged turbocharger cannot run even at reduced load (Case X)

NOTICE

This mode of operation is only recommendable if no time is available for carrying out the procedures described in Item 'Y', 'Running for an extended period with a Turbocharger out of Operation'.

Refer to the T/C manual regarding the maximum time of operation in condition 'Y', before the bearings will be damaged.

Engines with one turbocharger:

1. Stop the engine.
2. Lock the rotor of the defective turbocharger.
See T/C manual.
3. Remove the compensator between the compressor outlet and the scavenge air duct.
This reduces the suction resistance.
4. **Load restrictions:**
See drawing 6655-0220.

Engines with two or more turbochargers:

1. Stop the engine.
2. Lock the rotor of the defective turbocharger.
See T/C manual.
3. Insert an orifice plate in the compressor outlet.
A small air flow is required through the compressor to cool the impeller.
4. **Load restrictions:**
See drawing 6655-0220.

NOTICE

The load limit can be increased considerably if an orifice plate is also inserted in the turbine inlet, as described in Item Y, 'Engines with **two or more** Turbochargers'.

5.3 Running for an extended period with a turbocharger out of operation (Case Y)**Engines with one turbocharger:
Engines with exhaust by-pass (Option)****NOTICE**

The blanking plates mentioned in item 3 below, are optional for BBC / ABB and MHI turbochargers.

1. Stop the engine.
2. Lock the turbocharger rotor.
See T/C manual.
3. Remove the blanking plate from the exhaust by-pass pipe.
4. Remove the compensator between the compressor outlet and the scavenge air duct. This reduces the suction resistance.
5. **Load restrictions:**
See drawing 6655-0220.

Engines without exhaust by-pass.

1. Stop the engine.
2. Remove the rotor and nozzle ring of the turbocharger.
See T/C manual.
3. Insert blanking plates.
See T/C manual.
4. Remove the compensator between the compressor outlet and the scavenge air duct.
This reduces the suction resistance.
5. **Load restrictions:**
See drawing 6655-0220.

Engines with two or more turbochargers:

1. Stop the engine.
2. Lock the rotor of the defective turbocharger.
See T/C manual.
3. Insert orifice plates in the compressor outlet and the turbine inlet.
A small air flow is required to cool the impeller, and a small gas flow is desirable to prevent corrosion.
4. **Load restrictions:**
See drawing 6655-0220.

5.4 Repair to be carried out during voyage (Case Z).**Engines with two or more turbochargers:**

1. Stop the engine.
2. Insert blanking plates in compressor outlet, turbine inlet and turbine outlet.

3. Load restrictions:
See drawing 6655-0220.

Engines with one turbocharger, equipped with exhaust by-pass (Option):

1. Stop the engine.
2. Insert blanking plates in turbine inlet and turbine outlet.
3. Remove the blanking plate from the exhaust by-pass pipe.
4. Remove the compensator between the compressor outlet and the scavenge air duct.
5. Load restrictions:
See Item "Y", 'Engines with exhaust by-pass (Option)'.

6 Putting an Auxiliary Blower out of Operation

If one of the auxiliary blowers becomes inoperative, it is automatically cut out by the built-in non-return valve, and there are no restrictions in the operation of the engine.

See work card 5465-0501.

1 Cylinder Cover Studs

- 8 studs; one stud cracked, reduce cylinder pressure to 85 % of $p_{\max}$
- 8 studs; two studs cracked, reduce cylinder pressure to 75 % of $p_{\max}$
- 16 studs; one stud cracked, no reduction
- 16 studs; two studs cracked, reduce cylinder pressure to 85 % of $p_{\max}$

Always ensure that no gasleak occurs from the cylinder with cracked bolts. Gas-leaks will cause burnings on the joint surfaces of the cylinder cover and liner.

2 Staybolts, Mono and Twin Staybolts

Cylinder cover studs and staybolts must be replaced at first opportunity. For end mono-staybolts we recommend that both staybolts (manoeuvring side and exhaust side) are replaced.

The replacement should be done according to the below guideline:

	End staybolt	Center staybolt Across longitudinal joint of two separate cylinder units	Center staybolt Across unified cylinder units
Mono stay-bolt design	Reduce the cylinder pressure down to 75% of $P_{\max}$ 	Reduce the cylinder pressure down to 80% of $P_{\max}$ 	Reduce the cylinder pressure down to 80% of $P_{\max}$ 
Twin stay-bolt design	Reduce the cylinder pressure down to 85% of $P_{\max}$ 	Reduce the cylinder pressure down to 80% of $P_{\max}$ 	Reduce the cylinder pressure down to 90% of $P_{\max}$ 

NOTICE

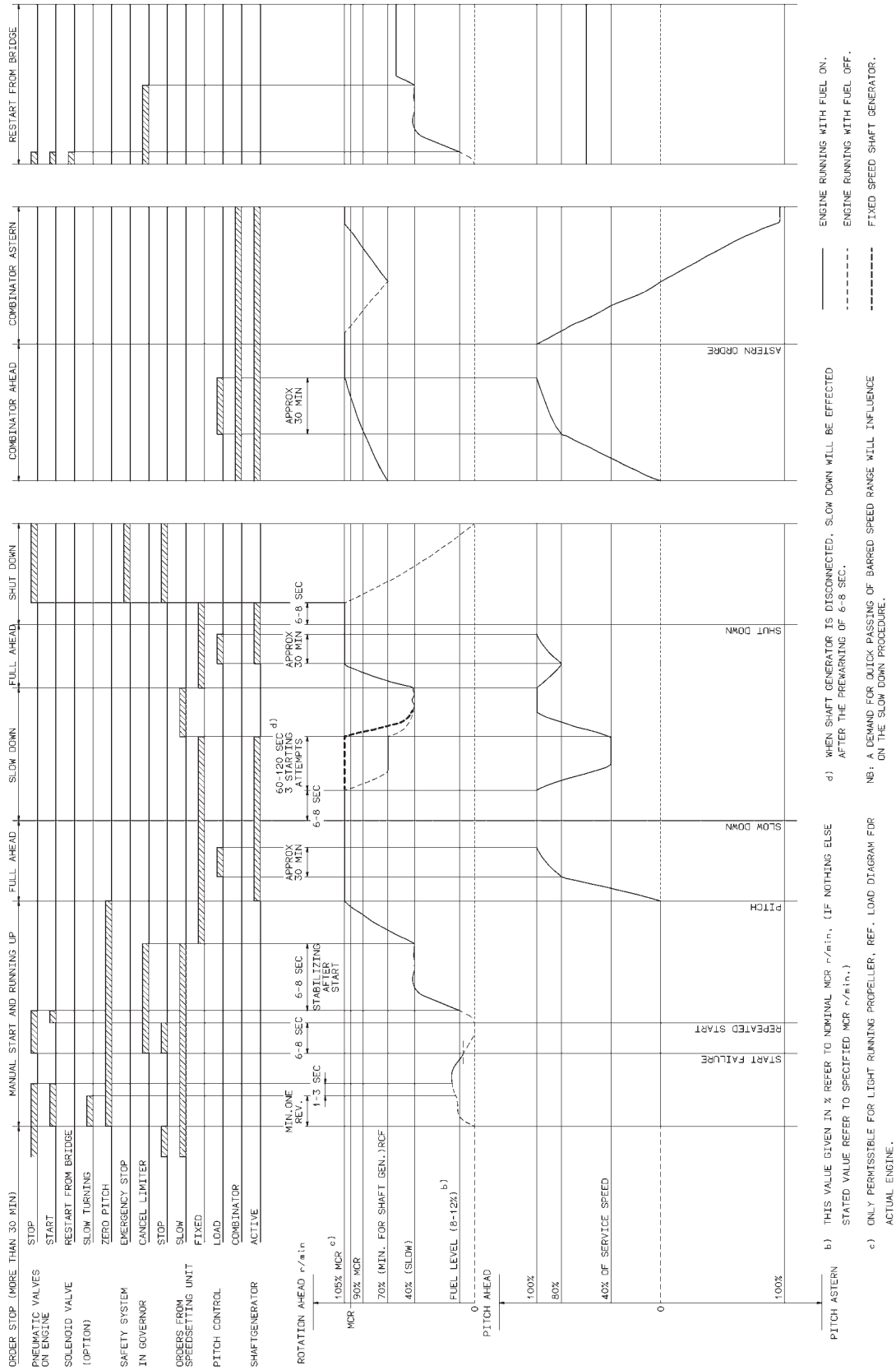
- $P_{\max}$ is the value specified in the "Technical data - Performance specification" in Design Specification.
- It is allowable to move a staybolt from a unified cylinder unit position in case of broken staybolt at ends or at longitudinal joint in order to minimize required reduction of $P_{\max}$. This is possible if sufficient lifting height is available in engine room.
- In a situation where the engine has to run for an extended period with a broken staybolt, the above load restrictions may be eased (In principle, the $P_{\max}$ reduction is only required for nearest cylinder on each side of the broken staybolt). This will require an individual assessment by the engine builder or MAN Diesel & Turbo with respect to thermal load of the cylinders and torsional vibration of the propeller shaft system.

In all other situations (than the above-mentioned) involving cracked cylinder cover, studs or staybolts, MAN Diesel & Turbo or the engine builder must be contacted.

2008-09-30

MAN Diesel

6655-0120-0002



Sequence Diagram, CPP Plant

Drawing
6655-0120-0002

Fig. 1

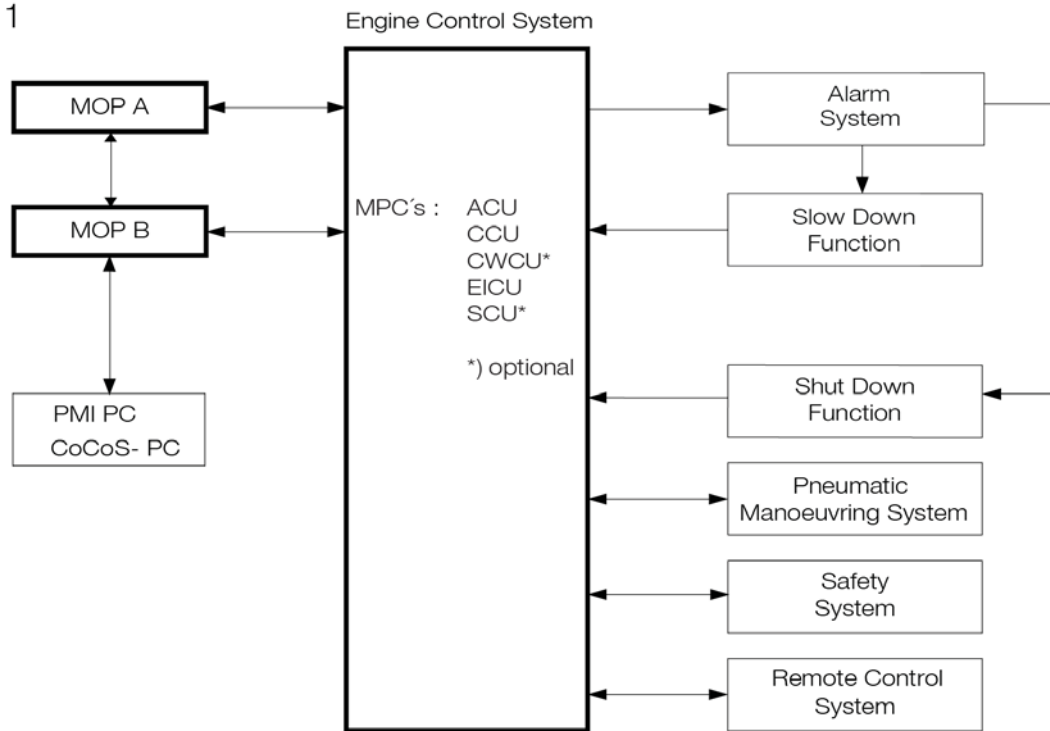
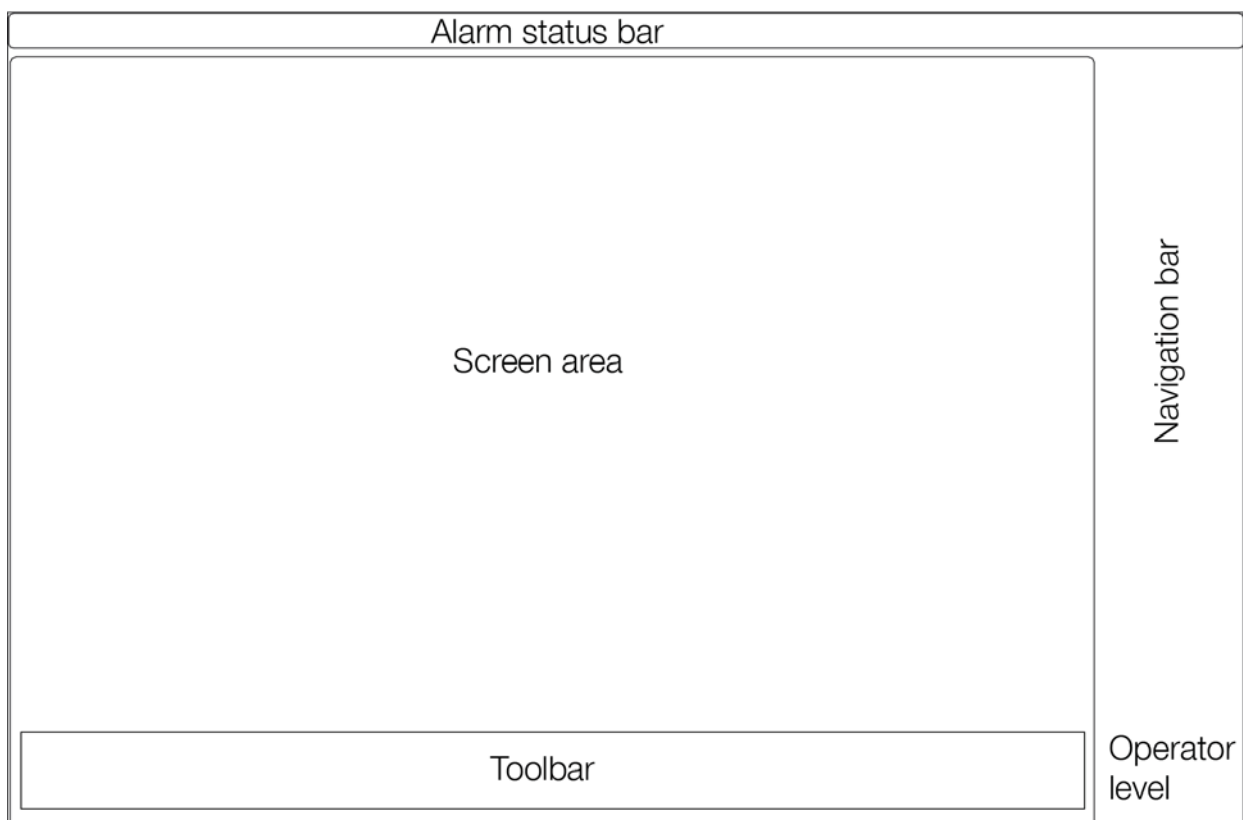


Fig. 2



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Net B not connected to MOPB

Normal

EICUA_SN1-MOPB

13:50:28

Alarms ▶ Alarm List

2013-05-27 13:59:17

Alarms

Ack	Description	Status	ID	Time
	GROUP: Tacho set A failure	Alarm	GROUP-TAF	13:58:53
	Tacho set A failure	Alarm	CCU1_01010328	13:58:52
	MOPB unavailable	Normal	EICUB_SNA-MOPB	13:50:31
	Net B not connected to MOPB	Normal	EICUB_SN1-MOPB	13:50:31
	Net A not connected to MOPB	Normal	EICUB_SNO-MOPB	13:50:31
	Net B not connected to MOPB	Normal	EICUA_SN1-MOPB	13:50:28
	Net A not connected to MOPB	Normal	EICUA_SNO-MOPB	13:50:28

Alarm List

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Manual Cut-Out List

Channel List

Engine

Auxiliaries

Maintenance

Admin

Power Off

Operator

✓Ack

✓All

Cut Out

Line/of
2 7

Info

MOP Alarm List



! Net B not connected to MOPB

6 1 41 0

Alarms ▶ Alarm List

2013-05-27 13:59:41

Ack	Description	Status	ID	Time
!	GROUP: Tacho set A failure	Alarm	GROUP-TAF	13:58:53
!	Tacho set A failure	Alarm	CCU1_01010328	13:58:52
!	MOPB unavailable	Normal	EICUB_SNA-MOPB	13:50:31
!	Net B not connected to MOPB	Normal	EICUB_CN1 MOPB	13:50:31

Info

GROUP: Tacho set A failure - GROUP-TAF

Description :
Abnormal tacho set A signals on multiple CCUs/ECUs .

This group alarm is caused by multiple 'Tacho set A failure' alarms. Other alarms in the group are raised as a consequence of this condition. To view the alarms in the group: Press +/- at the bottom of the MOP screen.

Cause :

- Cabling failure (loose connection etc.), or
- Flywheel marker sensor failure, or
- Encoder failure, or
- Tacho amplifier A failure, or
- Sensor support console failure, or
- Power failure (ECUA powers tacho set A)

If trigger ring is fitted, this alarm may be caused by:

- Trigger/marker ring is damaged, or
- Trigger/marker sensor failure

✓Ack

✓All

Out Out

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Power Off ⓘ

Operator ⓘ

00410

Alarms

Alarms ► Event Log

2013-05-27 14:02:19

Alarms

ID: Unit Tag	Date	Time	Description	Status	MCo	ACo	Ack	
CCCU9_03041104	2013-05-27	14:02:10,93	FIVA Amp. Current Supervision	Alarm	X			Alarm List
CCCU7_03041104	2013-05-27	14:02:10,88	FIVA Amp. Current Supervision	Alarm	X			Event Log
CCCU12_03041104	2013-05-27	14:02:10,83	FIVA Amp. Current Supervision	Alarm	X			Manual Cut-Out List
CCCU8_03041104	2013-05-27	14:02:10,22	FIVA Amp. Current Supervision	Alarm	X			Channel List
CCCU6_03041104	2013-05-27	14:02:08,86	FIVA Amp. Current Supervision	Alarm	X			Engine
CCCU10_03041104	2013-05-27	14:02:08,84	FIVA Amp. Current Supervision	Normal	X			Auxiliaries
CCCU11_03041104	2013-05-27	14:02:08,53	FIVA Amp. Current Supervision	Alarm	X			Maintenance
CCCU5_03041104	2013-05-27	14:02:08,27	FIVA Amp. Current Supervision	Alarm	X			Admin
CCCU9_03041104	2013-05-27	14:02:07,93	FIVA Amp. Current Supervision	Normal	X			
CCCU7_03041104	2013-05-27	14:02:07,85	FIVA Amp. Current Supervision	Normal	X			
CCCU12_03041104	2013-05-27	14:02:07,84	FIVA Amp. Current Supervision	Normal	X			
CCCU8_03041104	2013-05-27	14:02:07,22	FIVA Amp. Current Supervision	Normal	X			
EICUB_SN0-MOPB	2013-05-27	14:02:06,84	Net A not connected to MOPB	Normal			X	
EICUB_SN1-MOPB	2013-05-27	14:02:06,83	Net B not connected to MOPB	Normal			X	
EICUB_SNA-MOPB	2013-05-27	14:02:06,83	MOPB unavailable	Normal			X	
EICUA_SN0-MOPB	2013-05-27	14:02:06,81	Net A not connected to MOPB	Normal			X	
EICUA_SN1-MOPB	2013-05-27	14:02:06,81	Net B not connected to MOPB	Normal			X	
CCCU6_03041104	2013-05-27	14:02:05,87	FIVA Amp. Current Supervision	Normal	X			
CCCU10_03041104	2013-05-27	14:02:05,84	FIVA Amp. Current Supervision	Alarm	X			
CCCU11_03041104	2013-05-27	14:02:05,53	FIVA Amp. Current Supervision	Normal	X			

Power Off ⓘ

Operator ⓘ

Unit/Tag Filter

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Go to Date/Time

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Info

Drawing

6655-0135-0006

MOP Event Log

00410

Alarms

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Event Log

Manual Cut-Out List

Channel List

Engine

Auxiliaries

Maintenance

Admin

Power Off

Operator

Alarms ▶ Event Log

2013-05-27 14:02:42

ID: Unit_Tag	Date	Time	Description	Status	MCo	ACo	Ack
CCU9_03041104	2013-05-27	14:02:10,93	FIVA Amp. Current Supervision	Alarm	X		
CCU7_03041104	2013-05-27	14:02:10,88	FIVA Amp. Current Supervision	Alarm	X		
CCU12_03041104	2013-05-27	14:02:10,83	FIVA Amp. Current Supervision	Alarm	X		
CCU8_03041104	2013-05-27	14:02:10,22	FIVA Amp. Current Supervision	Alarm	X		
CCU6_03041104	2013-05-27	14:02:10,22	FIVA Amp. Current Supervision	Alarm	X		
CCU10_03041104	2013-05-27	14:02:05,84	FIVA Amp. Current Supervision	Alarm	X		
CCU11_03041104	2013-05-27	14:02:05,53	FIVA Amp. Current Supervision	Normal	X		

Unit/Tag Filter

Unit CCU

Index

Tag

Fetch Selected

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2013-10-21 - en

00410

Alarms

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Auxiliaries

Maintenance

Admin

Power Off

Operator

Alarms > Event Log

2013-05-27 14:03:37

ID: Unit_Tag	Date	Time	Description	Status	MCo	ACo	Ack
CCU9_03041104	2013-05-27	14:02:10,93	FIVA Amp. Current Supervision	Alarm	X		
CCU7_03041104	2013-05-27	14:02:10,88	FIVA Amp. Current Supervision	Alarm	X		
CCU12_03041104	2013-05-27	14:02:10,83	FIVA Amp. Current Supervision	Alarm	X		
CCU8_03041104	2013-05-27	14:02:10,22	FIVA Amp. Current Supervision	Alarm	X		

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CCU11_03041104	2013-05-27	14:02:05,53	FIVA Amp. Current Supervision	Normal	X		

Unit/Tag Filter

Time Span Filter

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MOP Event Log

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6655-0135-0006

00410

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Engine

Auxiliaries

Maintenance

Admin

Power Off

Operator

Alarms ▶ Event Log

2013-05-27 14:04:03

ID: Unit_Tag	Date	Time	Description	Status	MCo	ACo	Ack
CCU9_03041104	2013-05-27	14:02:10,93	FIVA Amp. Current Supervision	Alarm	X		
CCU7_03041104	2013-05-27	14:02:10,88	FIVA Amp. Current Supervision	Alarm	X		
CCU12_03041104	2013-05-27	14:02:10,83	FIVA Amp. Current Supervision	Alarm	X		
CCU8_03041104	2013-05-27	14:02:10,22	FIVA Amp. Current Supervision	Alarm	X		
CCU10_03041104	2013-05-27	14:02:05,84	FIVA Amp. Current Supervision	Alarm	X		
CCU11_03041104	2013-05-27	14:02:05,53	FIVA Amp. Current Supervision	Normal	X		

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Time Span Filter

Go to Date/Time

Export...

⏪

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⏵

Info

00410

Alarms

Alarms ► Manual Cut-Out List

2013-05-2714:04:17

ID	Date	Time	Description	Status	Limit	Current	
CCU9_03041104	2013-05-27	13:51:10	FIVA Amp. Current Supervision	Normal	-	-	Alarm List
CCU9_031220	2013-05-27	13:50:02	Failing Lubr. FeedBack (Slowdown)	Alarm	-	-	Event Log
EICUB_08053001	2013-05-27	13:46:52	Load Limit Integrator (Deviation)	Alarm	-	-	
CCU11_03041104	2013-05-27	13:51:11	FIVA Amp. Current Supervision	Alarm	-	-	Manual Cut-Out List
CCU5_03041104	2013-05-27	13:51:10	FIVA Amp. Current Supervision	Alarm	-	-	
CCU7_03041104	2013-05-27	13:51:10	FIVA Amp. Current Supervision	Normal	-	-	Channel List
CCU12_03041104	2013-05-27	13:51:10	FIVA Amp. Current Supervision	Normal	-	-	
CCU8_03041104	2013-05-27	13:51:08	FIVA Amp. Current Supervision	Alarm	-	-	Engine
CCU6_03041104	2013-05-27	13:51:08	FIVA Amp. Current Supervision	Alarm	-	-	
CCU10_03041104	2013-05-27	13:51:08	FIVA Amp. Current Supervision	Normal	-	-	Auxiliaries
ECUB_51010113	2013-05-27	13:51:06	Large dev. from model curve	Alarm	-	-	
ECUA_51010113	2013-05-27	13:51:06	Large dev. from model curve	Alarm	-	-	Maintenance
EICUB_SEICU	2013-05-27	13:47:51	Global Params. inconsist	Alarm	-	-	
ECUA_5131	2013-05-27	13:50:21	Hyd. press. deviates from setpoint	Alarm	-	-	Admin
ECUB_5131	2013-05-27	13:50:21	Hyd. press. deviates from setpoint	Alarm	-	-	
ECUA_510118	2013-05-27	13:47:28	Changing press. ctrl. pump	Normal	-	-	
ECUB_510118	2013-05-27	13:46:58	Changing press. ctrl. pump	Normal	-	-	
ECUB_51010123	2013-05-27	13:46:58	Pump Torque Limiter Reached	Normal	-	-	
FCUA_51010123	2013-05-27	13:46:54	Pump Torque Limiter Reached	Normal	-	-	

Power Off ⓘ

Operator ⓘ

Reactive

Line/of41

Info

MOP Manual Cut-Out List

Drawing

6655-0140-0006

Alarms ► Channel List							2013-05-27 14:04:27			Alarms								
ID	Date	Time	Description	Status	MCo	ACo	Ack	Alarm List	Event Log	Manual Cut-Out List	Channel List	Engine	Auxiliaries	Maintenance	Admin		Power Off ⓘ	Operator 
ACU1_010110	2013-05-27	13:49:48	No Commands from ECU A	Normal			X											
ACU1_010111	2013-05-27	13:49:46	No Commands from ECU B	Normal			X											
ACU1_0210	2013-05-27	13:46:46	Blower 1 Ctrl Failed	Normal			X											
ACU1_0701012350	2013-05-27	13:46:46	Generic HPS Observer alarm	Normal			X											
ACU1_070119	2013-05-27	13:46:46	Pump ctrl failure	Normal			X											
ACU1_070210	2013-05-27	13:46:47	Startup Pump Ctrl Failed	Normal			X											
ACU1_0708	2013-05-27	13:46:47	Hydraulic leakage (shutdown level)	Normal			X											
ACU1_1109-A04	2013-05-27	13:46:45	Suprv. Ch23,1109-A,Turning gear dis	Normal			X											
ACU1_1110-A04	2013-05-27	13:46:45	Suprv. Ch22,1110-A,Turning gear eng	Normal			X											
ACU1_1111-A04	2013-05-27	13:46:45	Suprv. Ch21,1111-A,Main start valve	Normal			X											
ACU1_1112-A04	2013-05-27	13:46:45	Suprv. Ch24,1112-A,Main start valve	Normal			X											
ACU1_1116-A04	2013-05-27	13:46:45	Suprv. Ch25,1116-A,Start air dist I	Normal			X											
ACU1_1201-104	2013-05-27	13:46:45	Suprv. Ch31,1201-1,Hydraulic Pressu	Normal			X											
ACU1_1202-A03	2013-05-27	13:46:46	Suprv. Ch80,1202-A,System bypass op	Normal			X											
ACU1_1204-104	2013-05-27	13:46:45	Suprv. Ch32,1204-1,Lube oil pressur	Normal			X											
ACU1_1222-104	2013-05-27	13:46:45	Suprv. Ch34,1222-1,Swash-Plate Posi	Normal			X											
ACU1_1230	2013-05-27	13:46:47	ECS insulation level below normal	Normal			X											
ACU1_1231	2013-05-27	13:46:47	Too low ECS insulation level	Normal			X											
ACU1_123604	2013-05-27	13:46:45	Suprv. Ch27,1236,Hyd. leak shutdown	Normal			X											
ACU1_2904-104	2013-05-27	13:47:08	Suprv. Ch33,2904-1,ECS Insulation	Alarm	X													
ACU1_8501-A04	2013-05-27	13:46:45	Suprv. Ch37,8501-A,Starting air pre	Normal			X											
Cut-Out		Reactivate		Line/of --- 1253														
Info																		

MOP Channel List

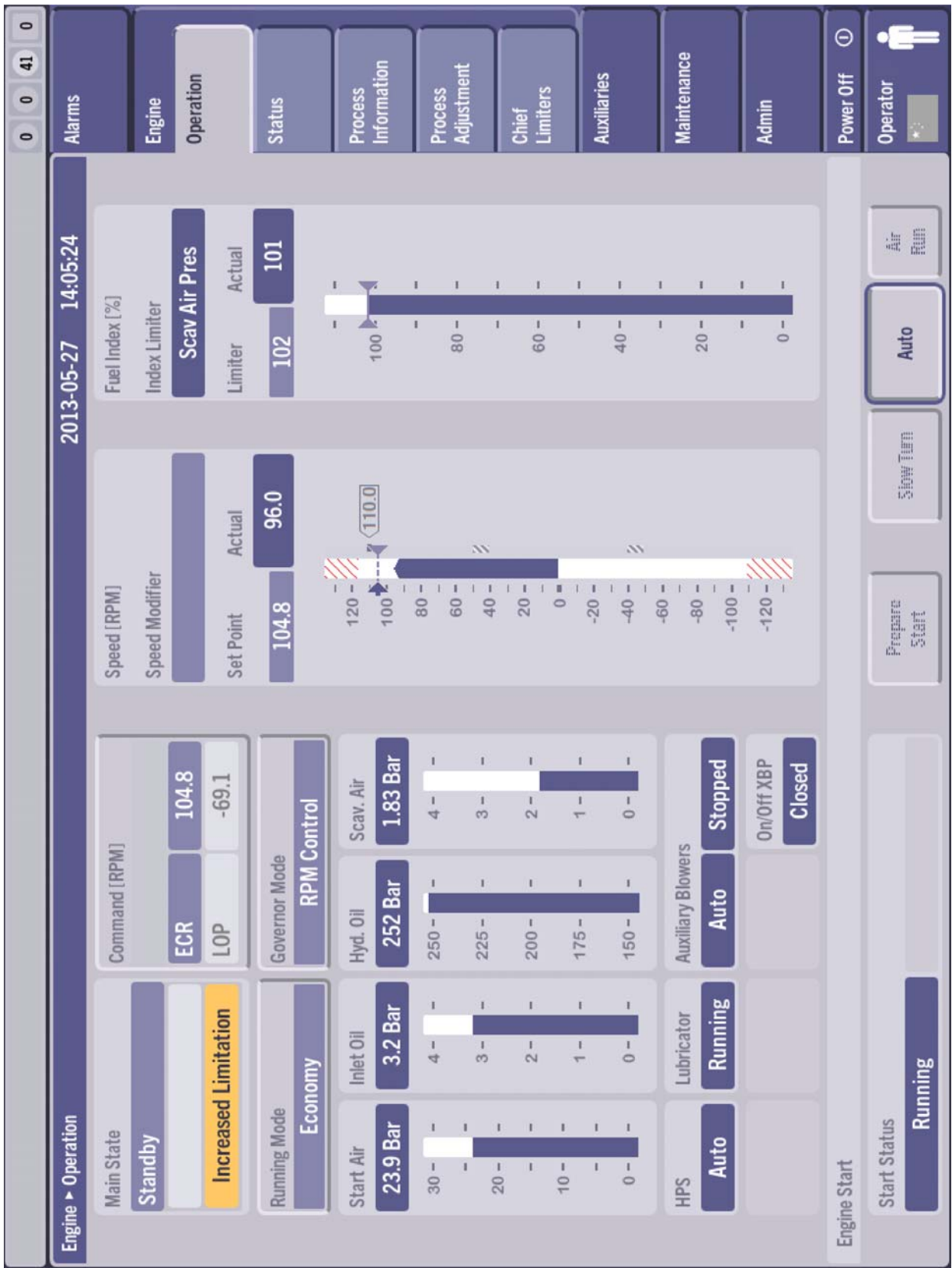


Figure 1:

MOP Operation

Drawing

6655-0150-0009

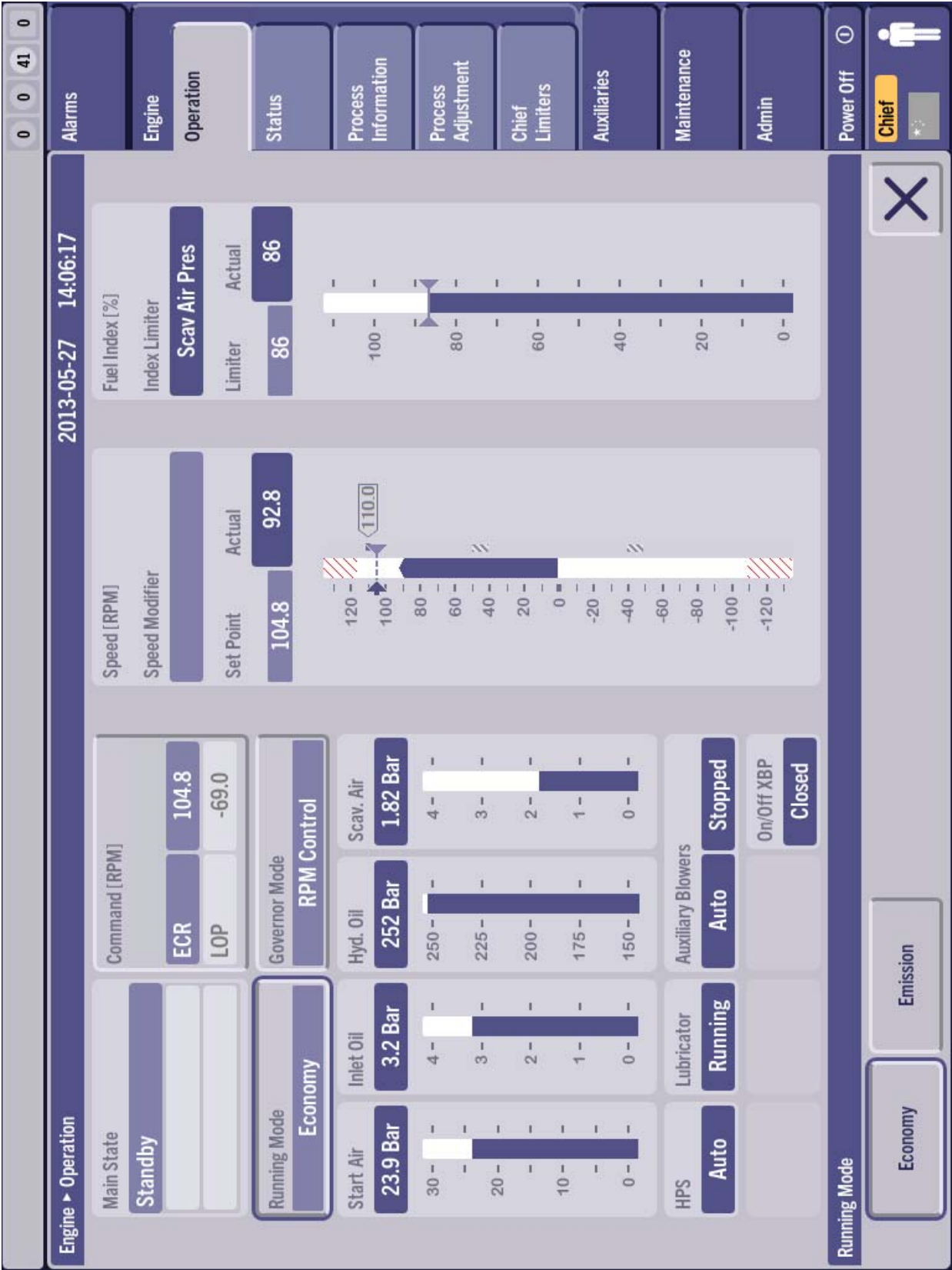


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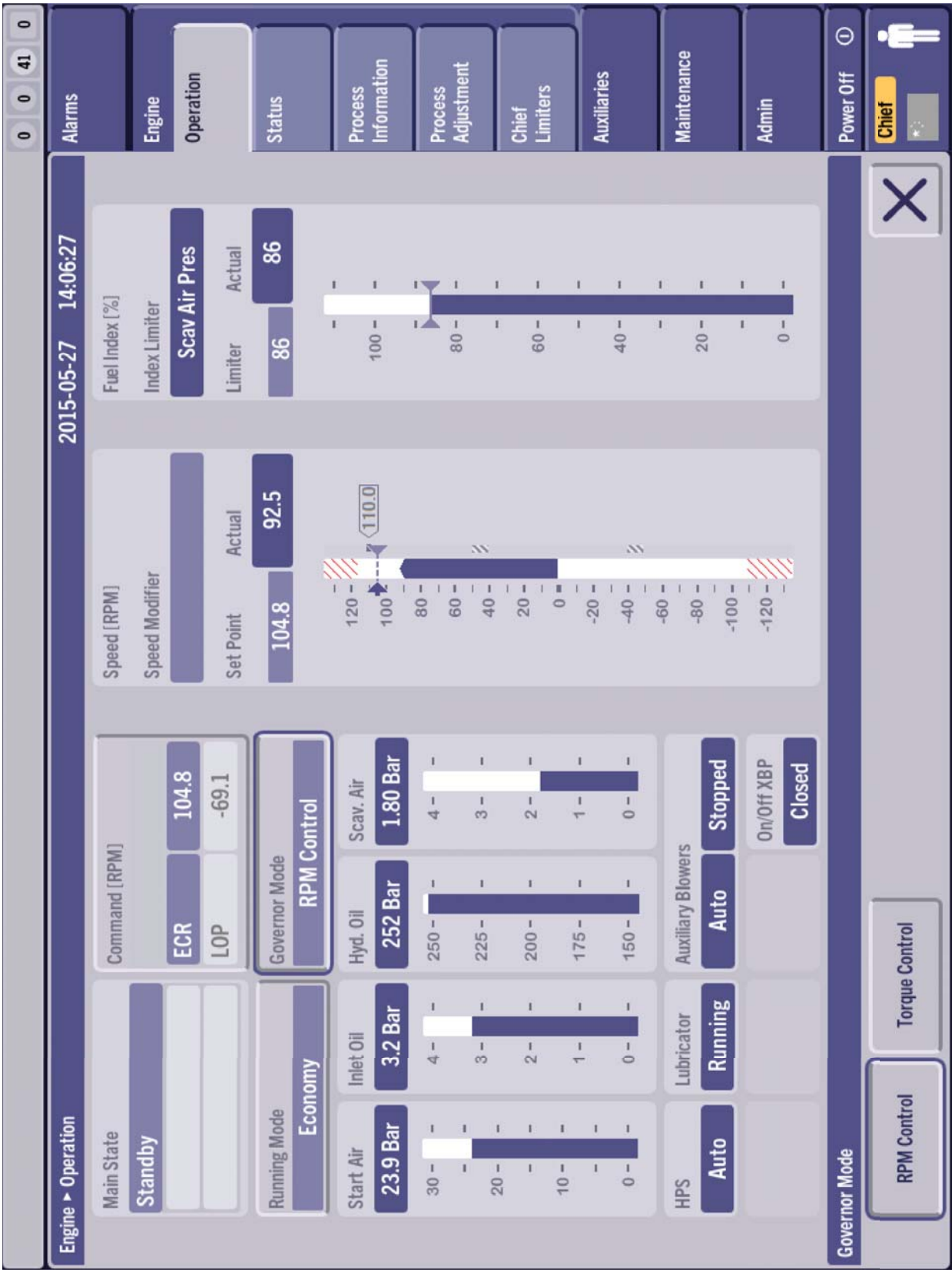
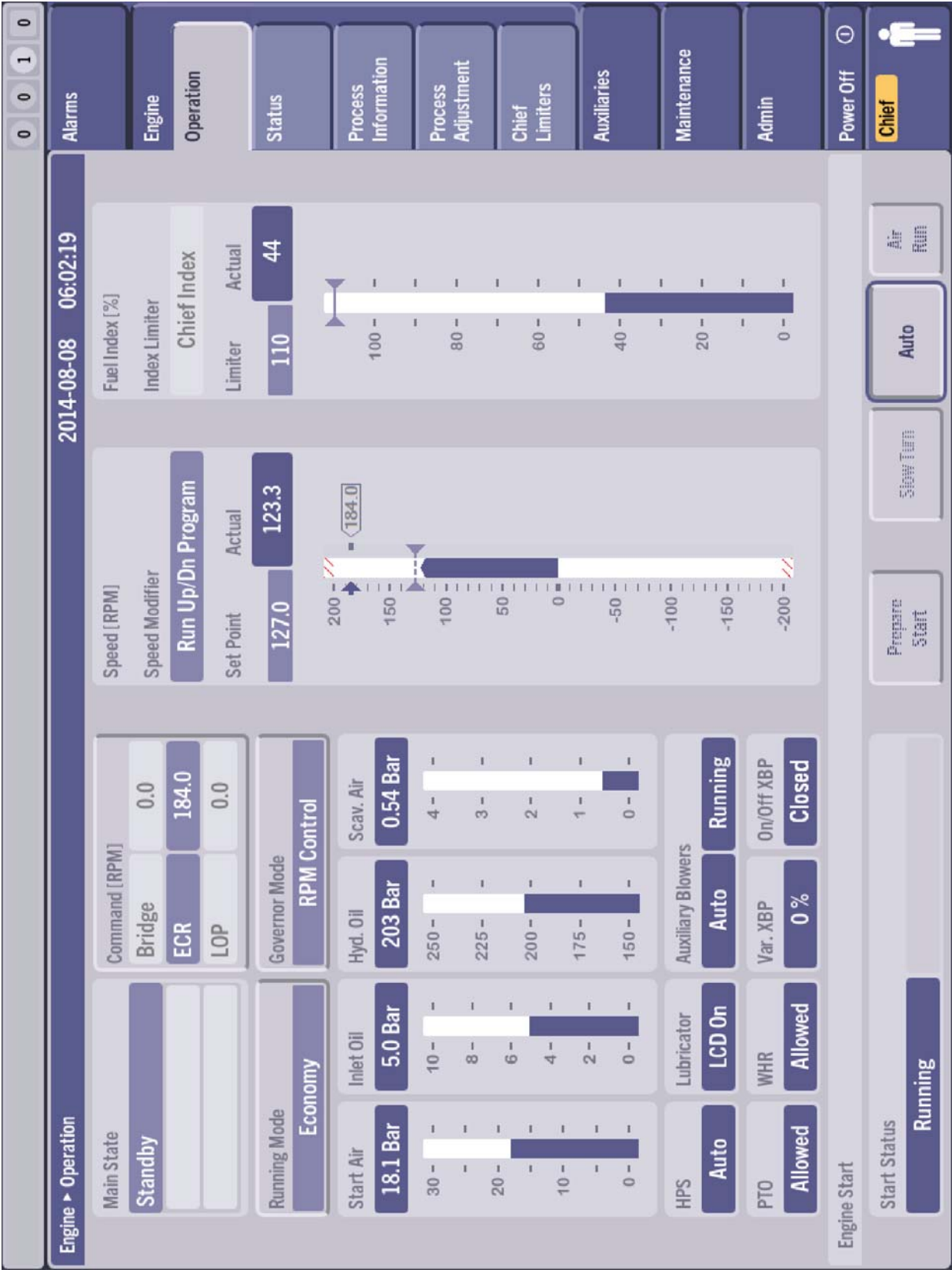


Figure 3:



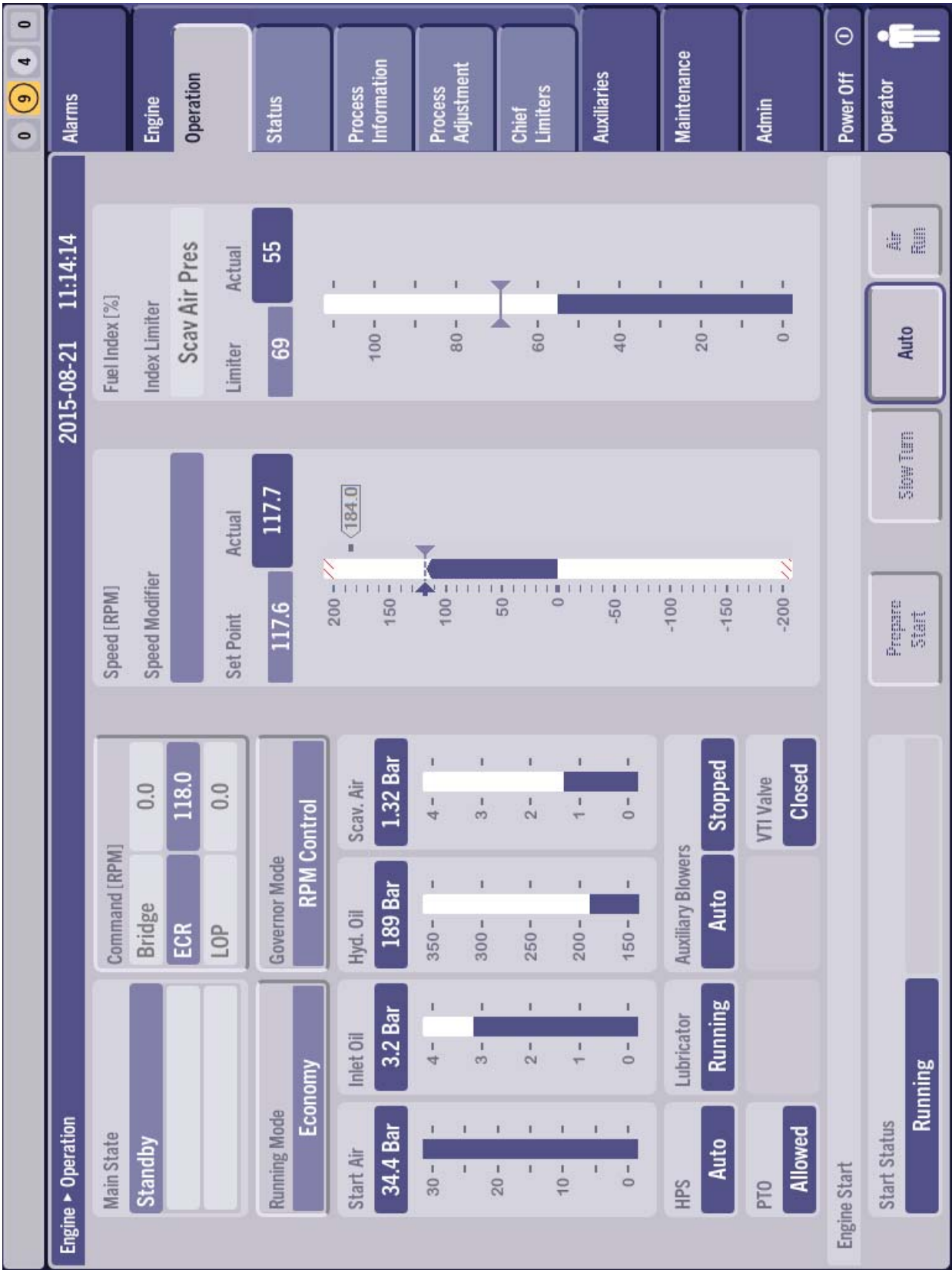


Figure 5:

MOP Operation

Drawing
6655-0150-0009

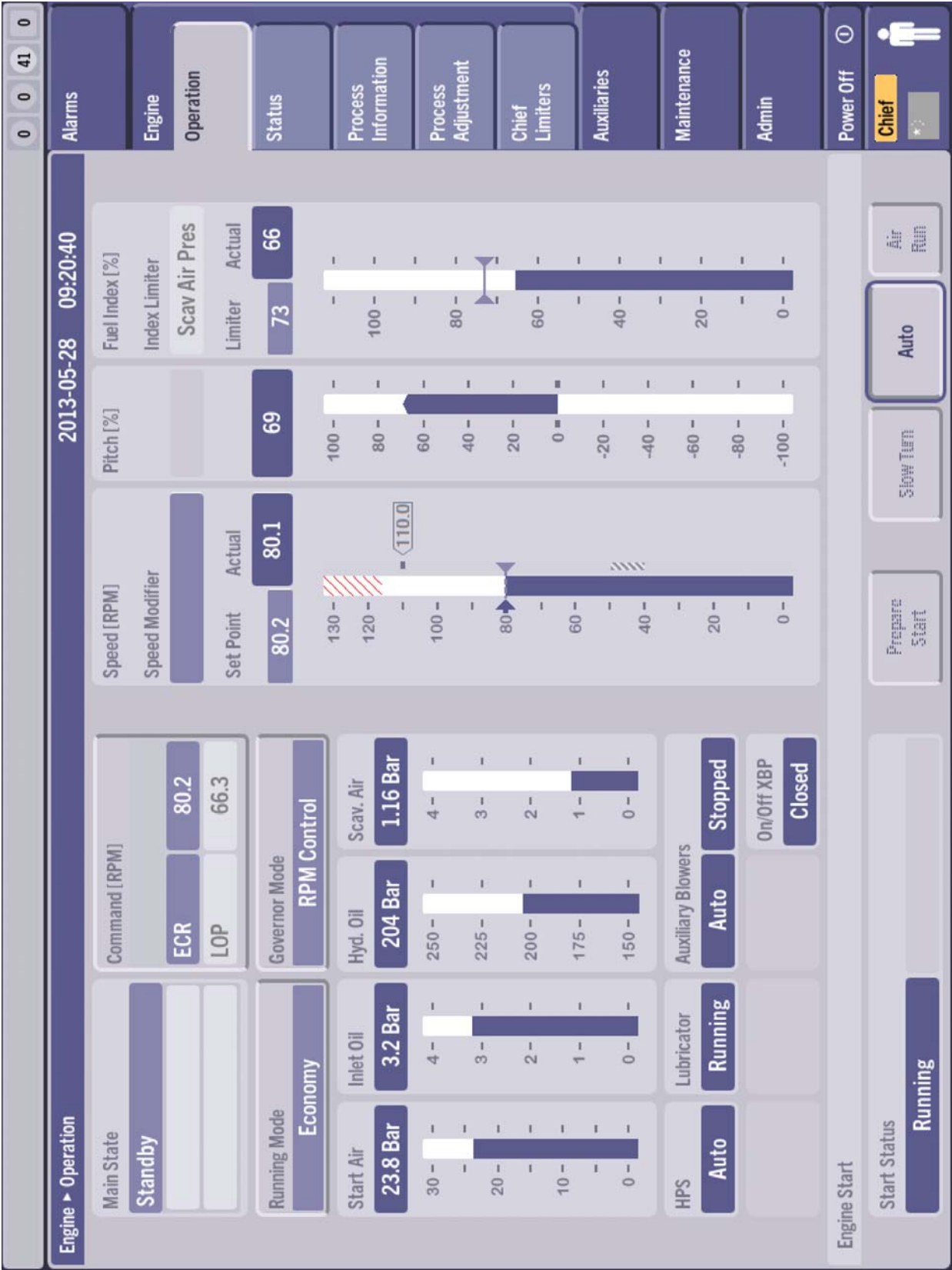
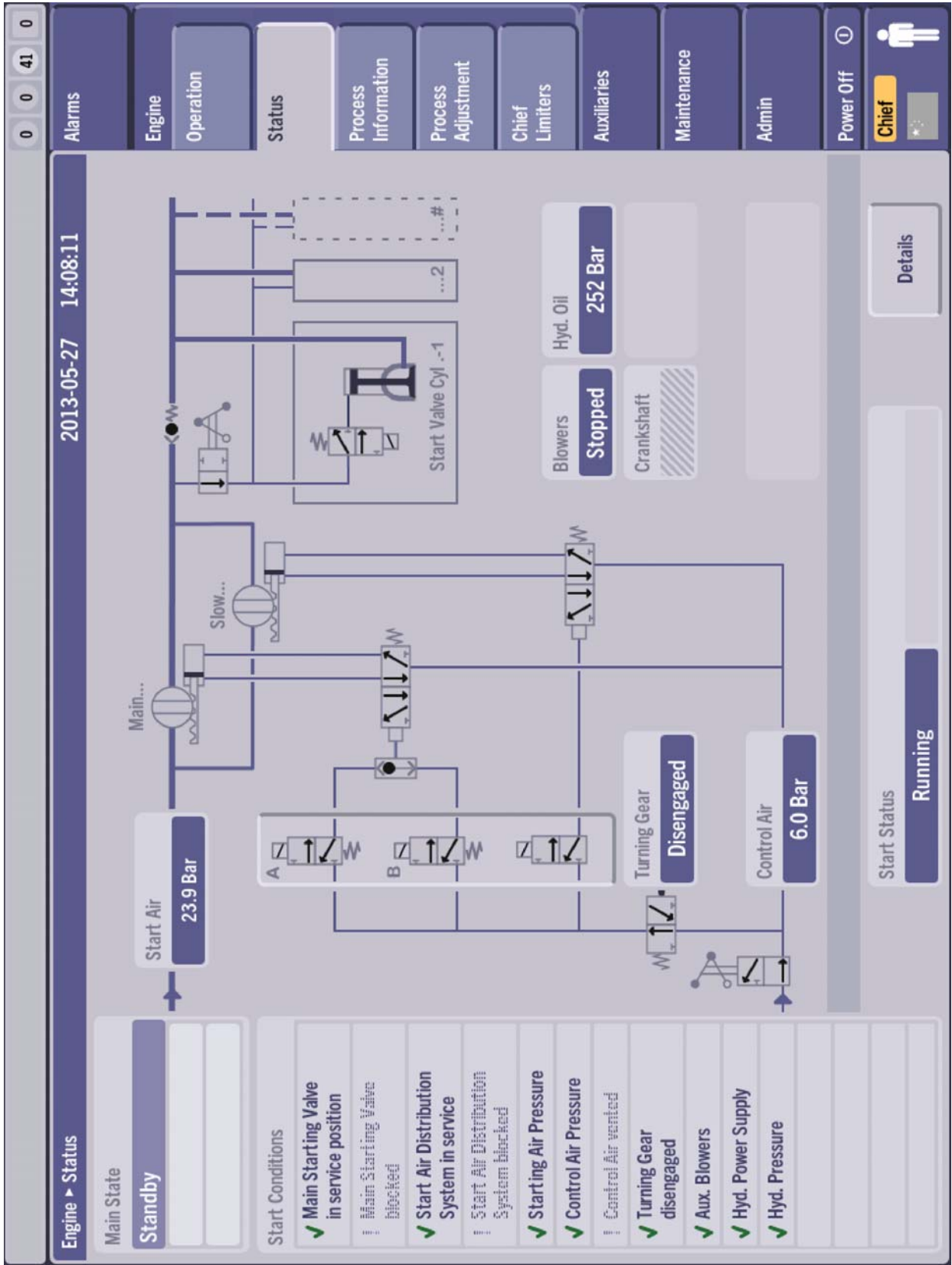
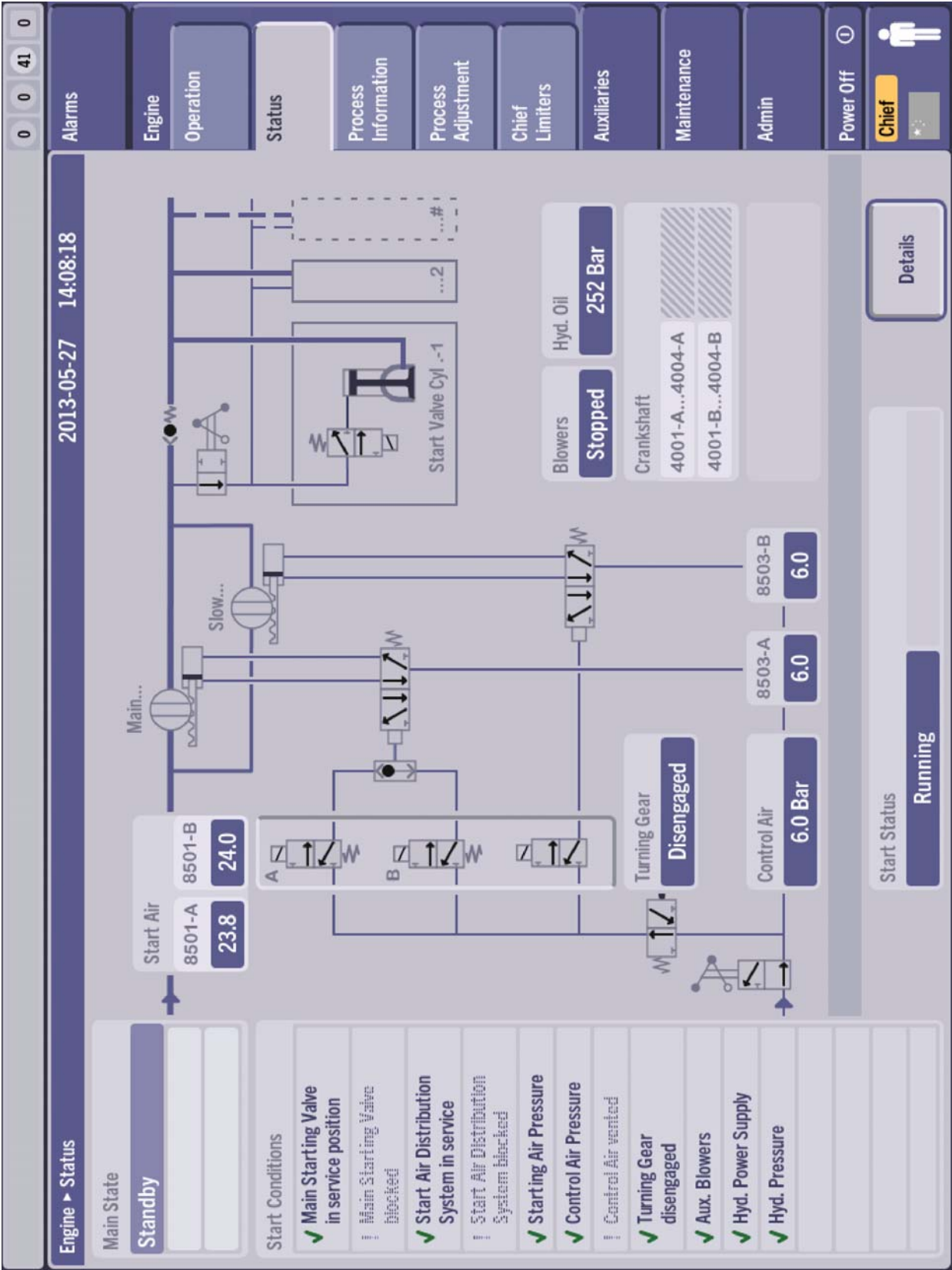


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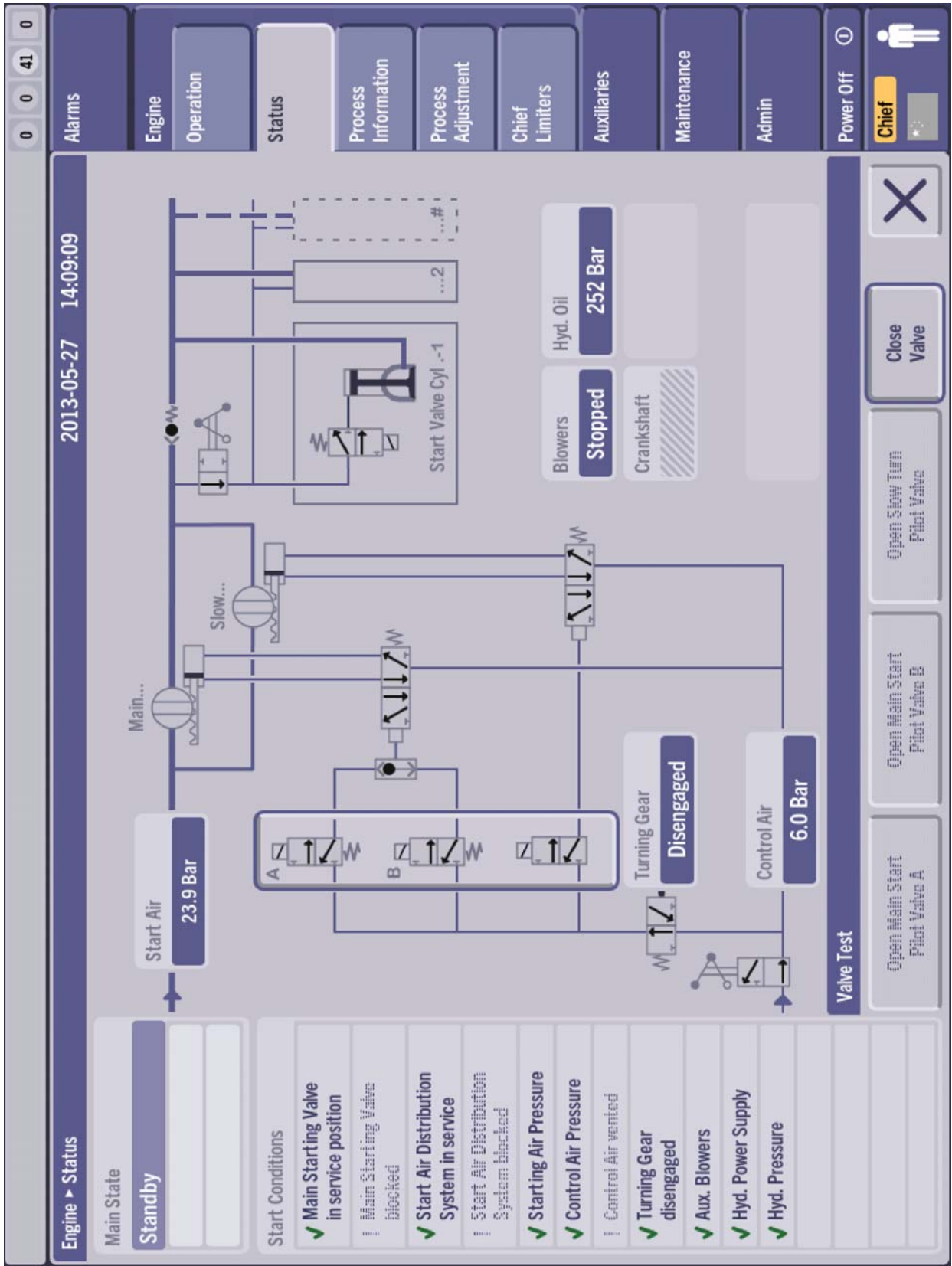


MOP Status

Drawing
6655-0155-0003

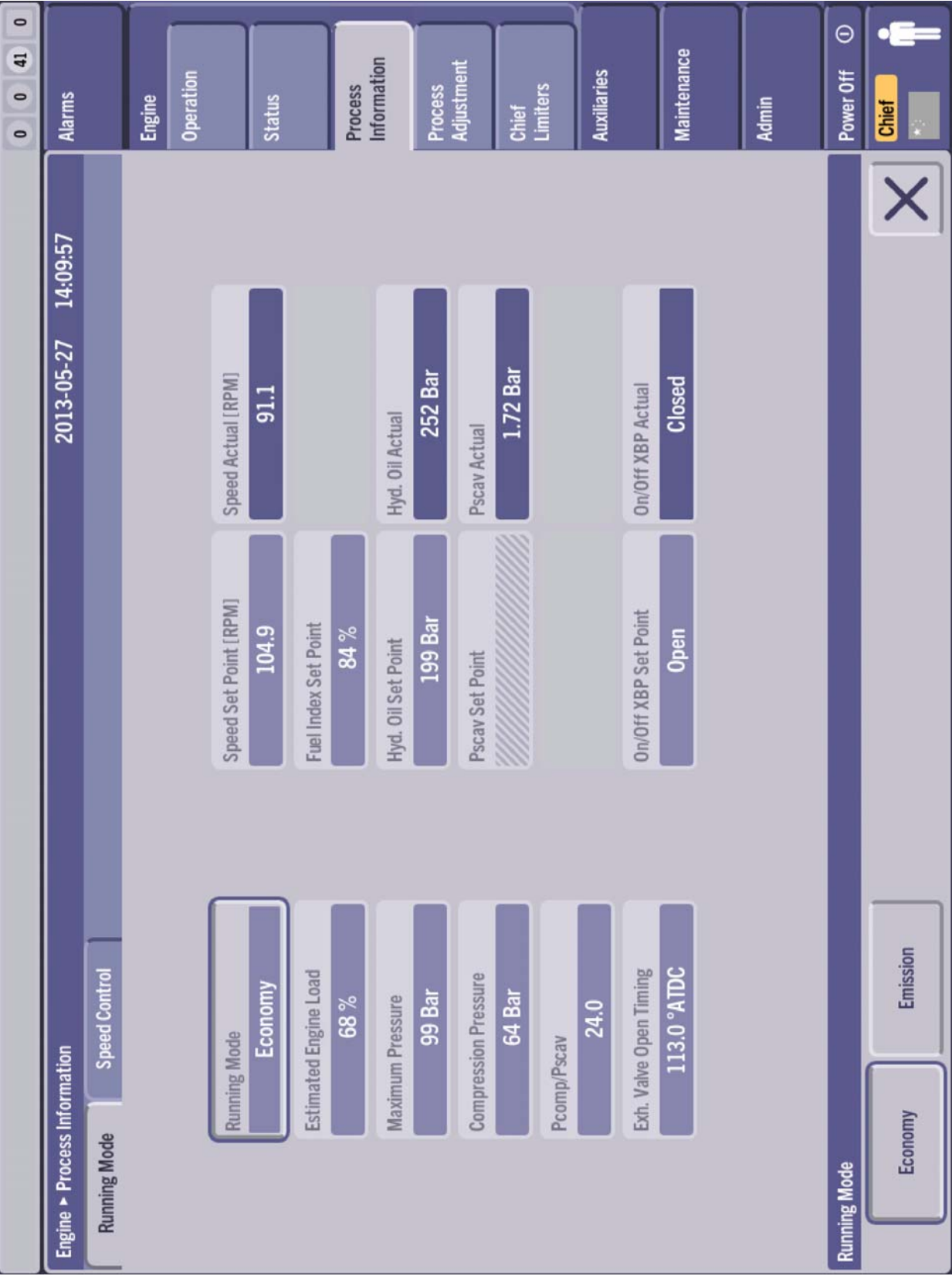


2013-10-21 - en



MOP Status

Drawing
6655-0155-0003



MOP Process Information



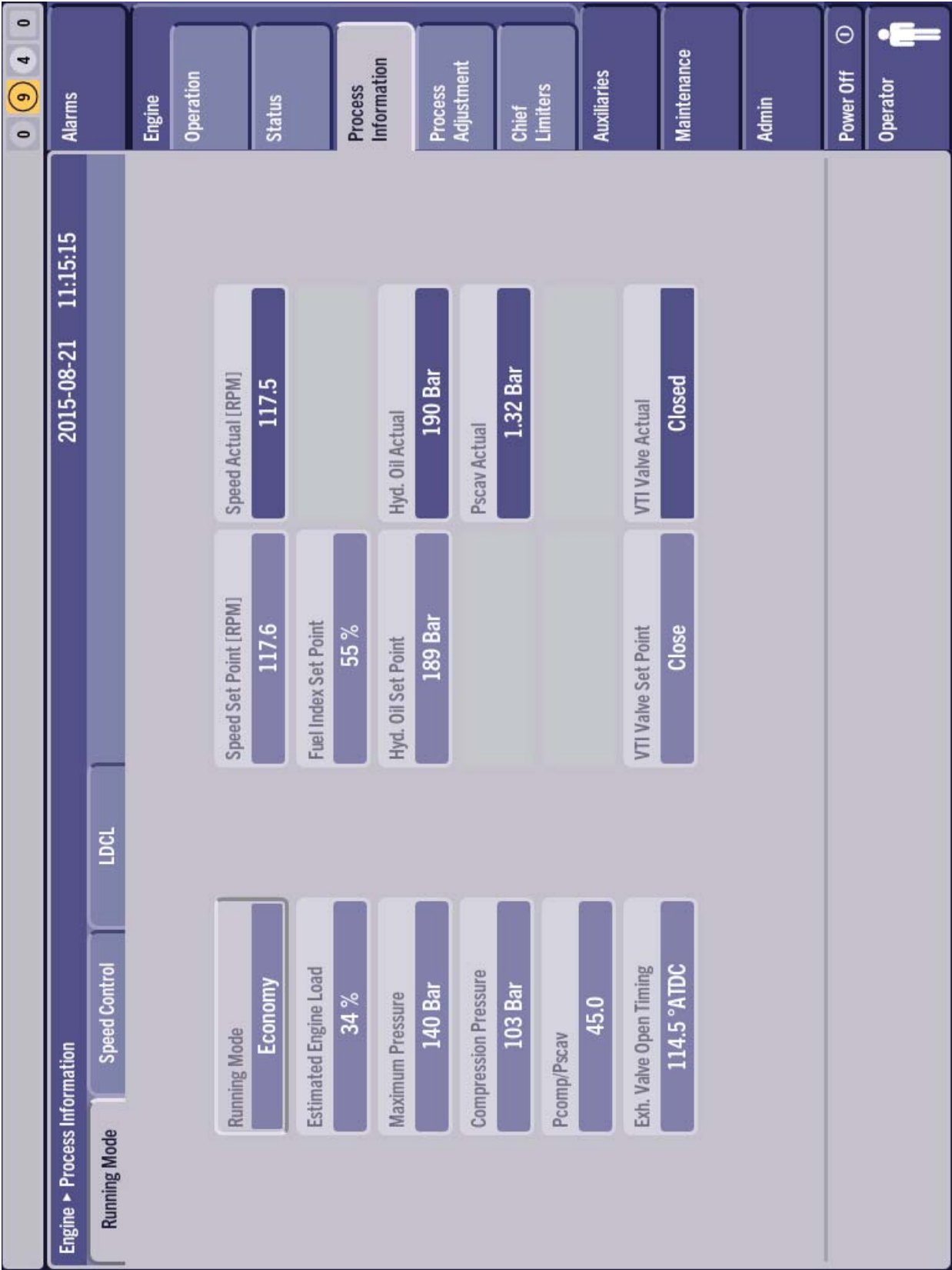
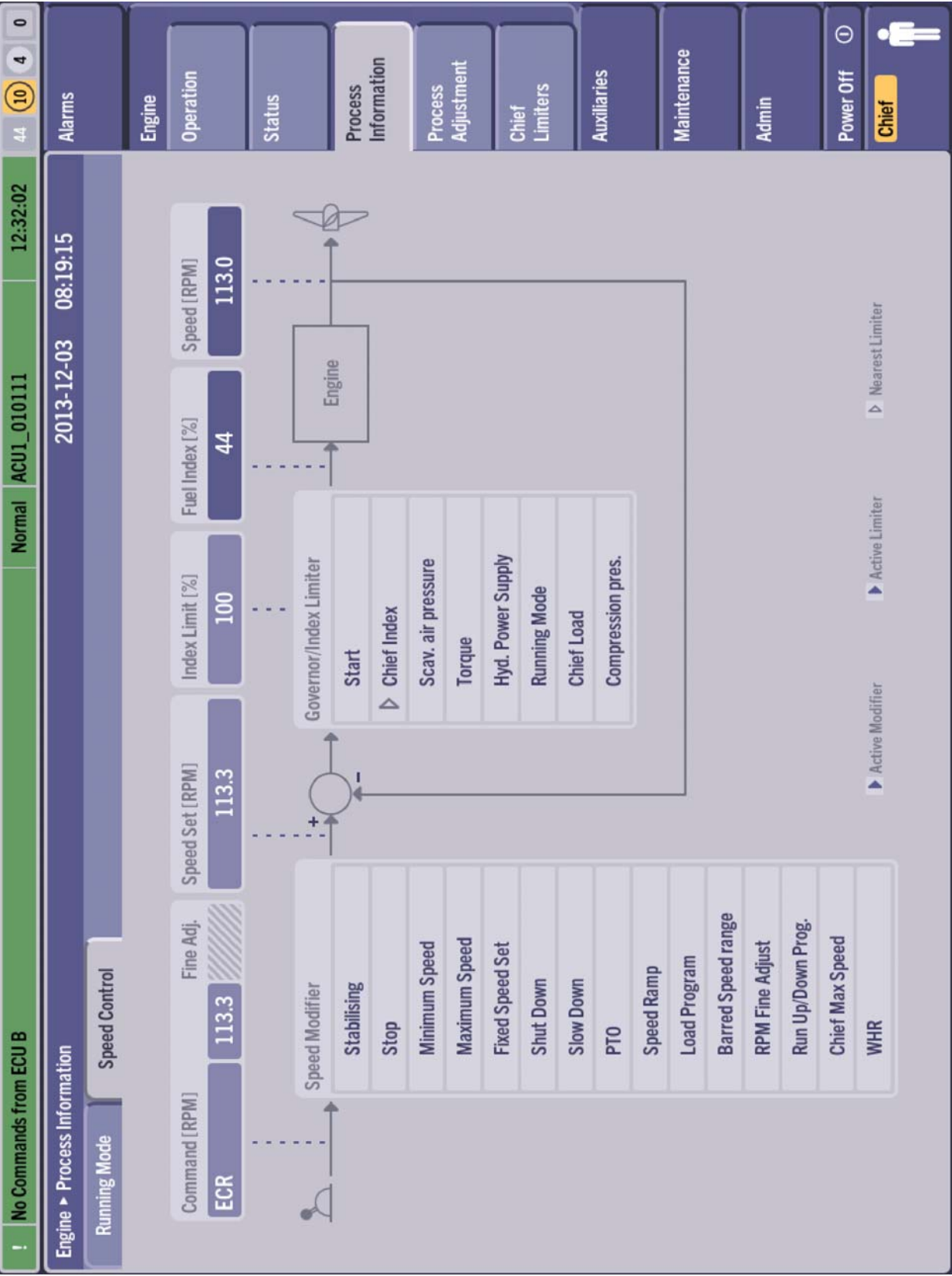
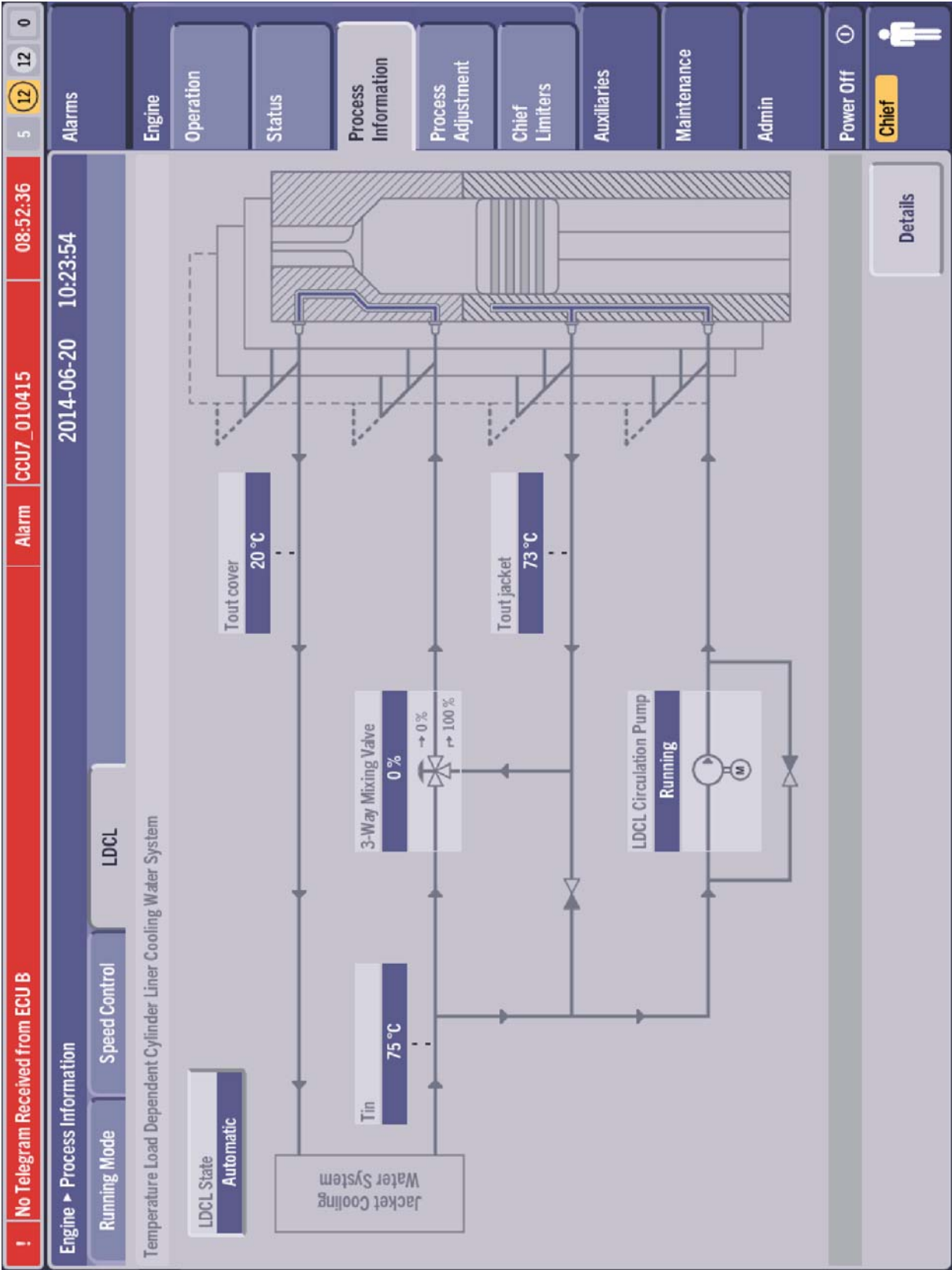


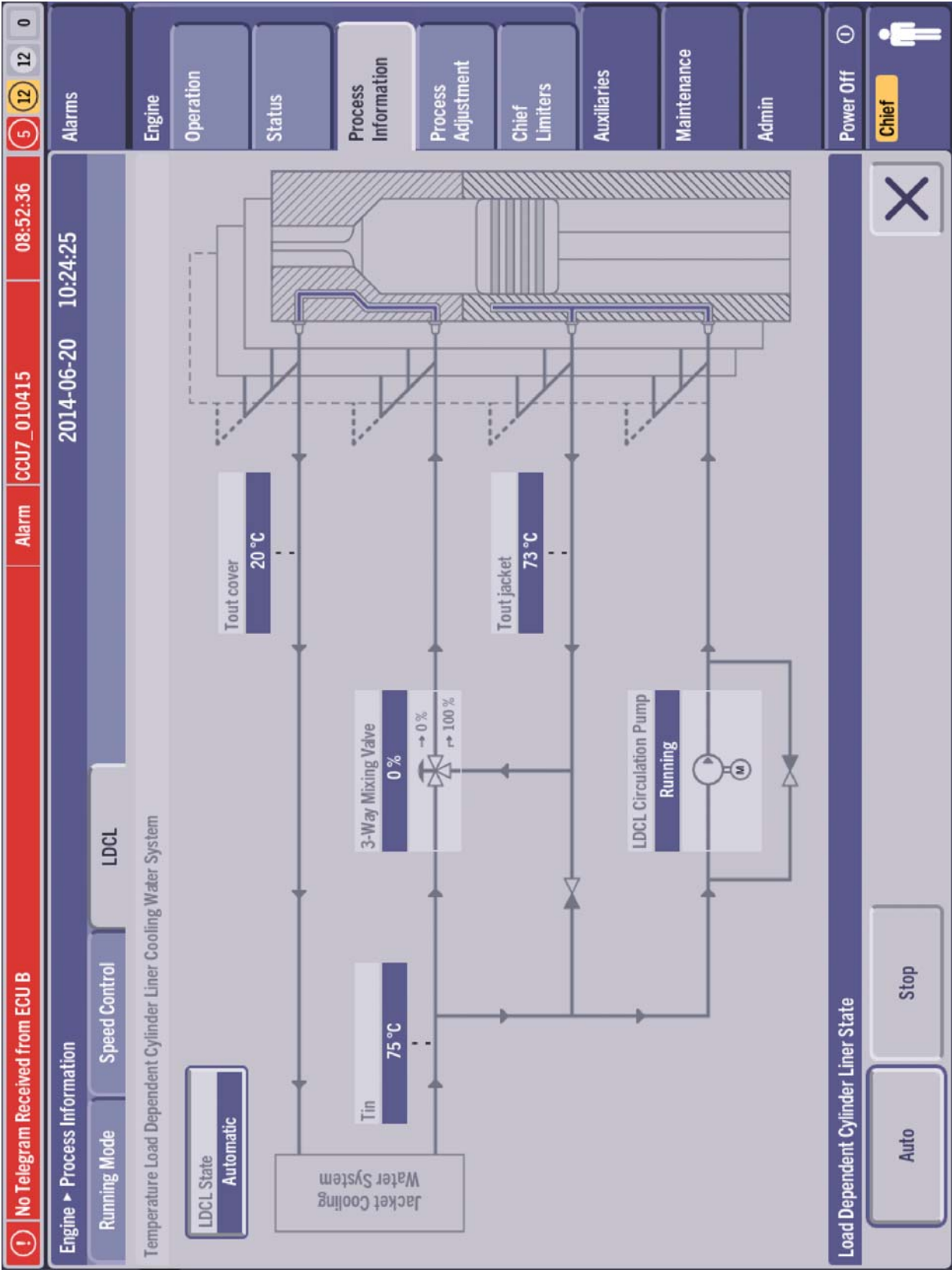
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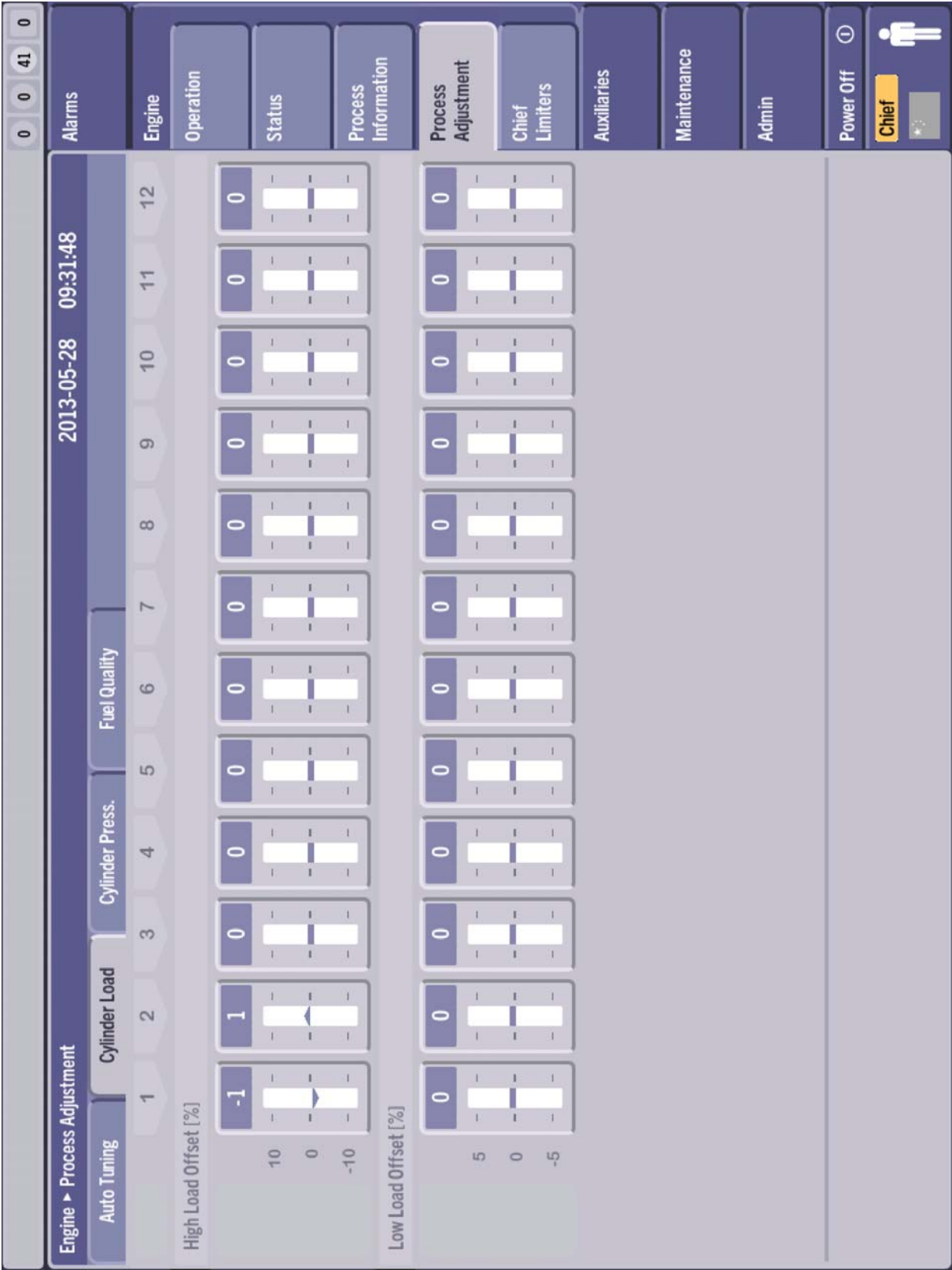
MOP Process Information





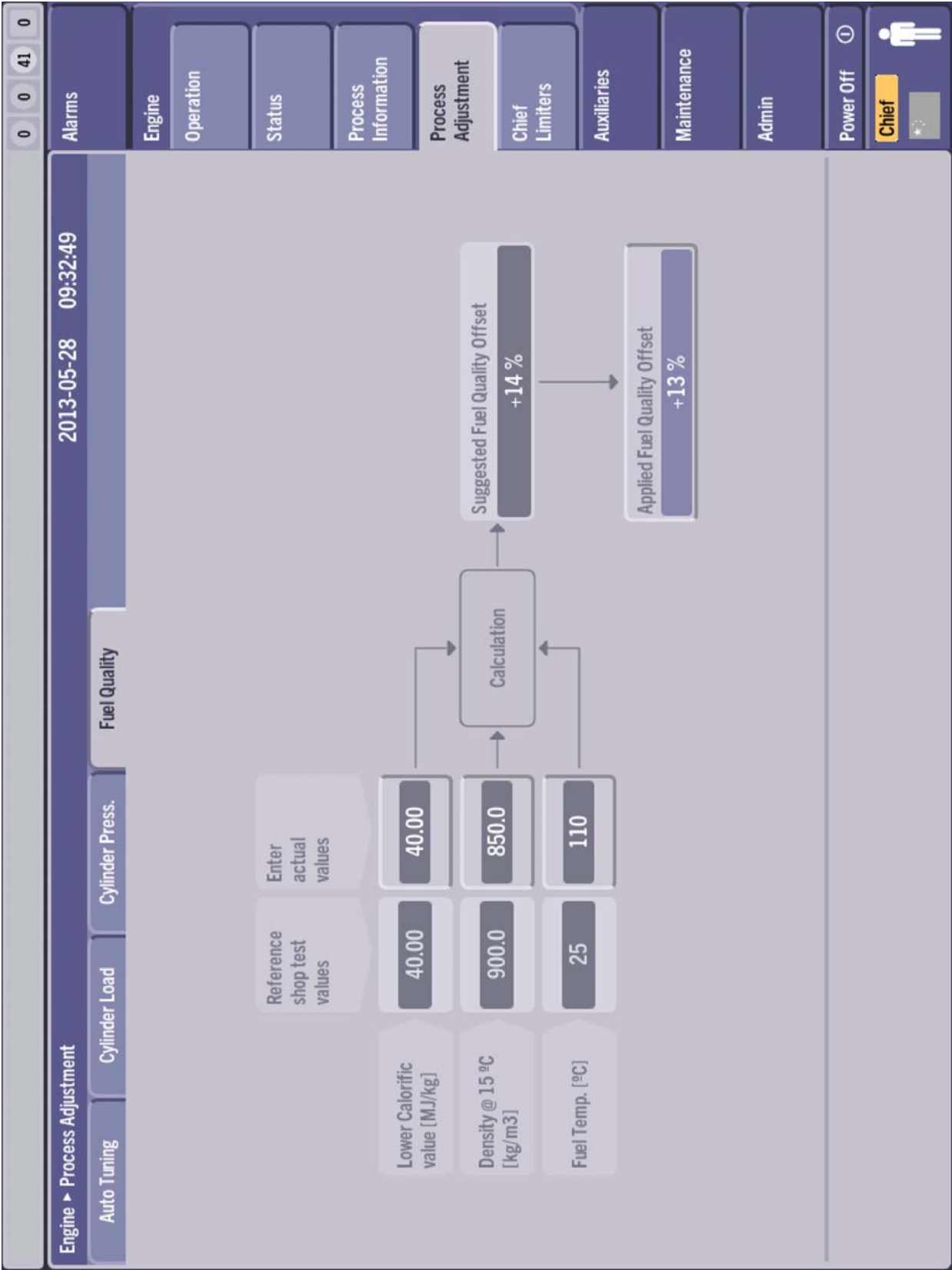


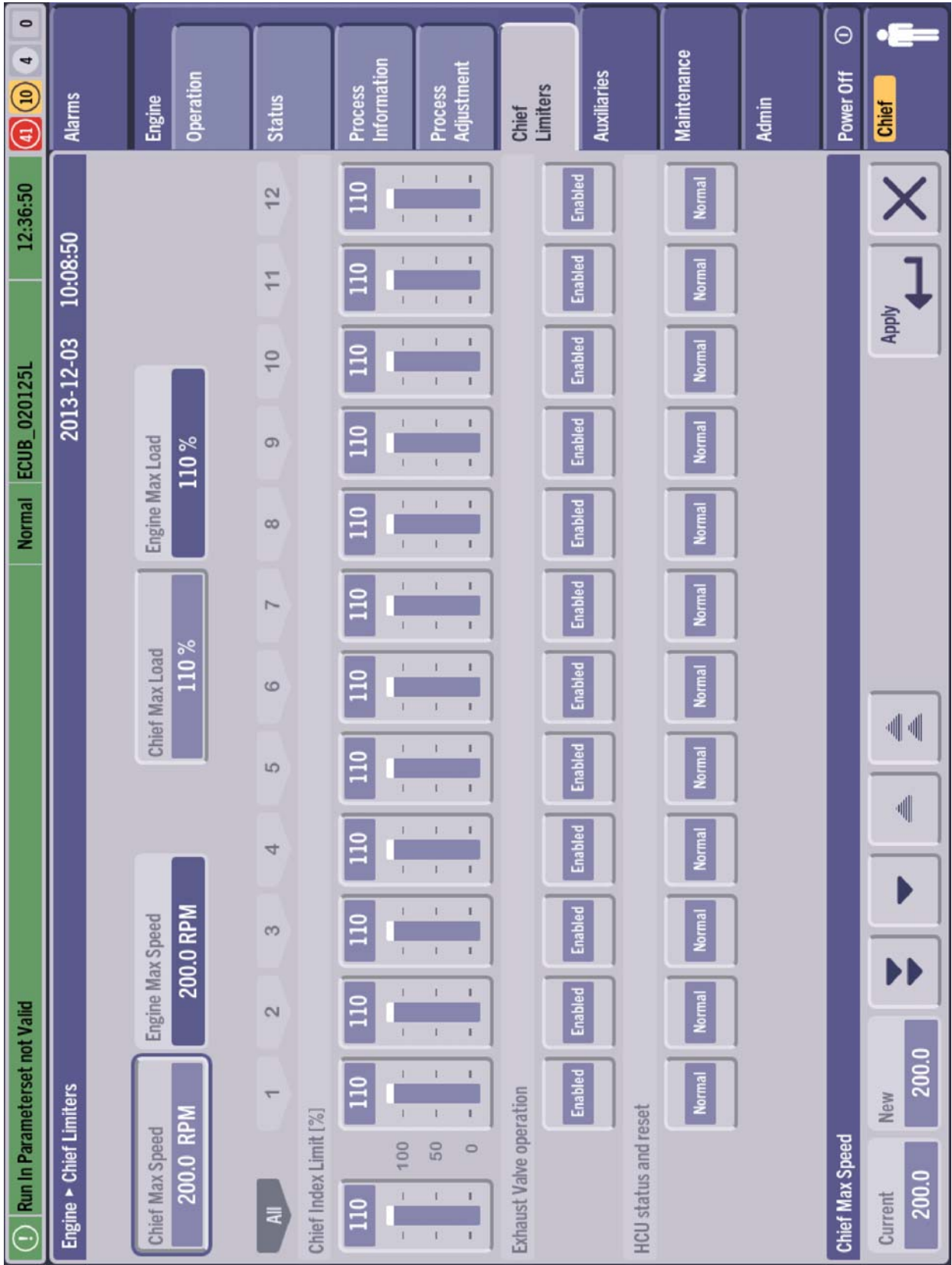




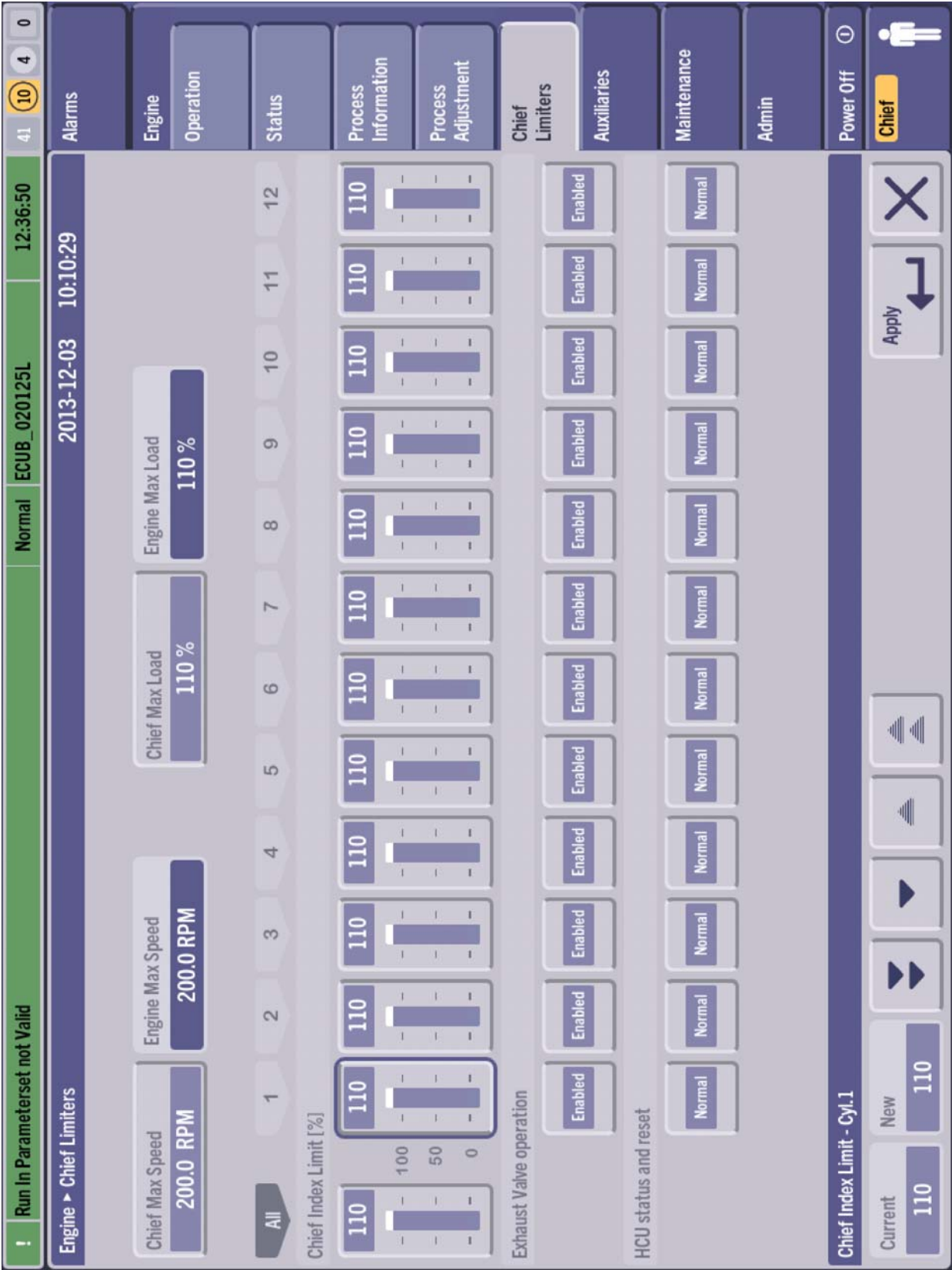


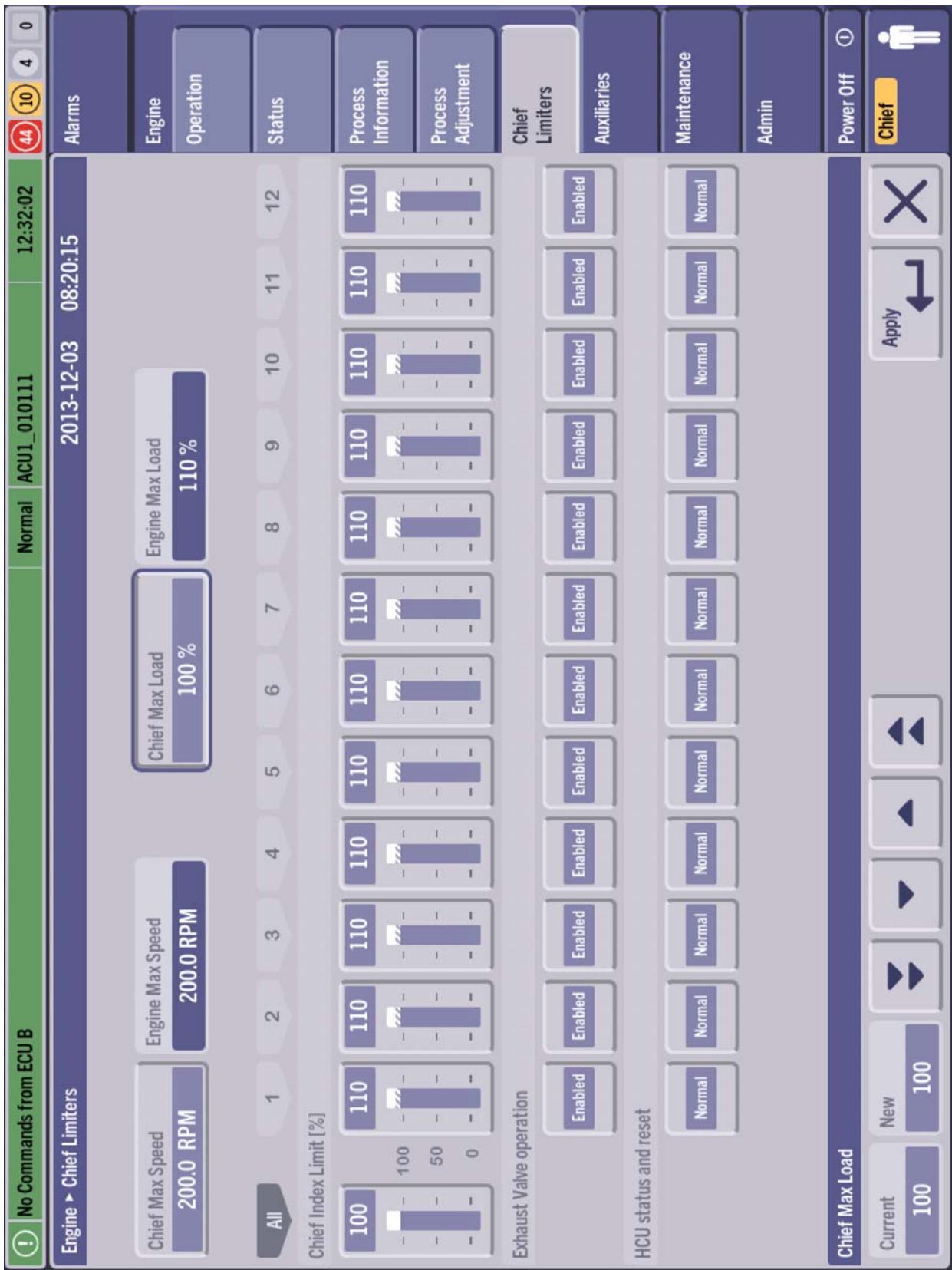
MOP Process Adjustment





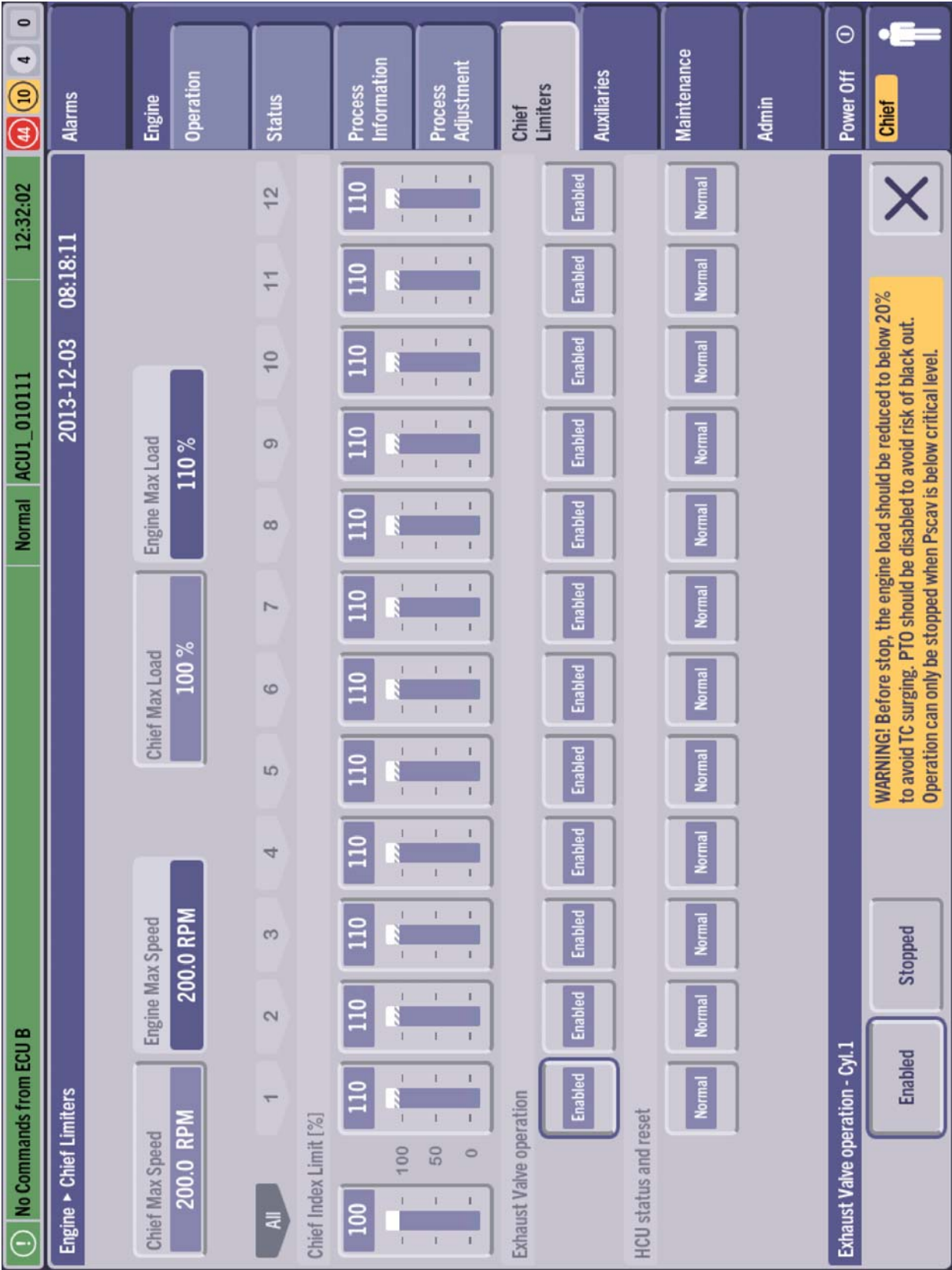
MOP Chief Limiters

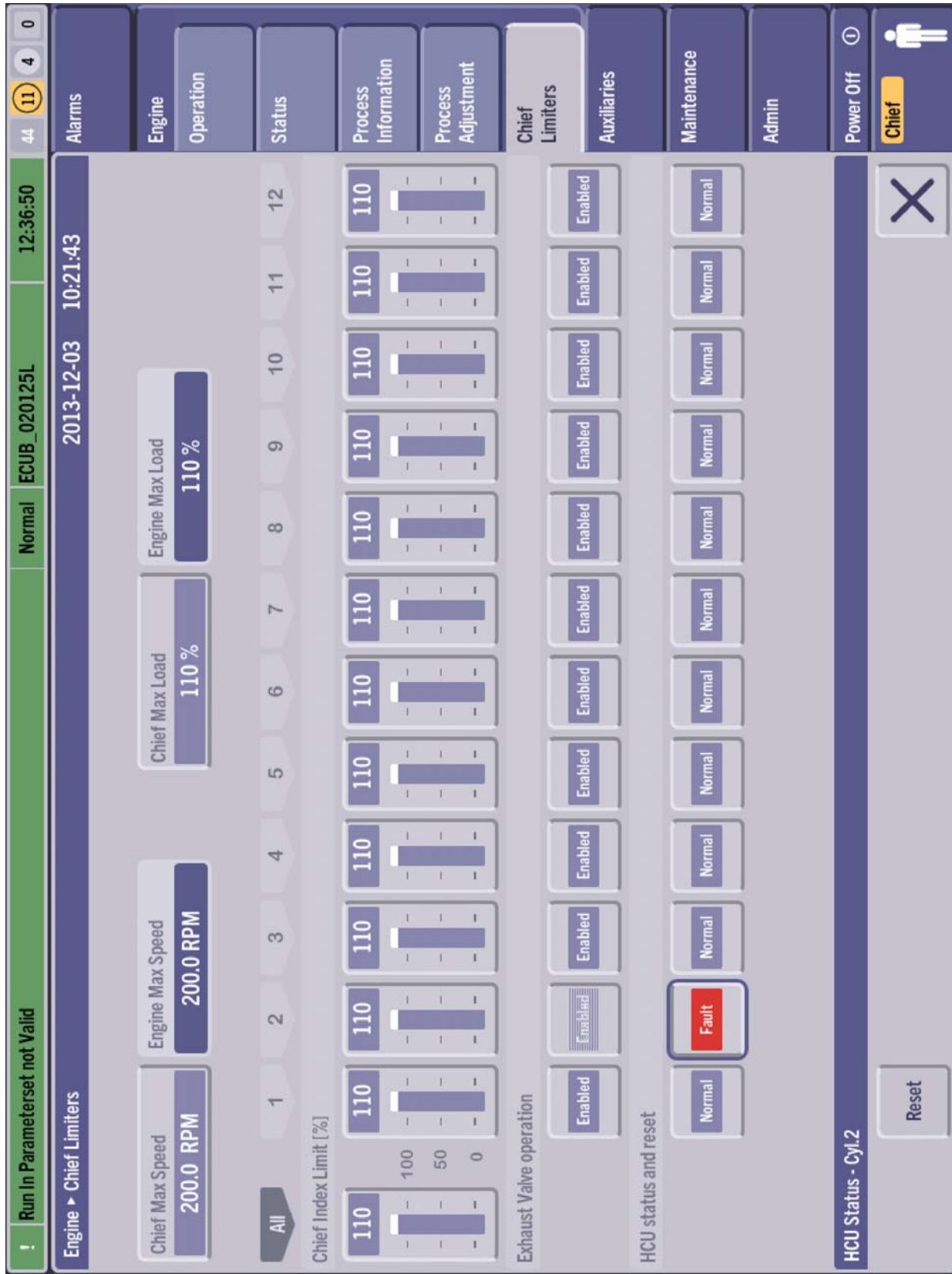




MOP Chief Limiters



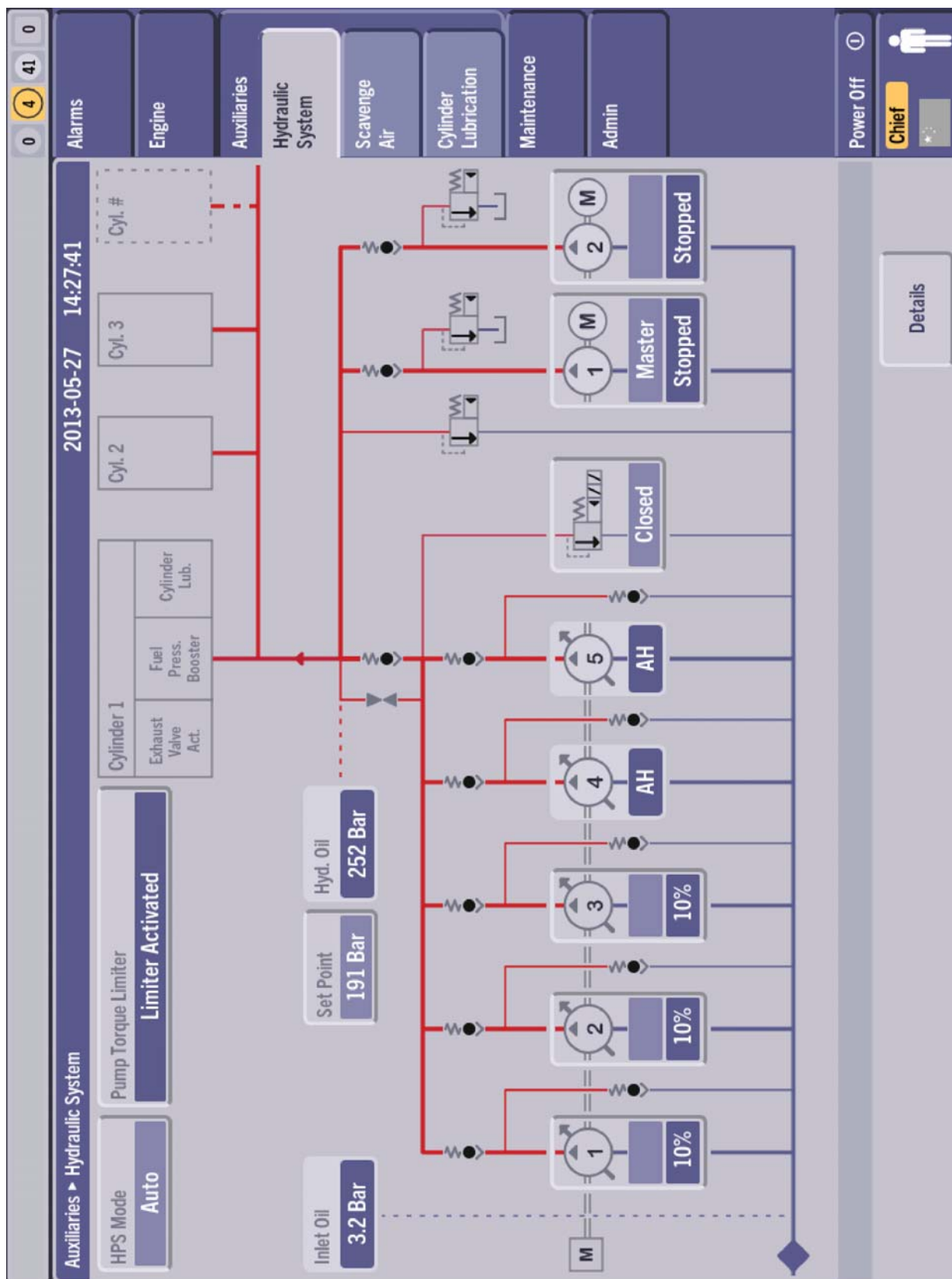




Drawing

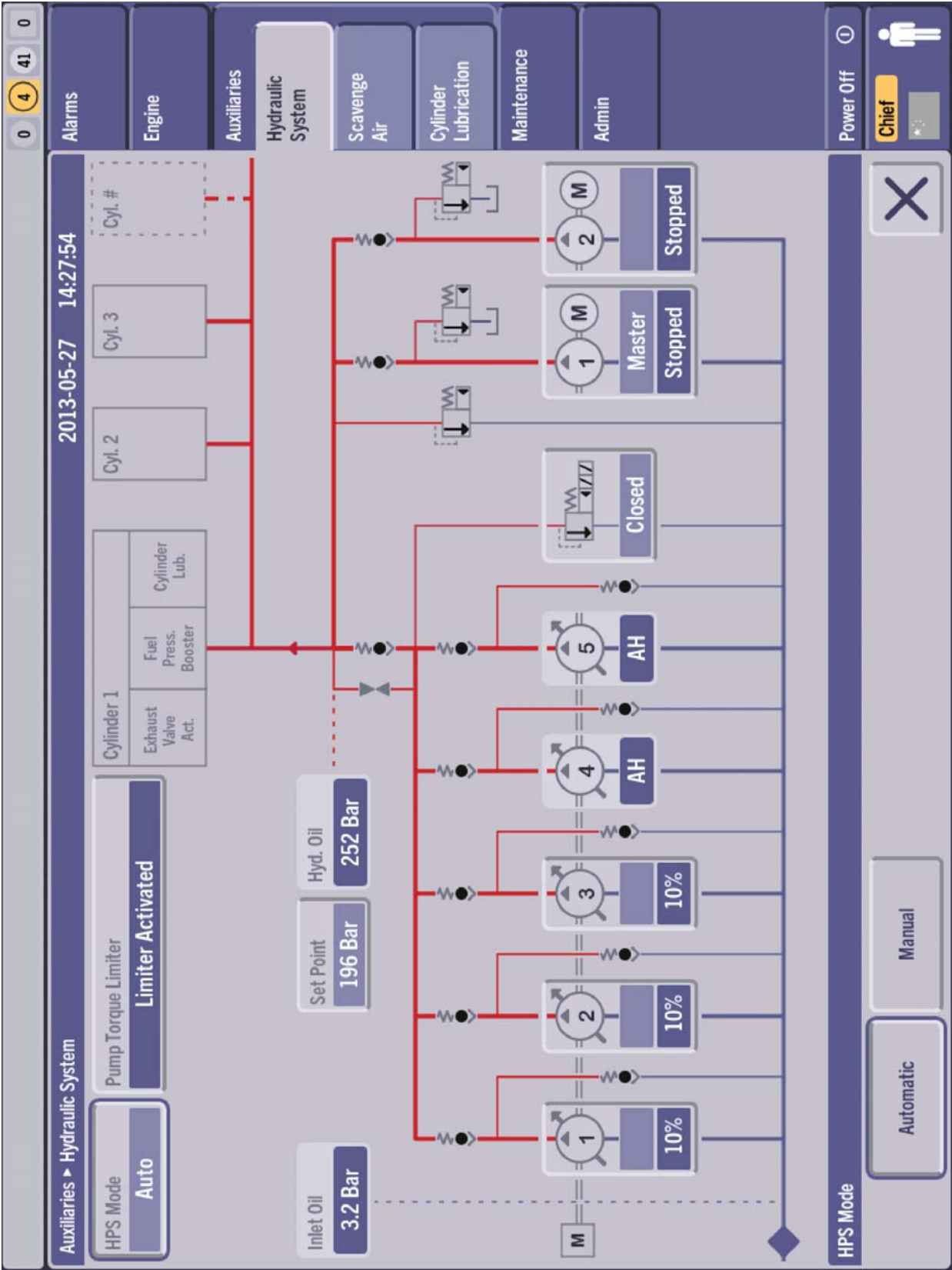
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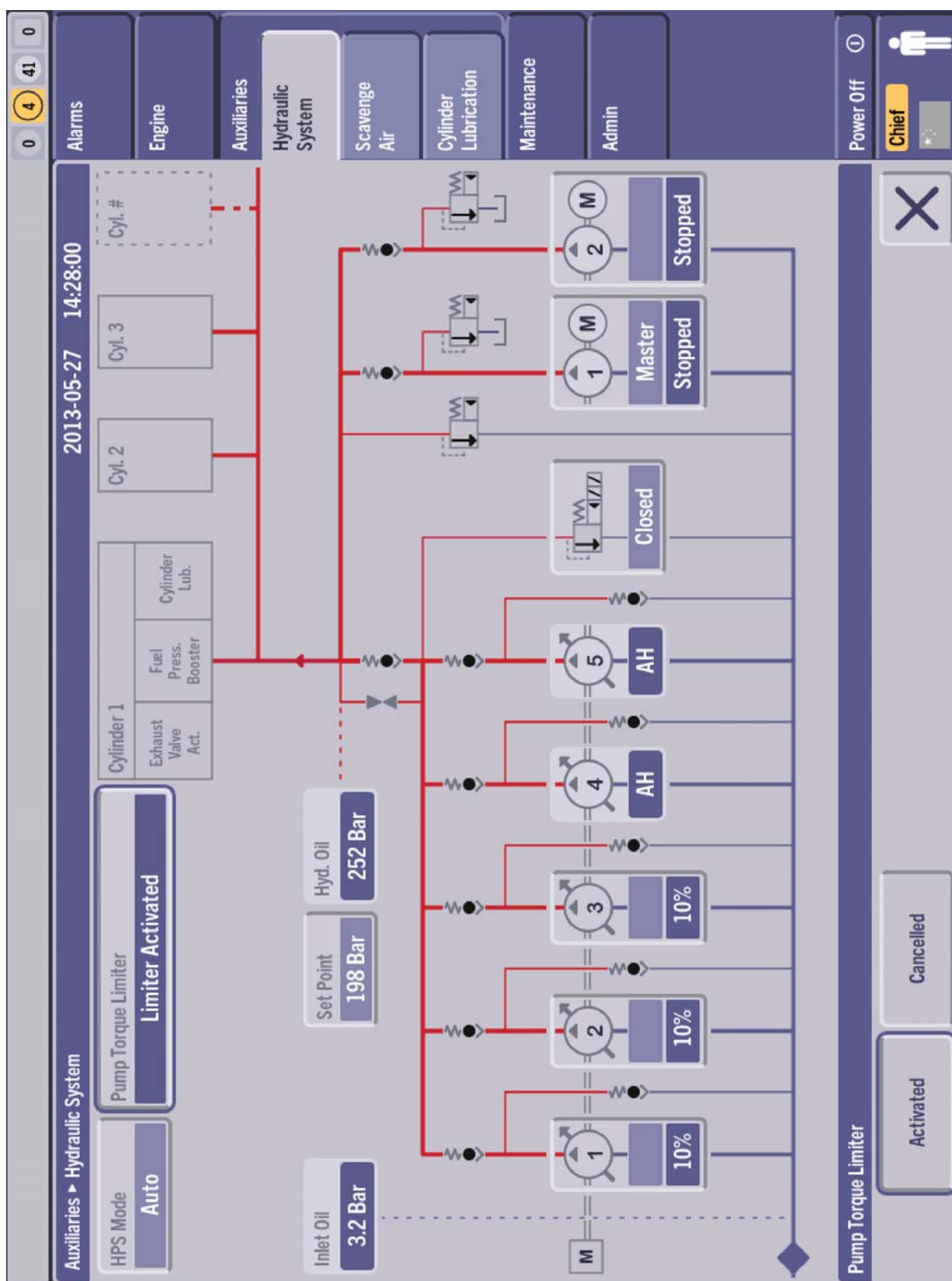
MOP Chief Limiters



MOP Hydraulic System

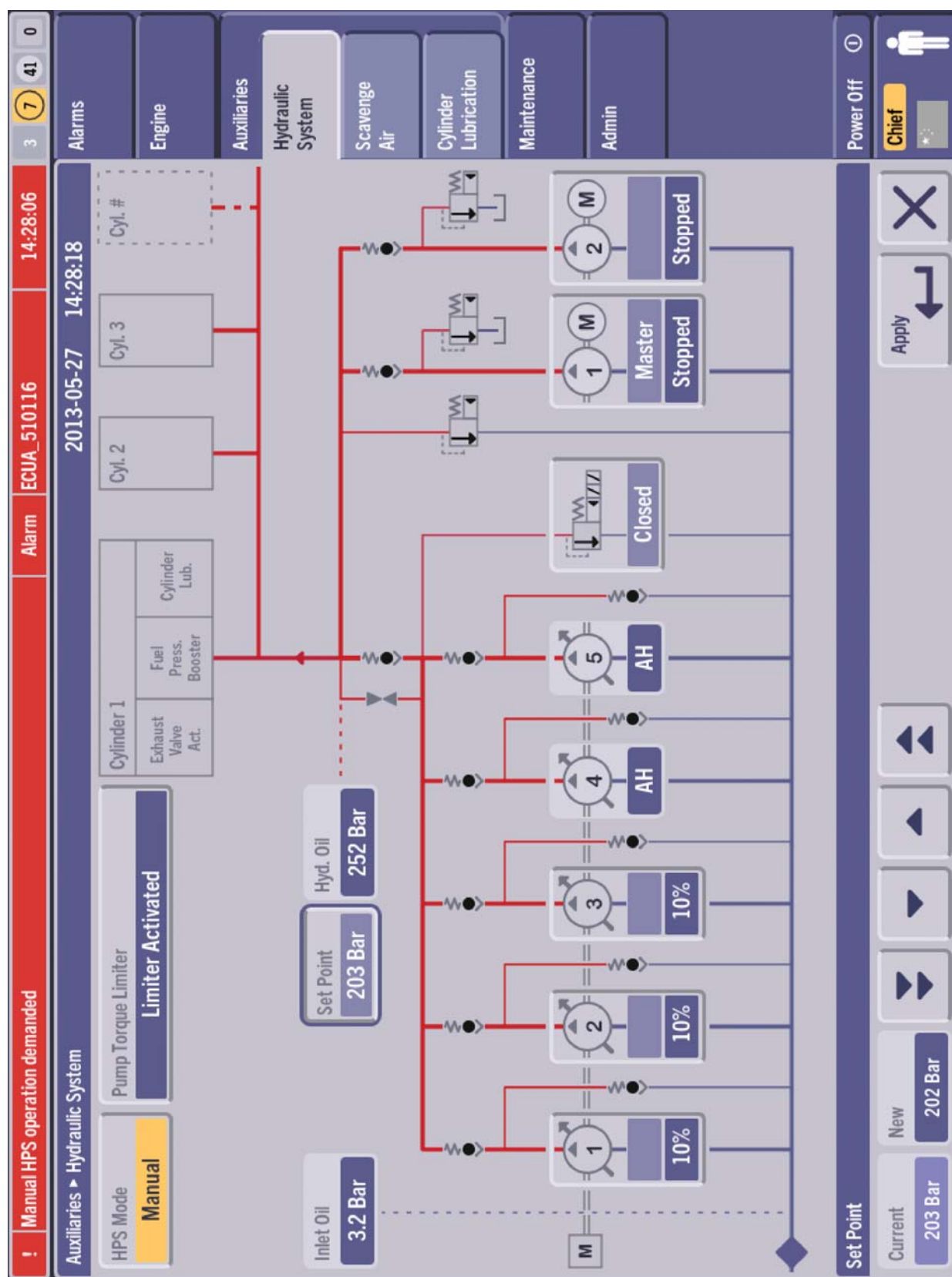
Drawing
6655-0175-0005

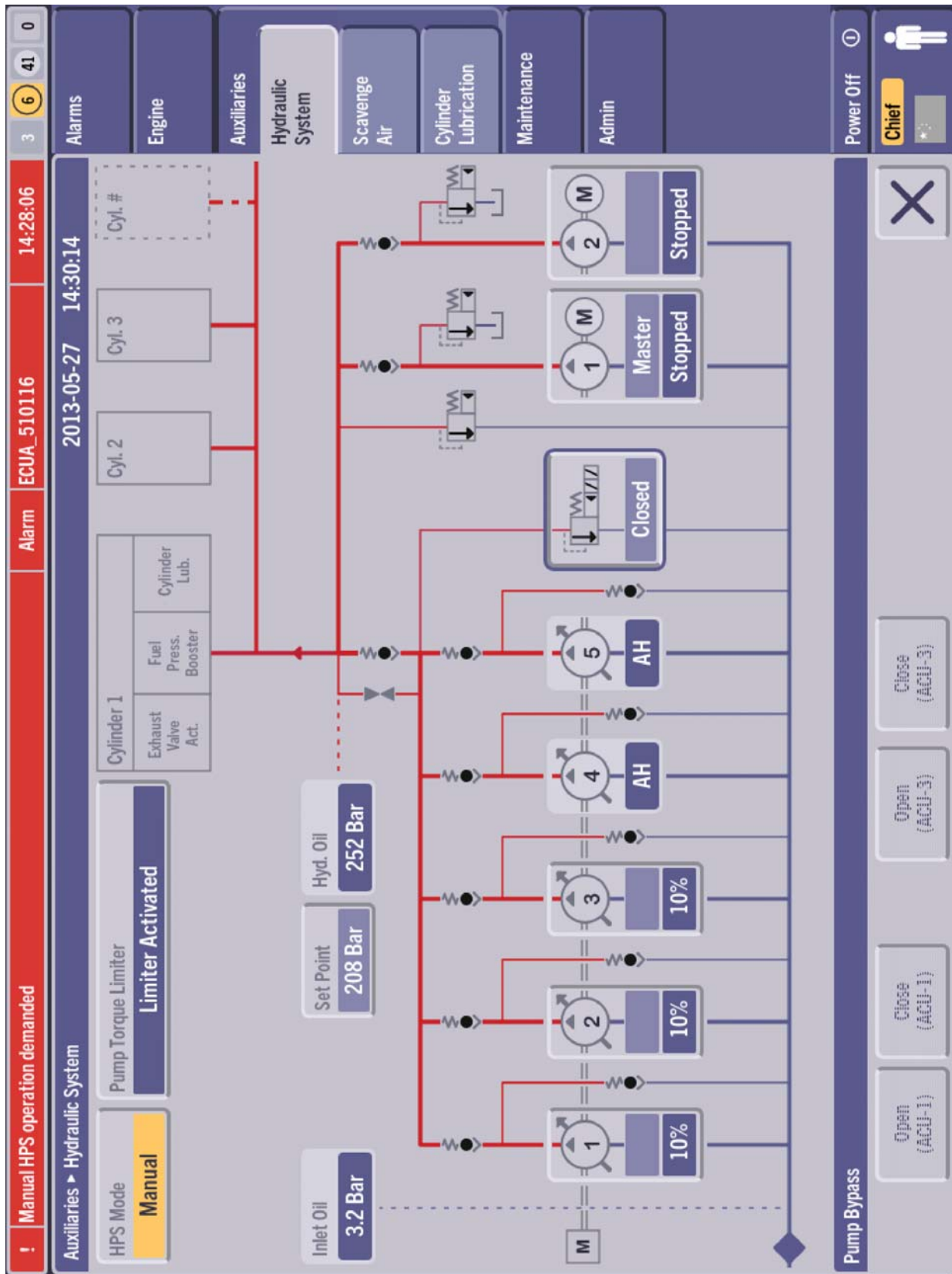




MOP Hydraulic System

Drawing
6655-0175-0005

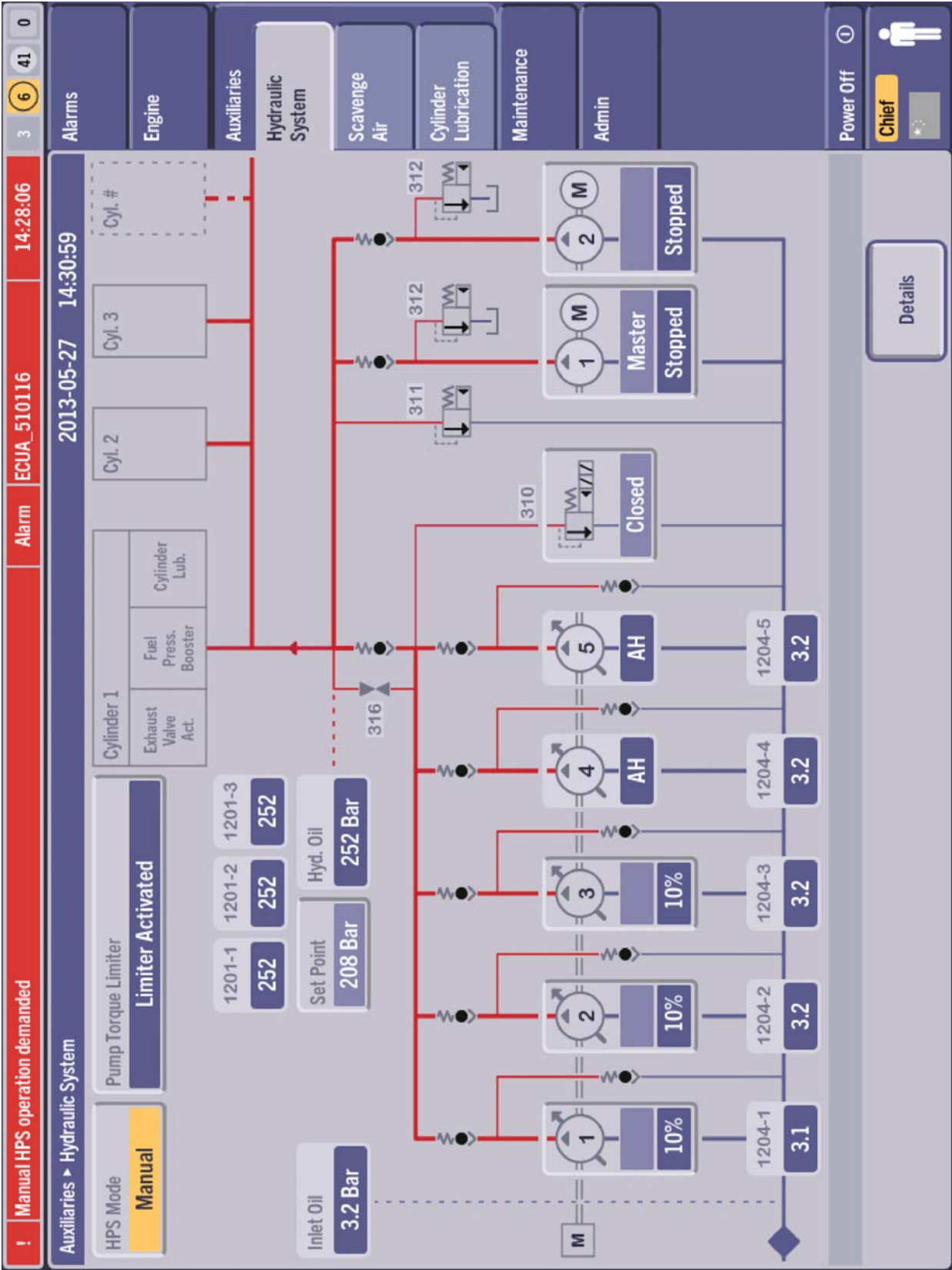


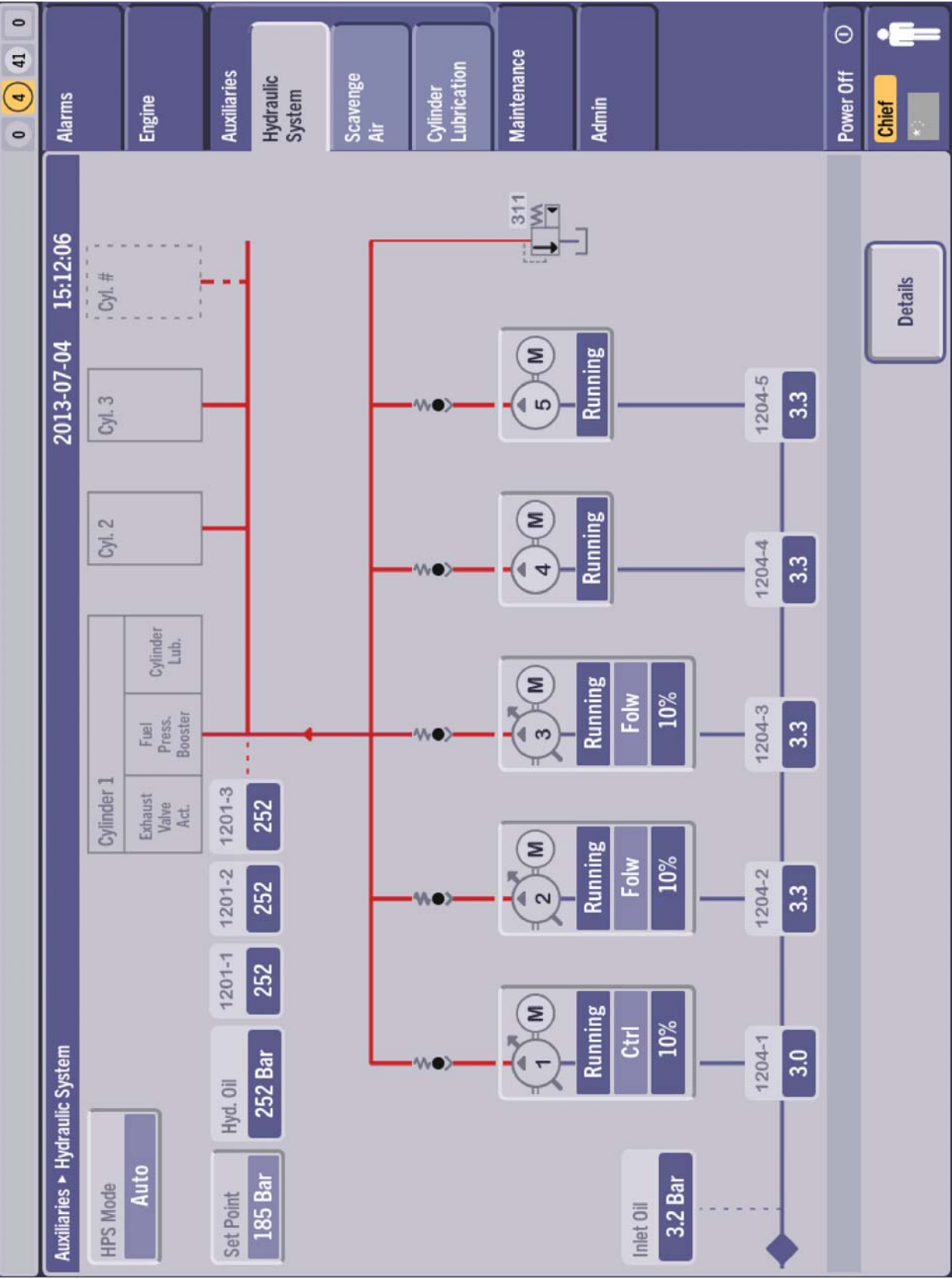


Drawing

6655-0175-0005

MOP Hydraulic System





MOP Hydraulic System

Drawing
6655-0175-0005

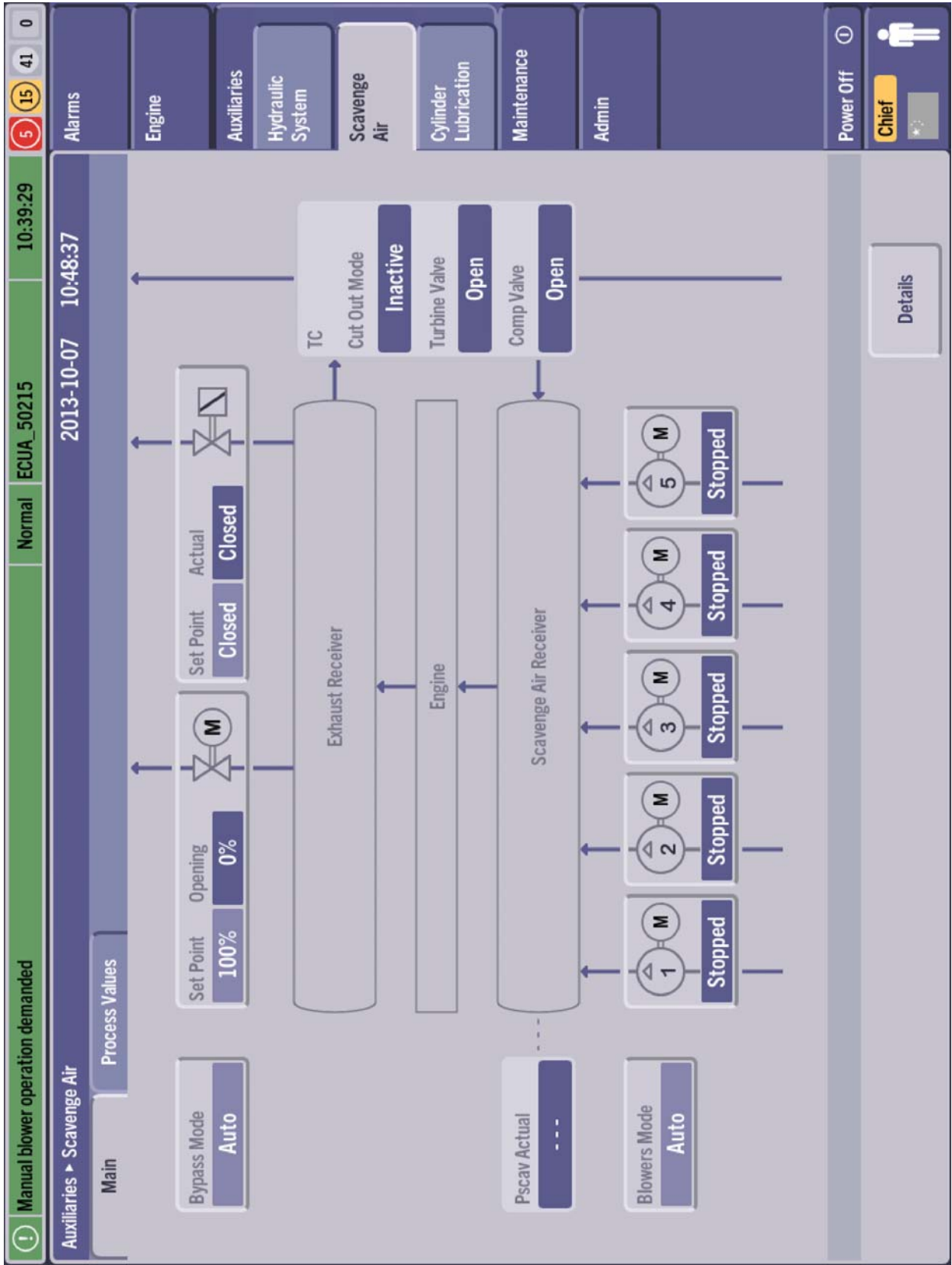


Figure 1:

MOP Scavenge Air

Drawing
6655-0180-0010

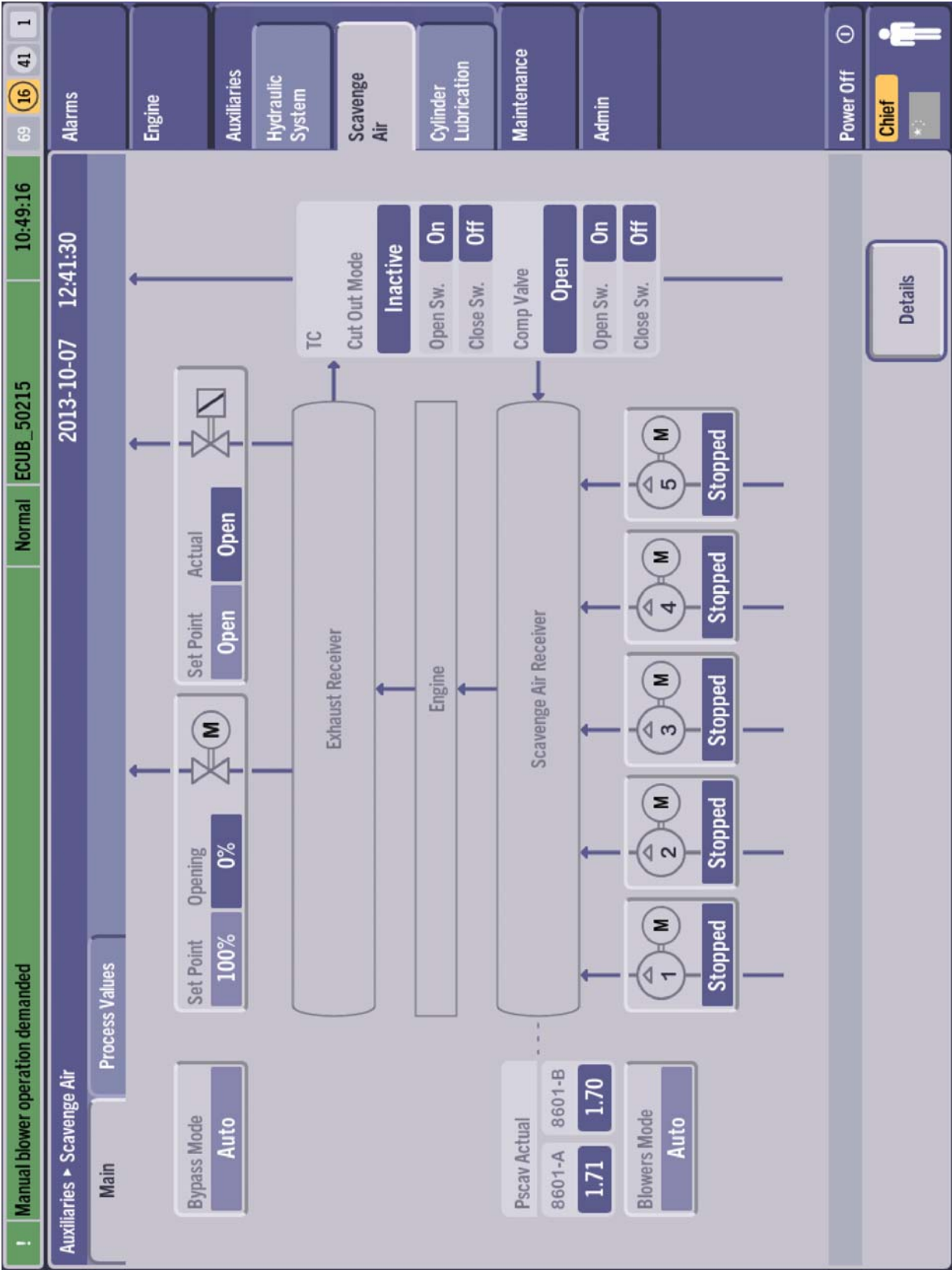
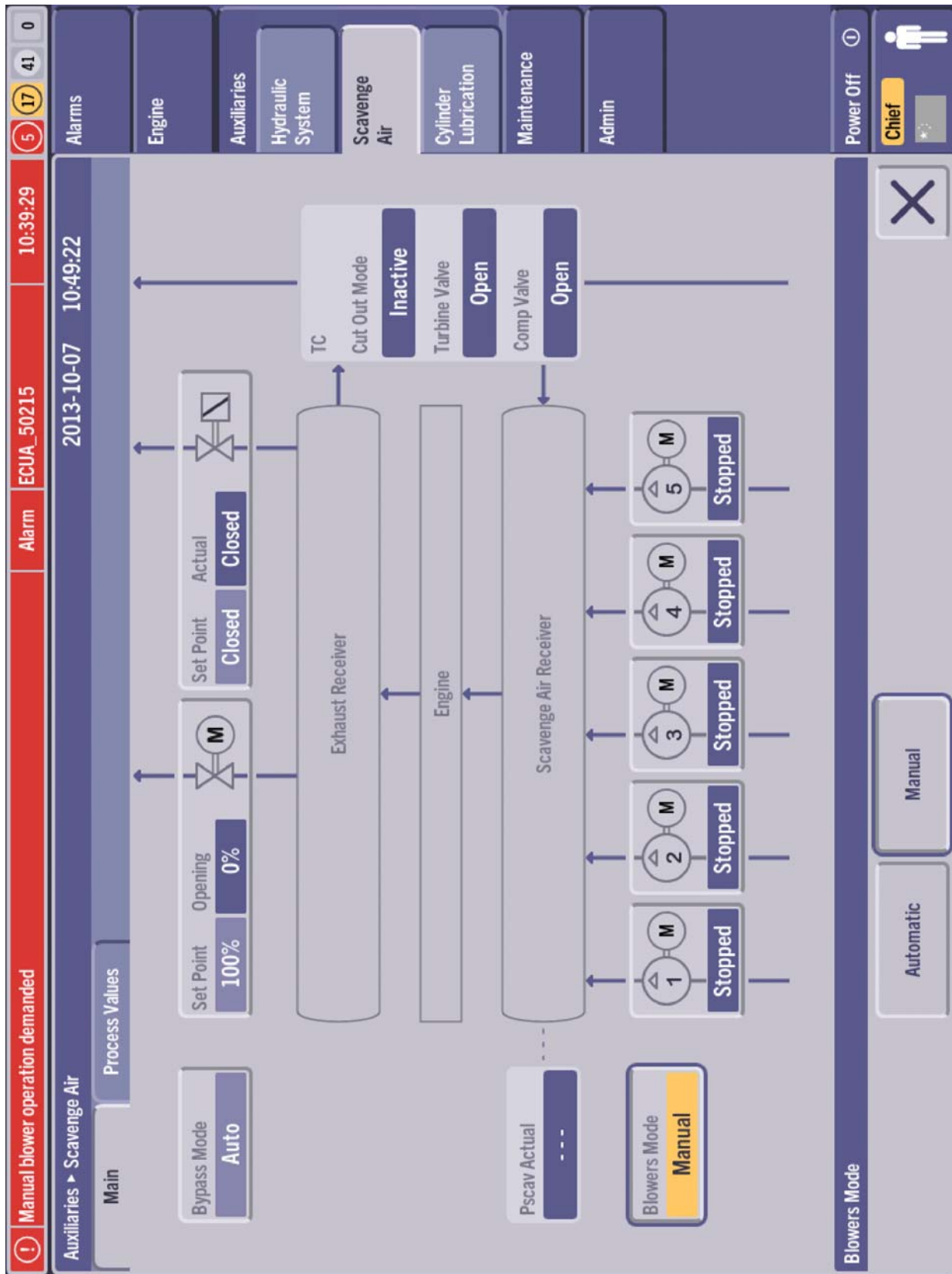


Figure 2:



MOP Scavenge Air

Drawing
6655-0180-0010

Figure 3:

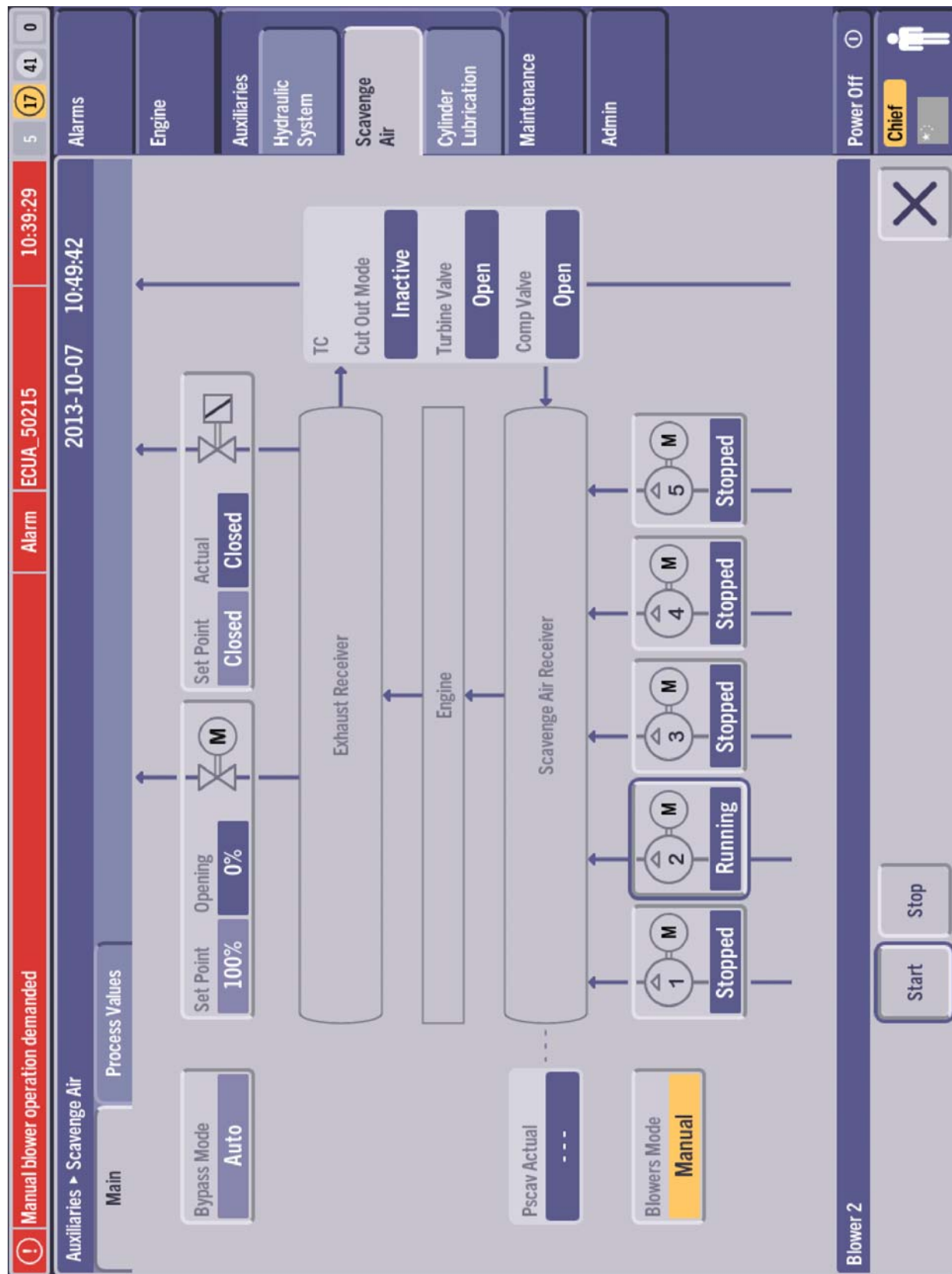


Figure 4:

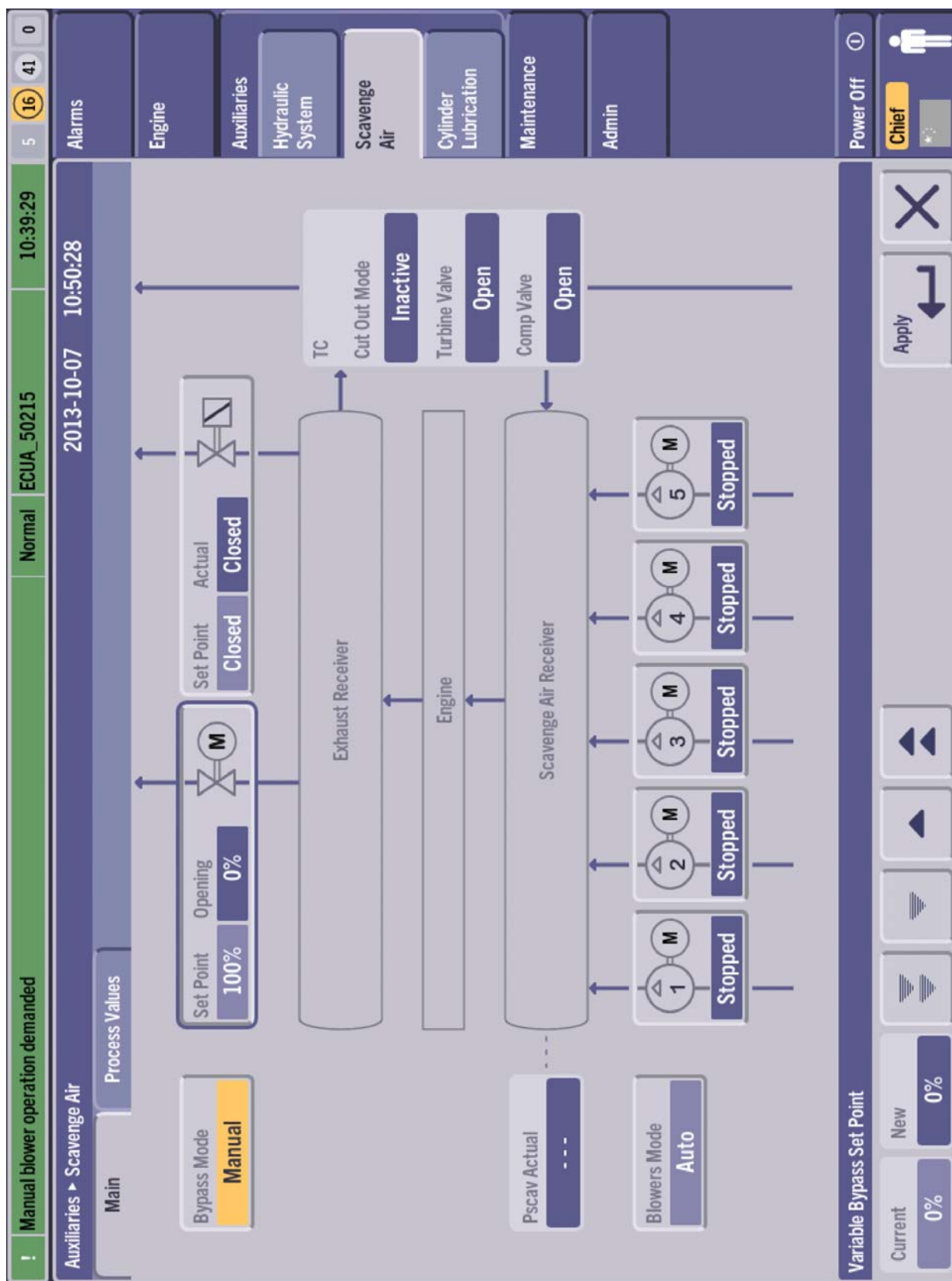


Figure 5:

Drawing

6655-0180-0010

MOP Scavenge Air

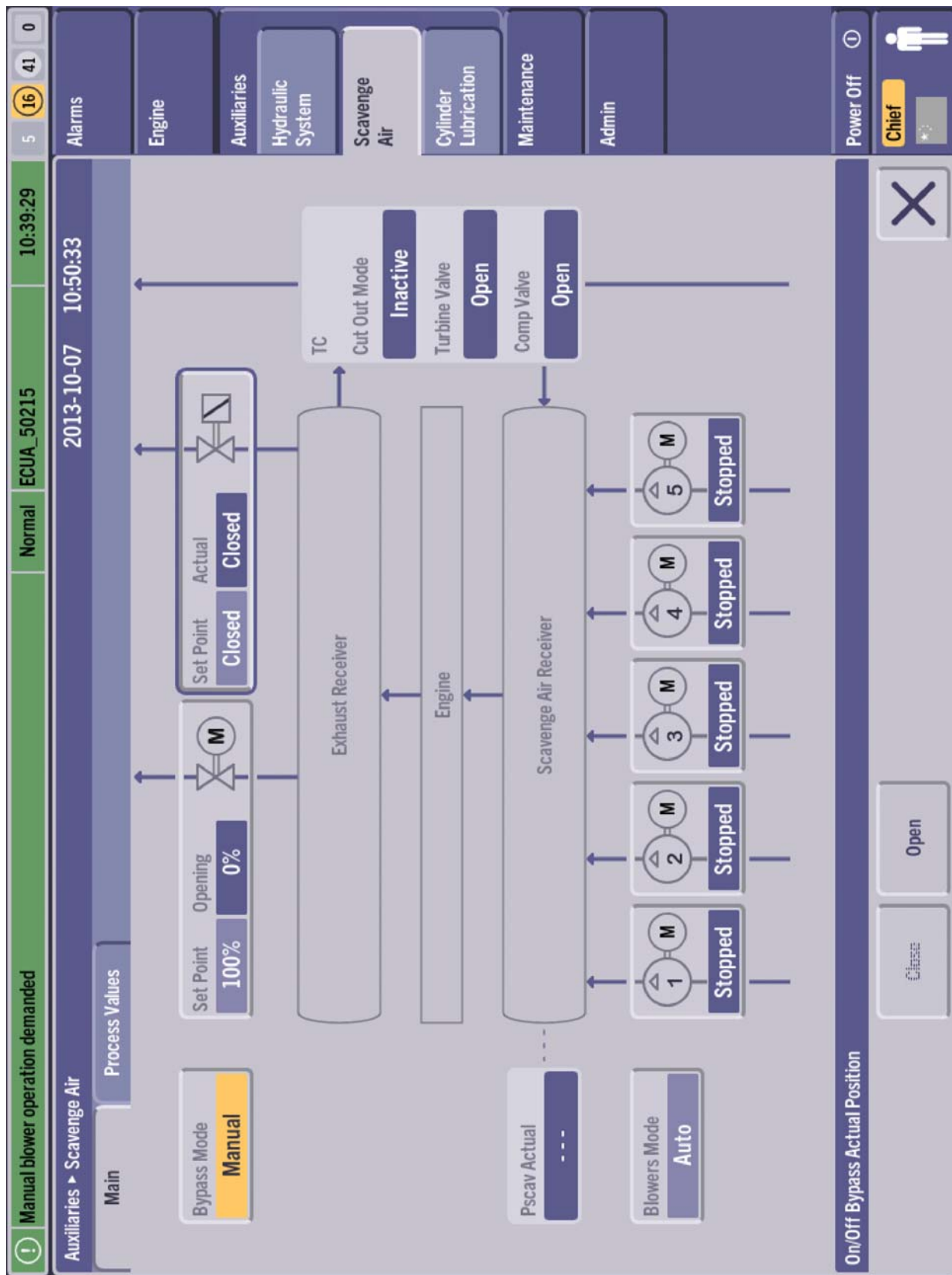


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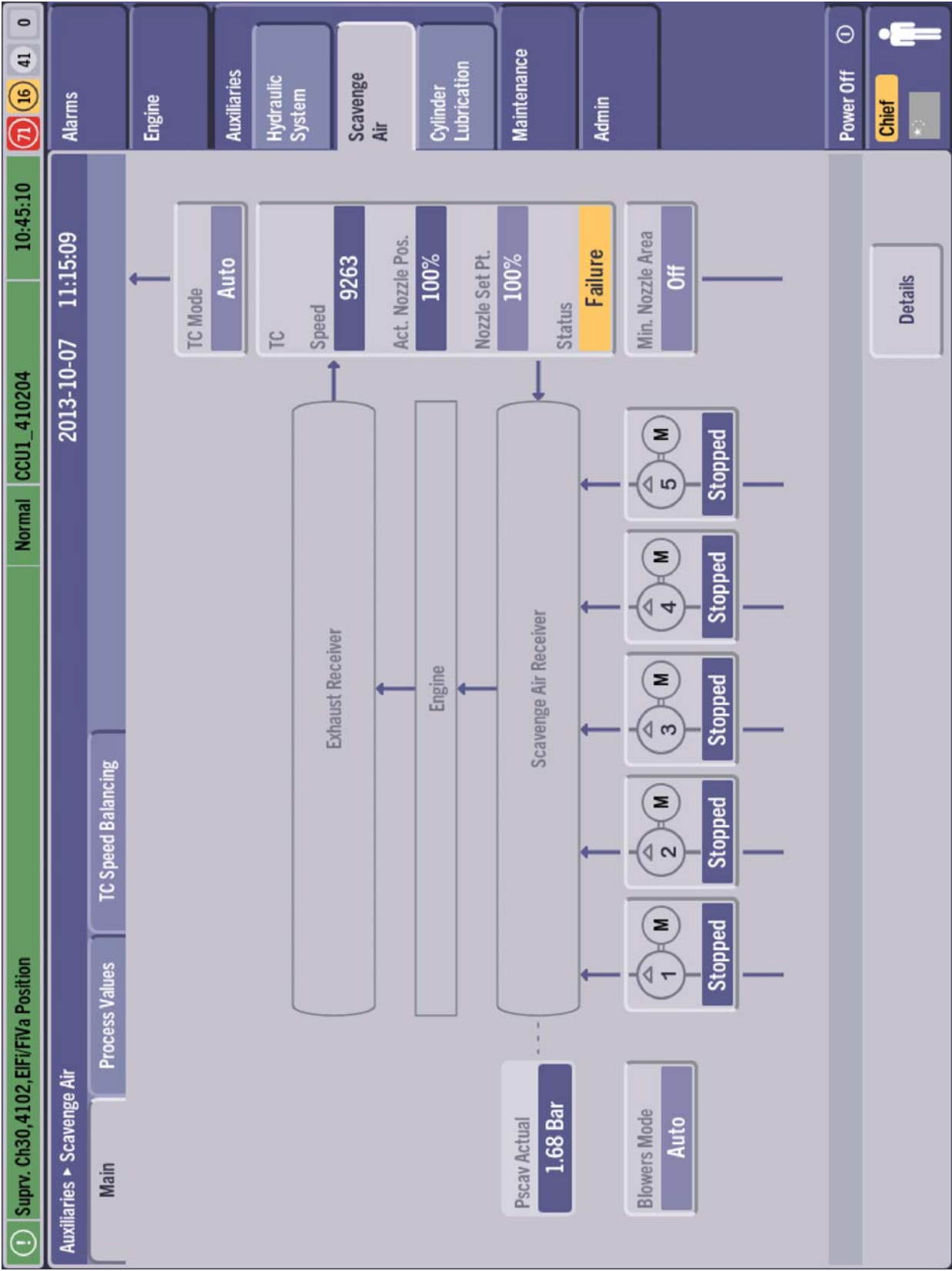


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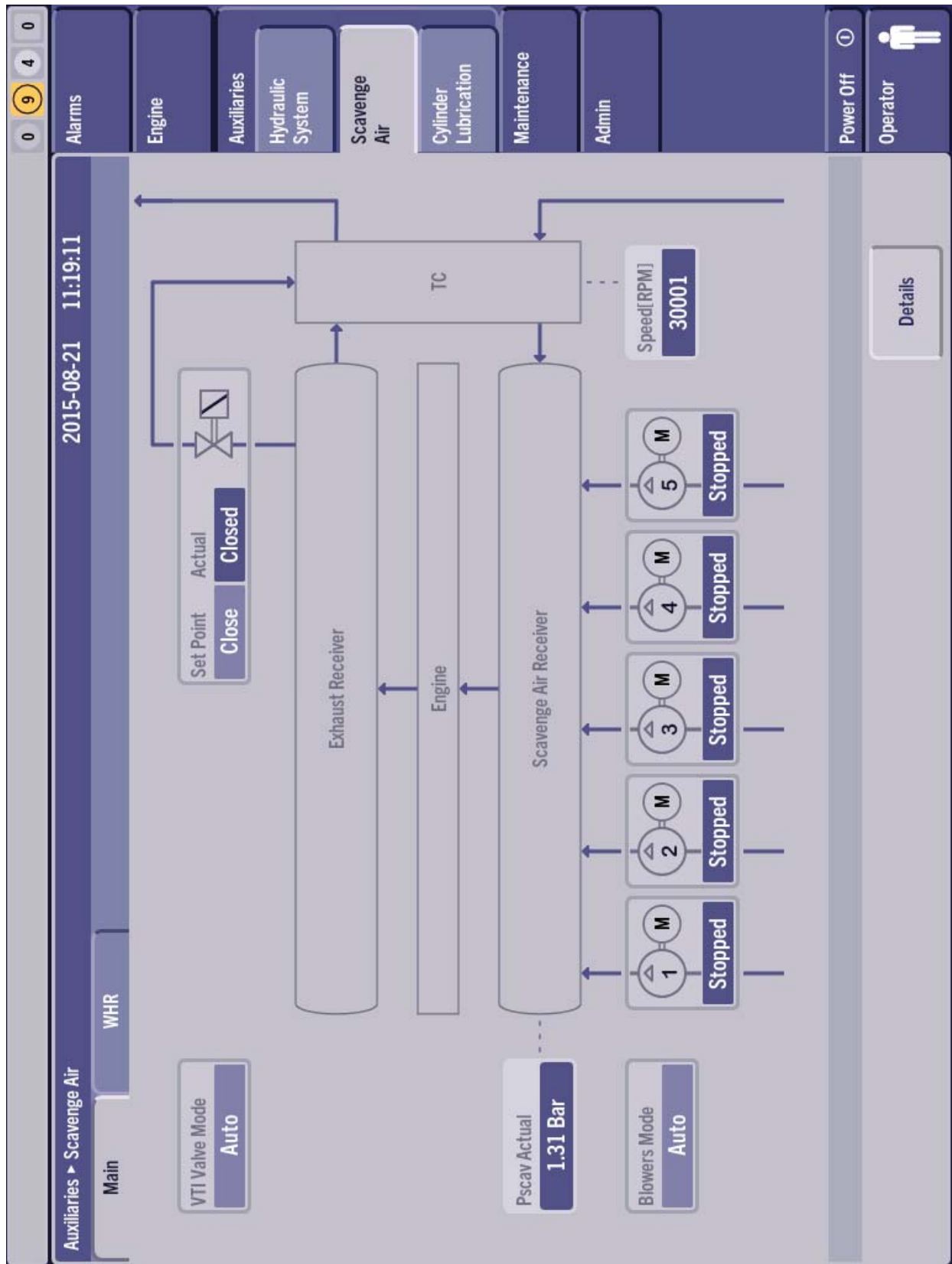
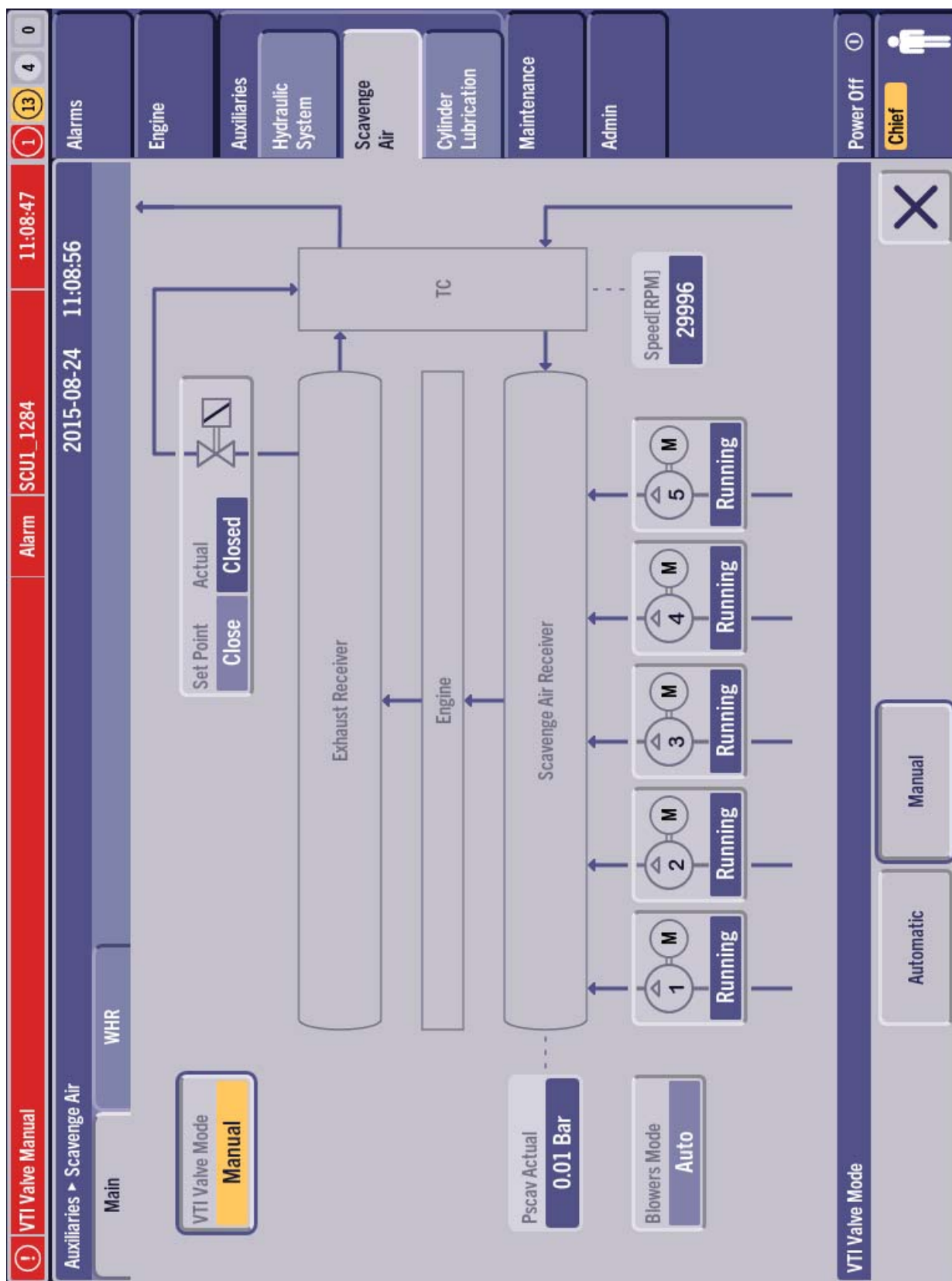


Figure 8:



MOP Scavenge Air

Drawing
6655-0180-0010

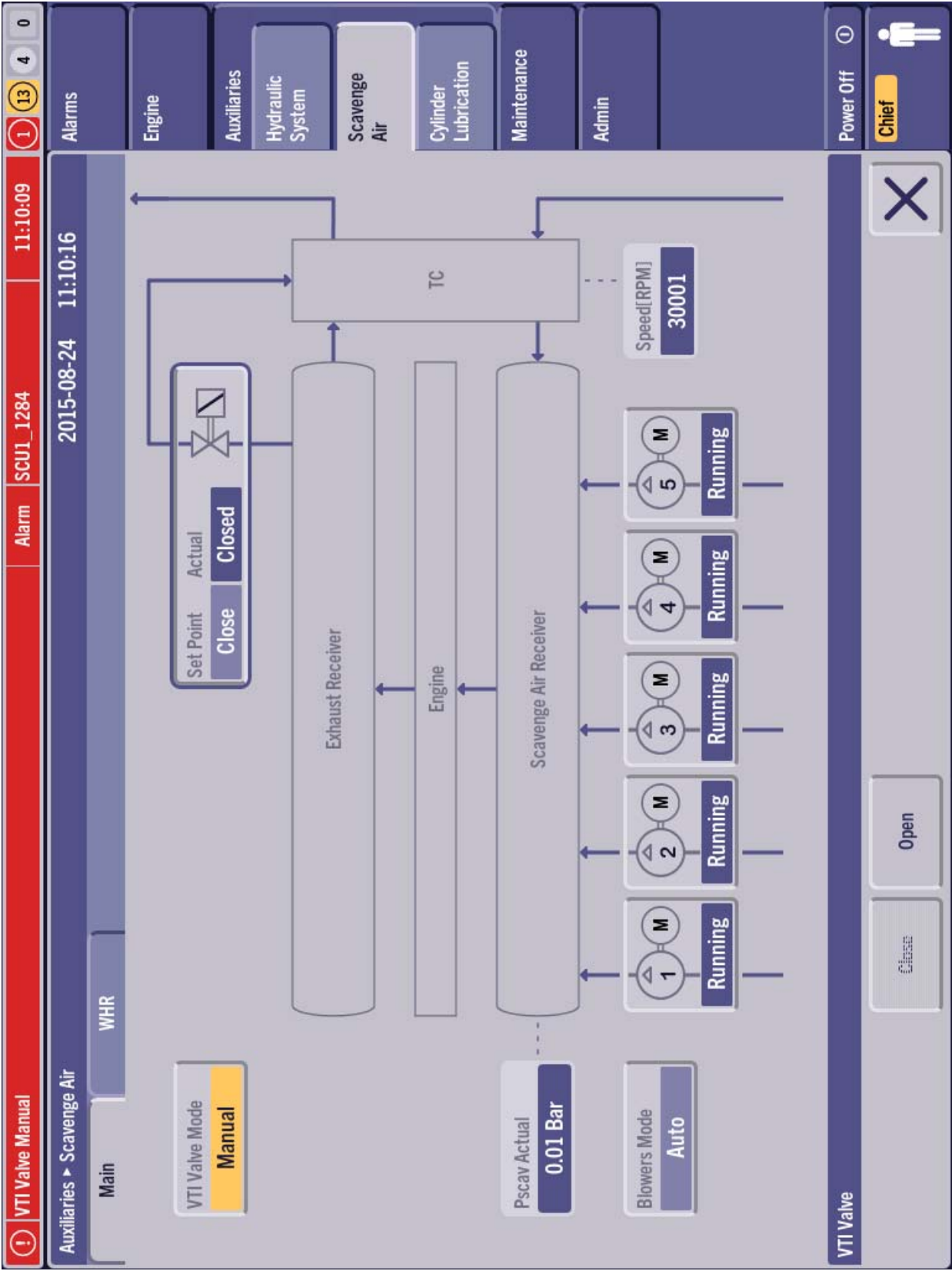


Figure 10:

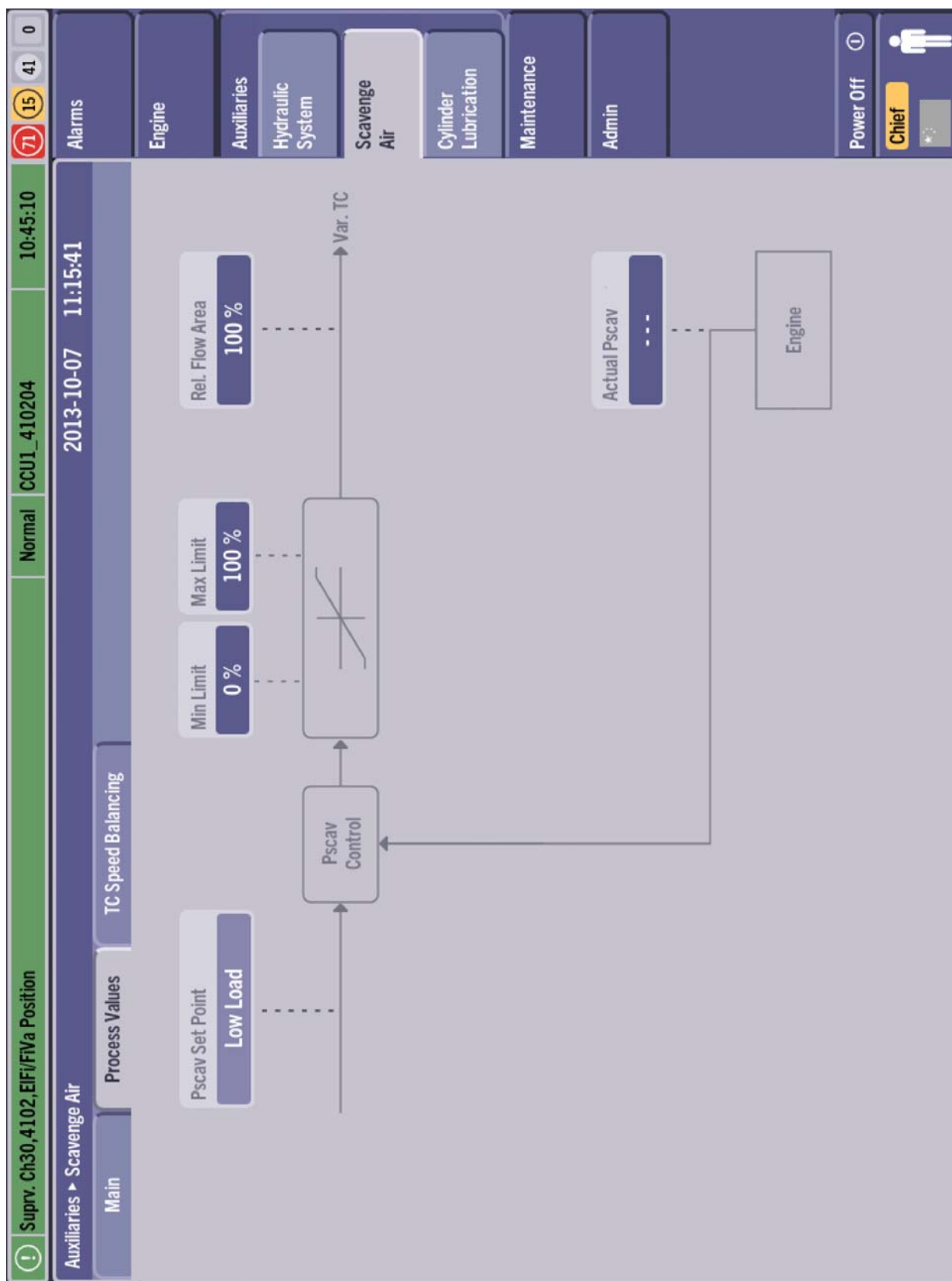


Figure 11:

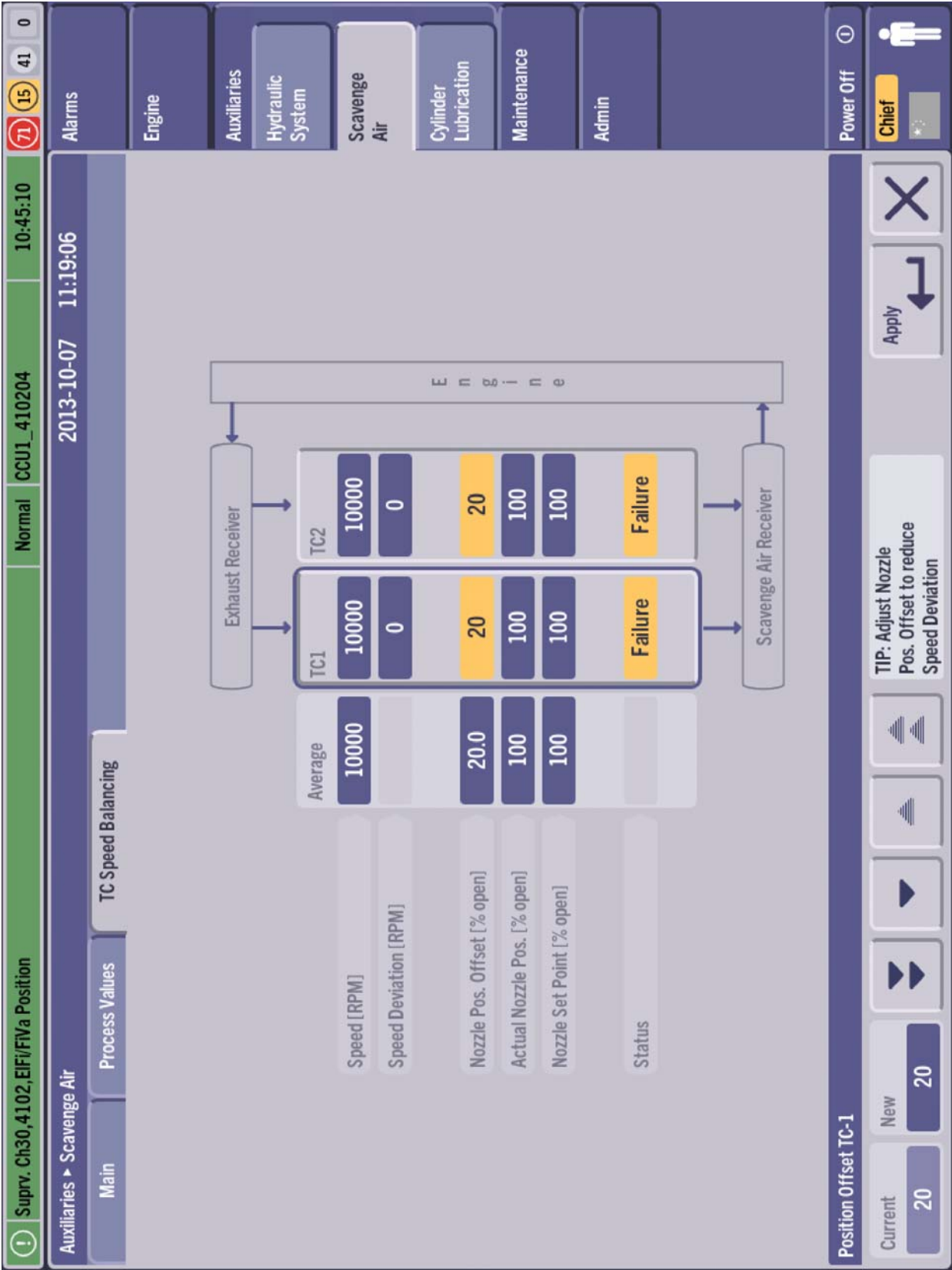


Figure 12:

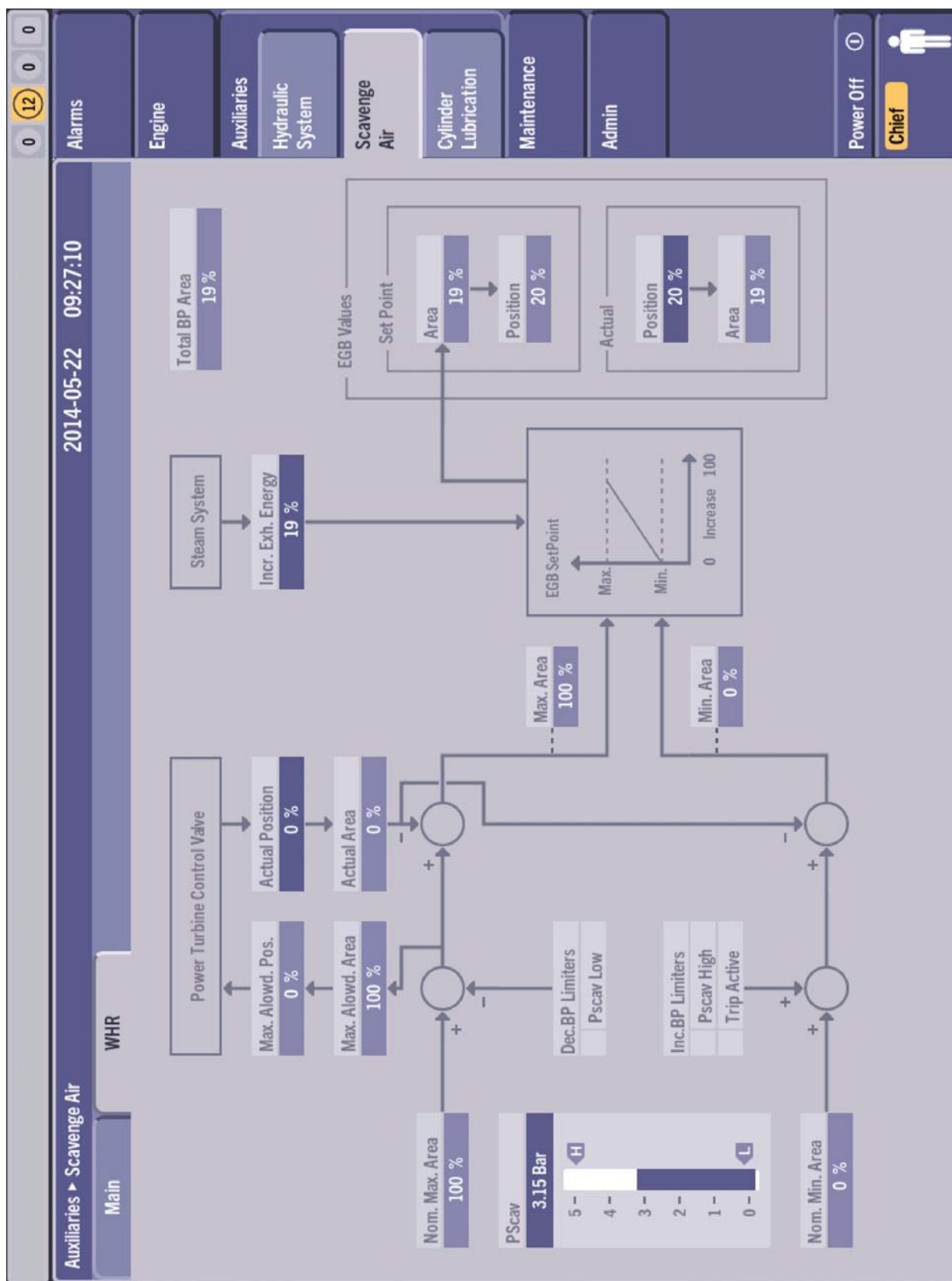


Figure 13:

MOP Scavenge Air

Drawing
6655-0180-0010

!

Suprv. Ch30,4102,EIF/FIVa Position

CCU1_410204

Normal

10:45:10

71

15

41

0

Alarms

Engine

Auxiliaries

Hydraulic System

Scavenge Air

Cylinder Lubrication

Maintenance

Admin

Power Off

Chief

Auxiliaries > Cylinder Lubrication

2013-10-07 11:19:46

Flow	40.9 l/h	Total	22 l	Prelube	Off	LCD	Off	S%	2.00	Brk. Pnt	40	Feed Rate Factor	0.20 g/kWhS%	Basic Feed Rate	0.60 g/kWh	Min. Feed Rate	0.60 g/kWh		
Actual Feed Rate [g/kWh]	1.4	1.2	1.0	0.8	0.6	0.4	0.2	1	2	3	4	5	6	7	8	9	10	11	12
Feed Rate Adjust Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
Running In [g/kWh]	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off		
Lubricator Test Sequence	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off		

Break Point

Current

New

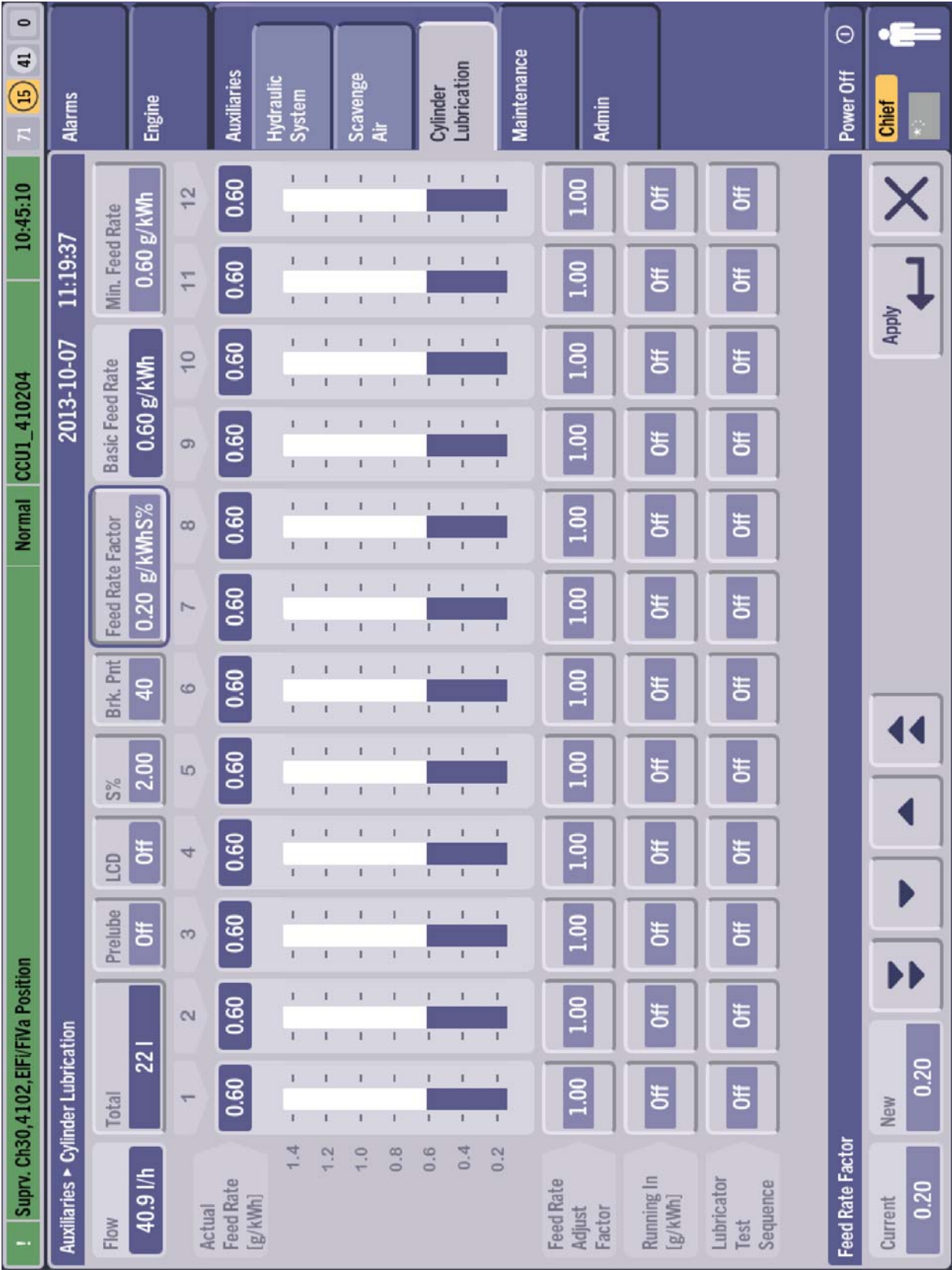
40

40

Apply

MOP Cylinder Lubrication

Drawing
6655-0185-0006



! Suprv. Ch30, 4102, EIF/FIVa Position CCU1_410204 Normal 10:45:10 71 15 41 0

Auxiliaries > Cylinder Lubrication 2013-10-07 11:19:43

Flow	Total	Pretube	LCD	S%	Brk. Pnt	Feed Rate Factor	Basic Feed Rate	Min. Feed Rate
40.9 l/h	22 l	Off	Off	2.00	40	0.20 g/kWhS%	0.60 g/kWh	0.60 g/kWh

Actual Feed Rate [g/kWh]	1	2	3	4	5	6	7	8	9	10	11	12
1.4	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
1.2	-	-	-	-	-	-	-	-	-	-	-	-
1.0	-	-	-	-	-	-	-	-	-	-	-	-
0.8	-	-	-	-	-	-	-	-	-	-	-	-
0.6	-	-	-	-	-	-	-	-	-	-	-	-
0.4	-	-	-	-	-	-	-	-	-	-	-	-
0.2	-	-	-	-	-	-	-	-	-	-	-	-

Feed Rate Adjust Factor	Running In [g/kWh]	Lubricator Test Sequence
1.00	Off	Off
1.00	Off	Off
1.00	Off	Off
1.00	Off	Off
1.00	Off	Off
1.00	Off	Off
1.00	Off	Off
1.00	Off	Off
1.00	Off	Off
1.00	Off	Off
1.00	Off	Off
1.00	Off	Off

Feed Rate Adjust Factor - Cyl.1

Current 1.00 New 1.00

Apply

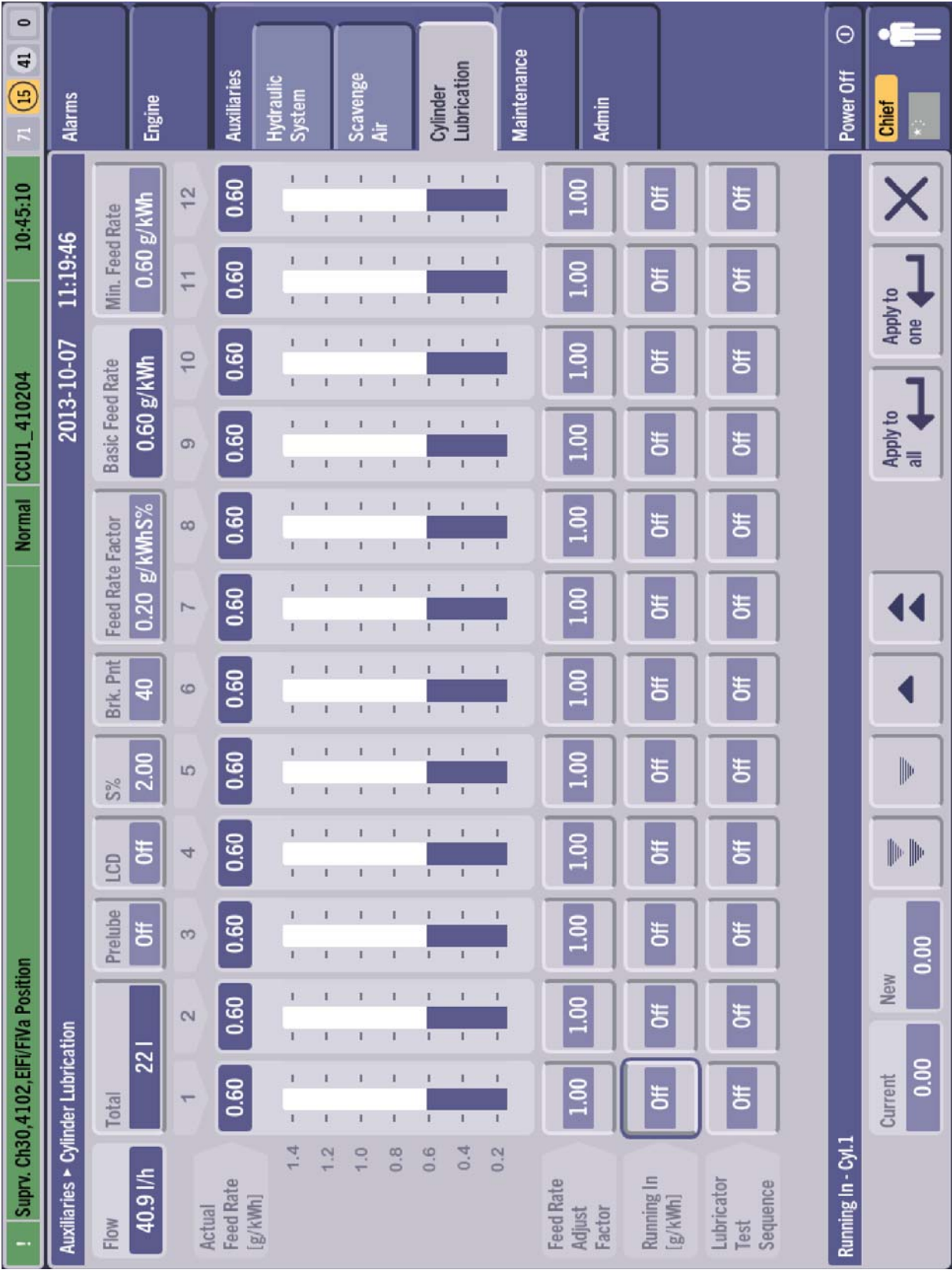
Power Off

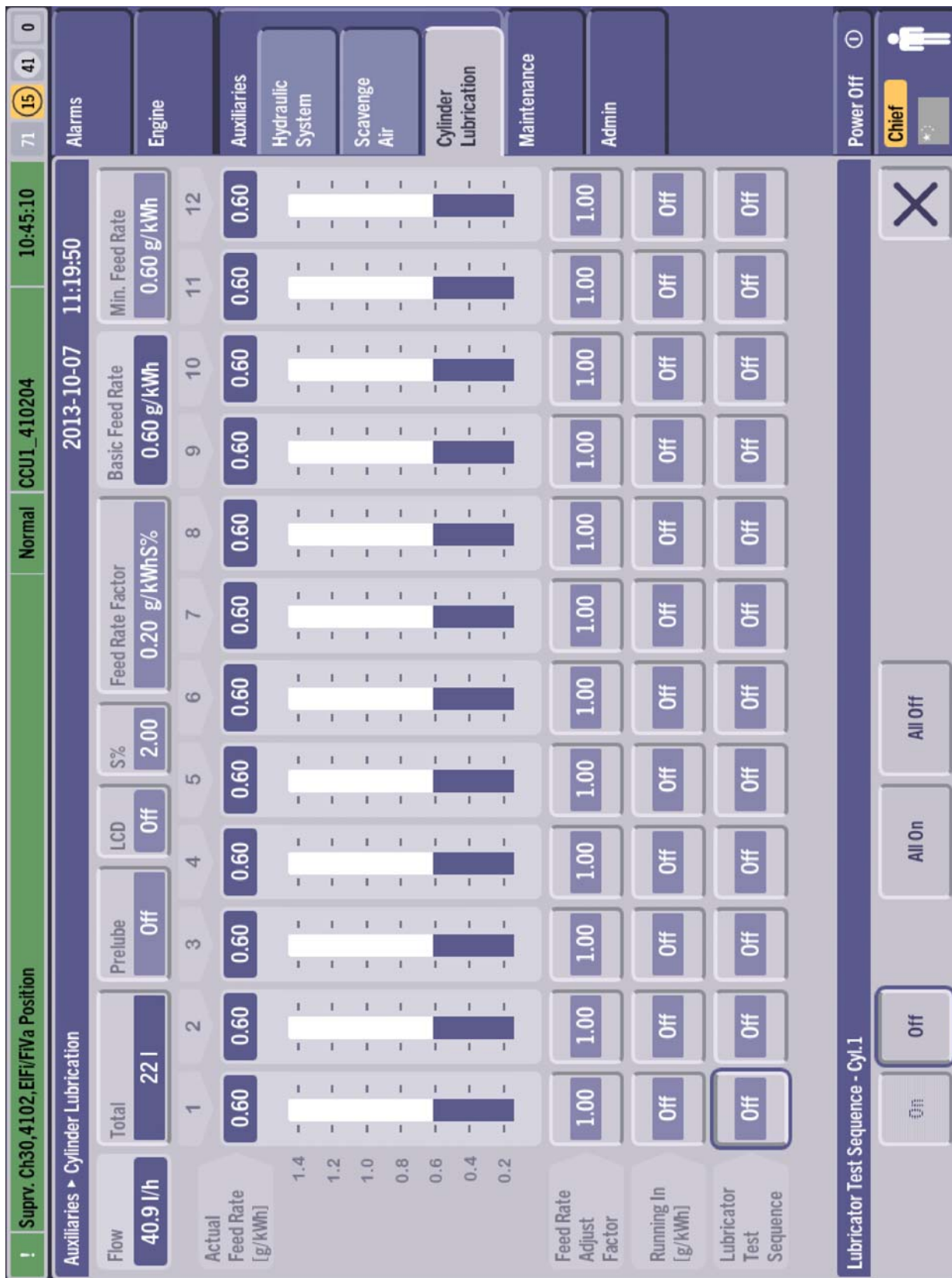
Chief

MOP Cylinder Lubrication

Drawing

6655-0185-0006





MOP Cylinder Lubrication

Drawing
6655-0185-0006

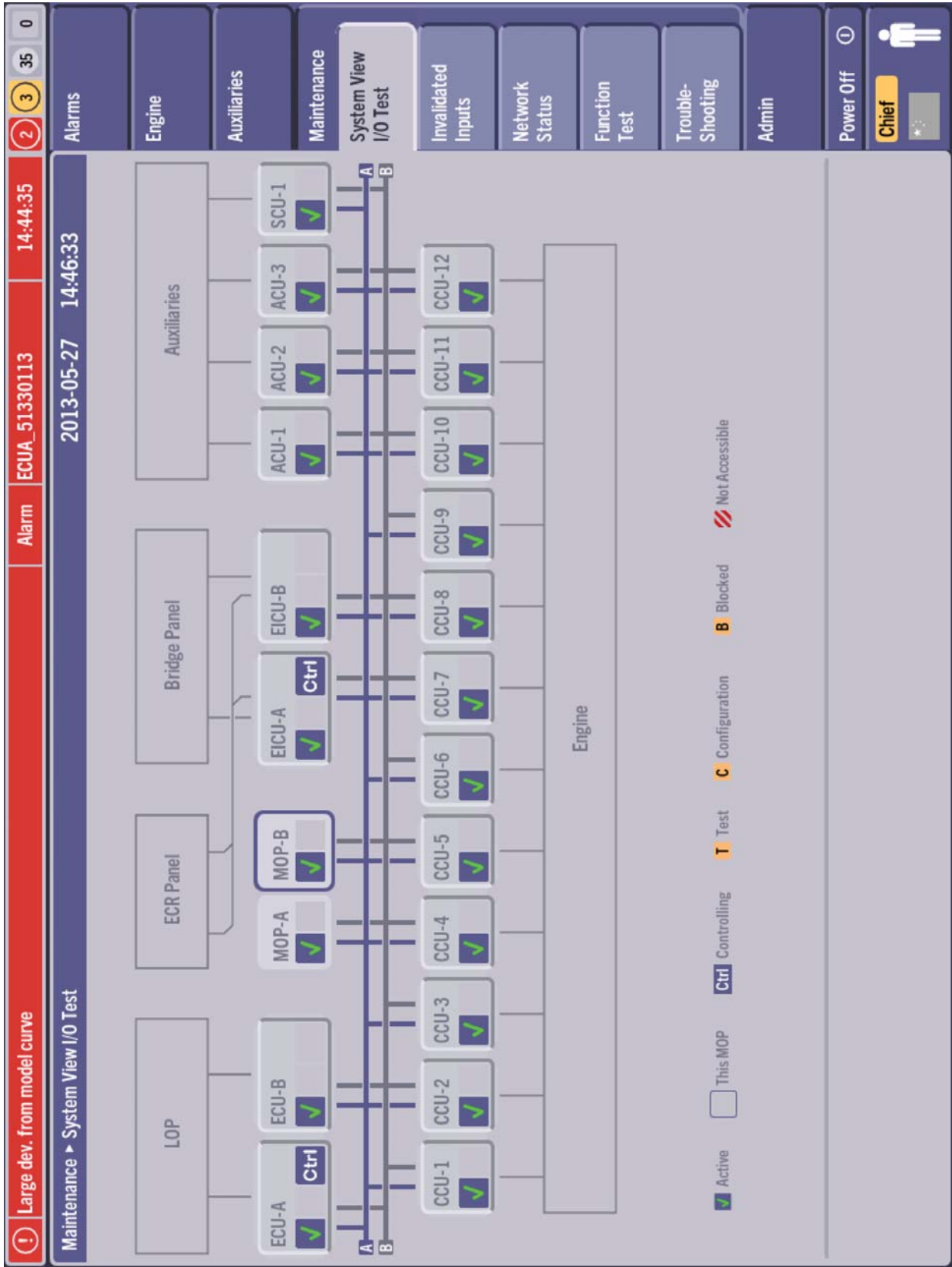


Figure 1:

MOP System View I/O Test

Drawing
6655-0190-0007

Start air press. sensor deviation

Normal

ECUB_50321

04:57:56

2

22

28

0

Maintenance ▶ System View I/O Test

ACU-1

Mode

Normal

Type

MPC

Analog Input

Analog Output

Digital Input

Digital Output

Invalidated

Alarm

N/A

Not available

×

Engine

Auxiliaries

Maintenance

System View I/O Test

Invalidated Inputs

Network Status

Function Test

Trouble-Shooting

Admin

Power Off

Chief

#	Info	ID	Description	Process Value	#	Info	ID	Description	Process Value
21	D	1111-A	Main start valve blocke	OFF	50	D	2107-A	Start Failure	OFF
22	D	1110-A	Turning gear engaged	OFF	51	D	1264-A	Aux. Blowers Warning	OFF
23	D	1109-A	Turning gear disengaged	ON	52	D	1263-A	Aux. Blowers Running	OFF
24	D	1112-A	Main start valve in ser	ON	53	D	2181-A	Turning gear disengaged	ON
25	D	1116-A	Start air dist In Servi	ON	60	D	2108-A	Start Blocked	ON
26	D	2158-A	Lamp test for LOP	OFF	61	D	1210-1	Startup Pump Start/Stop	ON
27	D	1236	Hyd. leak shutdown level	OFF	70	A	1240-1I	Prop Valve SP	0.0 mA
30	A	1238-1	Prop. Valve Feedback	-89.4 %	71	A	1250	Hydraulic press. ECR (bar	0.42 -
31	A	1201-1	Hydraulic Pressure (bar	1.8 -	80	D	1202-A	System bypass open/clos	OFF
32	A	1204-1	Lube oil pressure (bar)	3.3 -	82	D	8620-1	Blower 1 Start/Stop	OFF
33	A	2904-1	ECS Insulation (kOhm)	0.0 -	83	D	2210-A	Engine Not Ready	ON
34	A	1222-1	Swash-Plate Position	-100.0 %	84	D	1170-A	Start air dist In Servi	ON
36	A	8503-A	Control air press. (bar	5.7 -	85	D	1171-A	Main Start valve In Ser	ON
37	A	8501-A	Starting air press. (ba	24.1 -					
40	D	8621-1	Blower 1 Remote op./Pow	ON					
41	D	8623-1	Blower 1 running	OFF					
44	D	1212-A	Remote op./Power	ON					
45	D	1213-A	Startup pump running	OFF					
47	D	ASUP	SupInp.System bypass open	ON					
49	D	2106-A	Load limitation	OFF					

Figure 2:

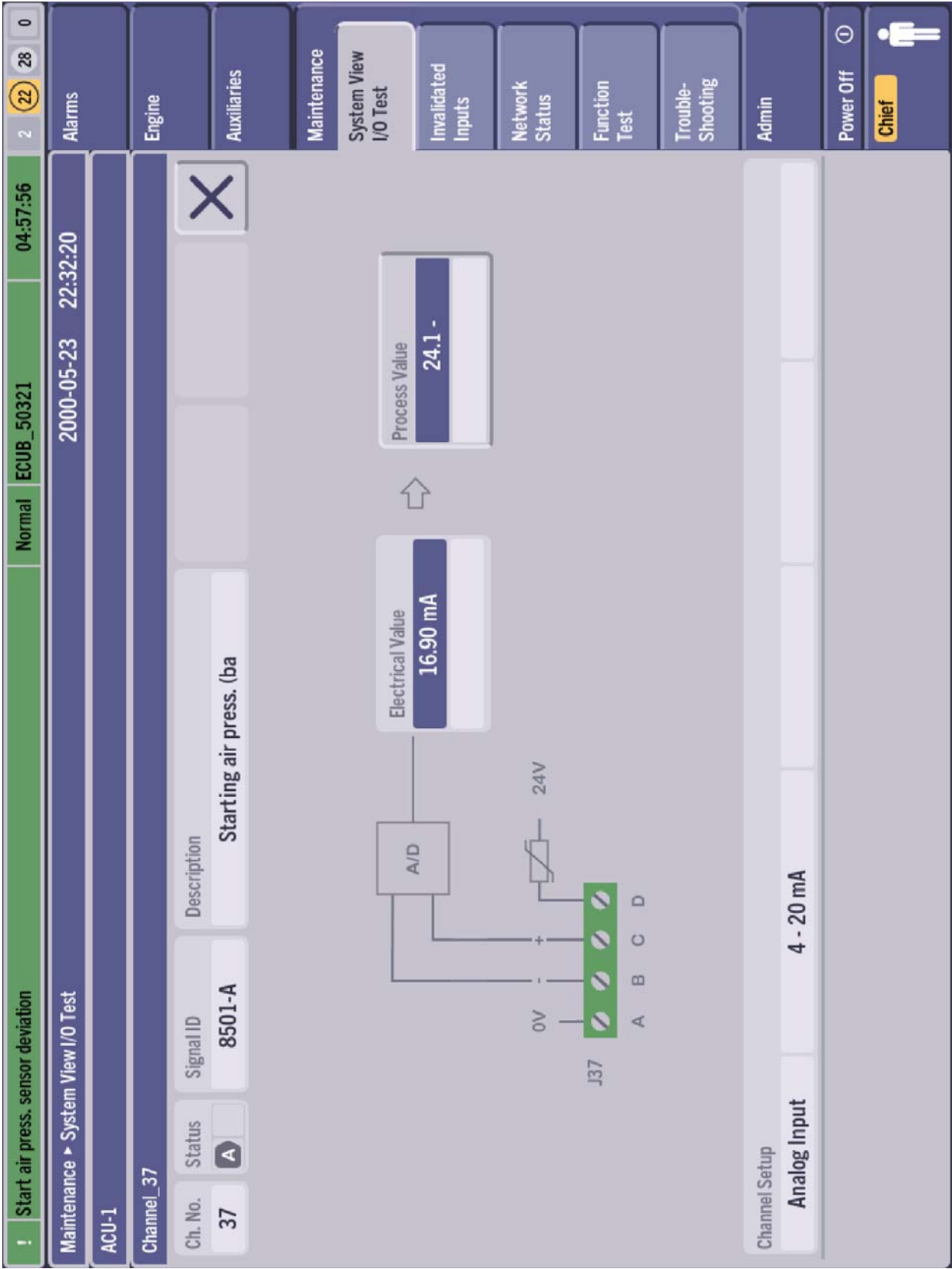


Figure 3:

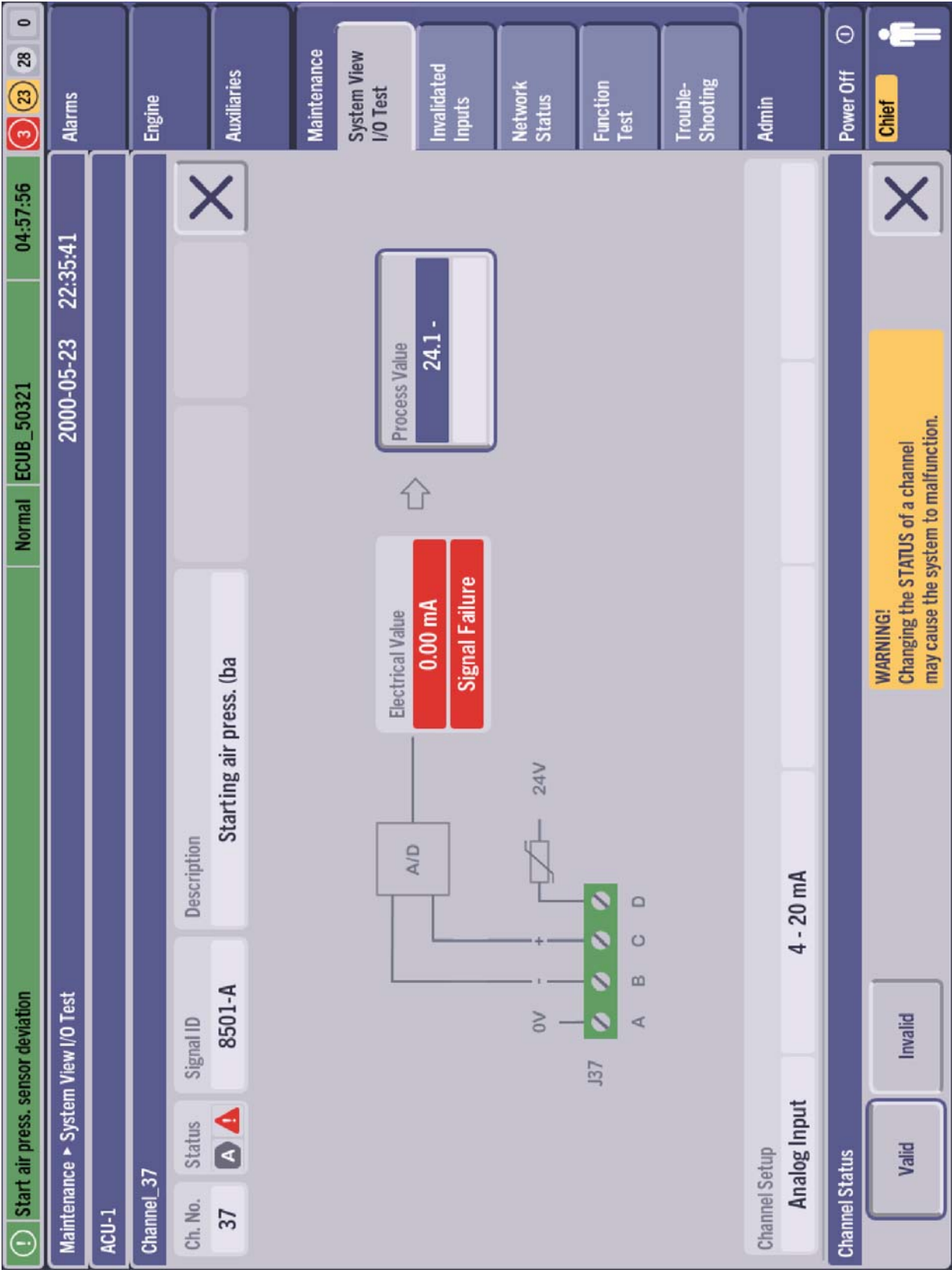


Figure 4:

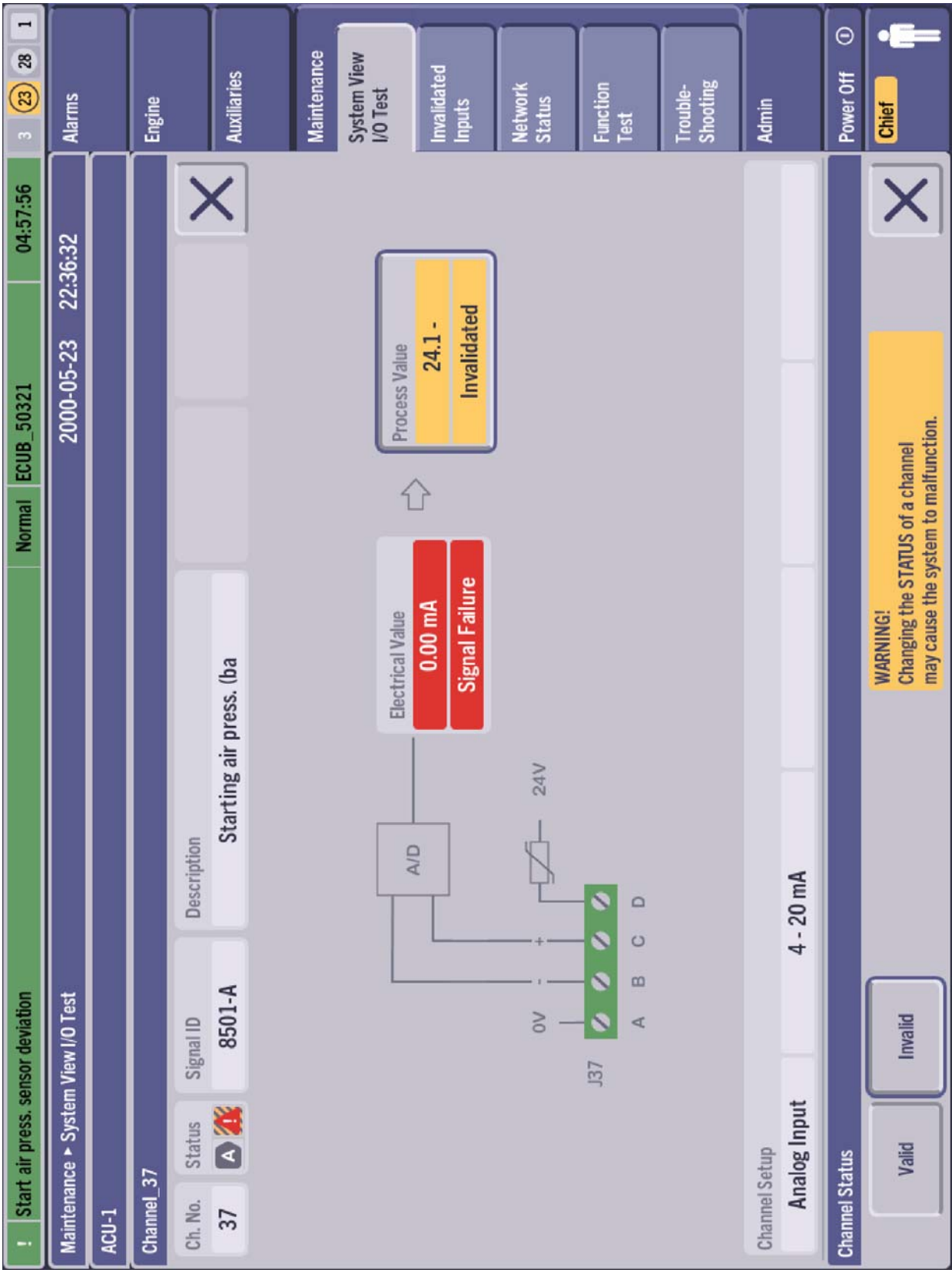
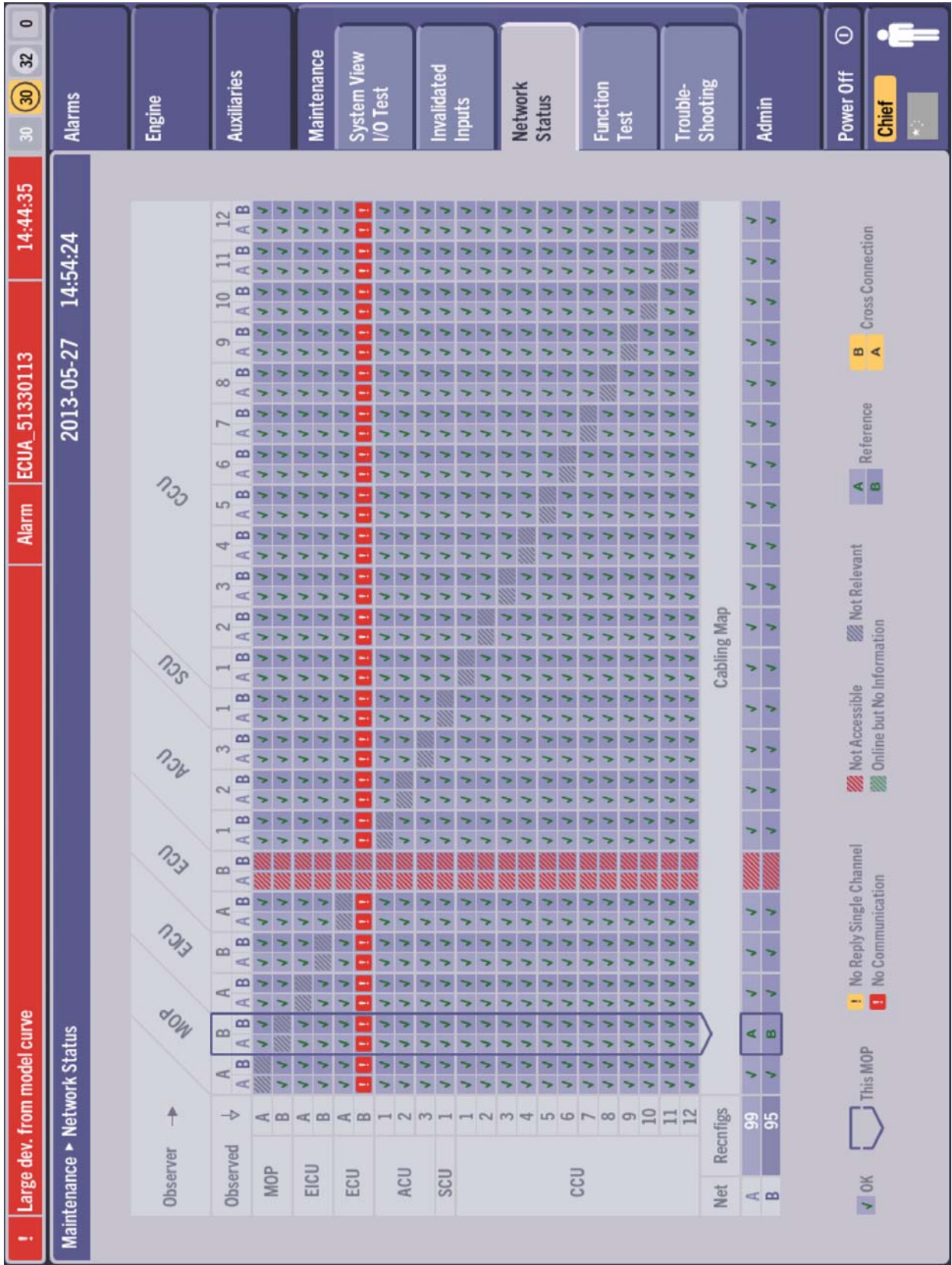


Figure 5:



MOP Network Status

Drawing
6655-0200-0006

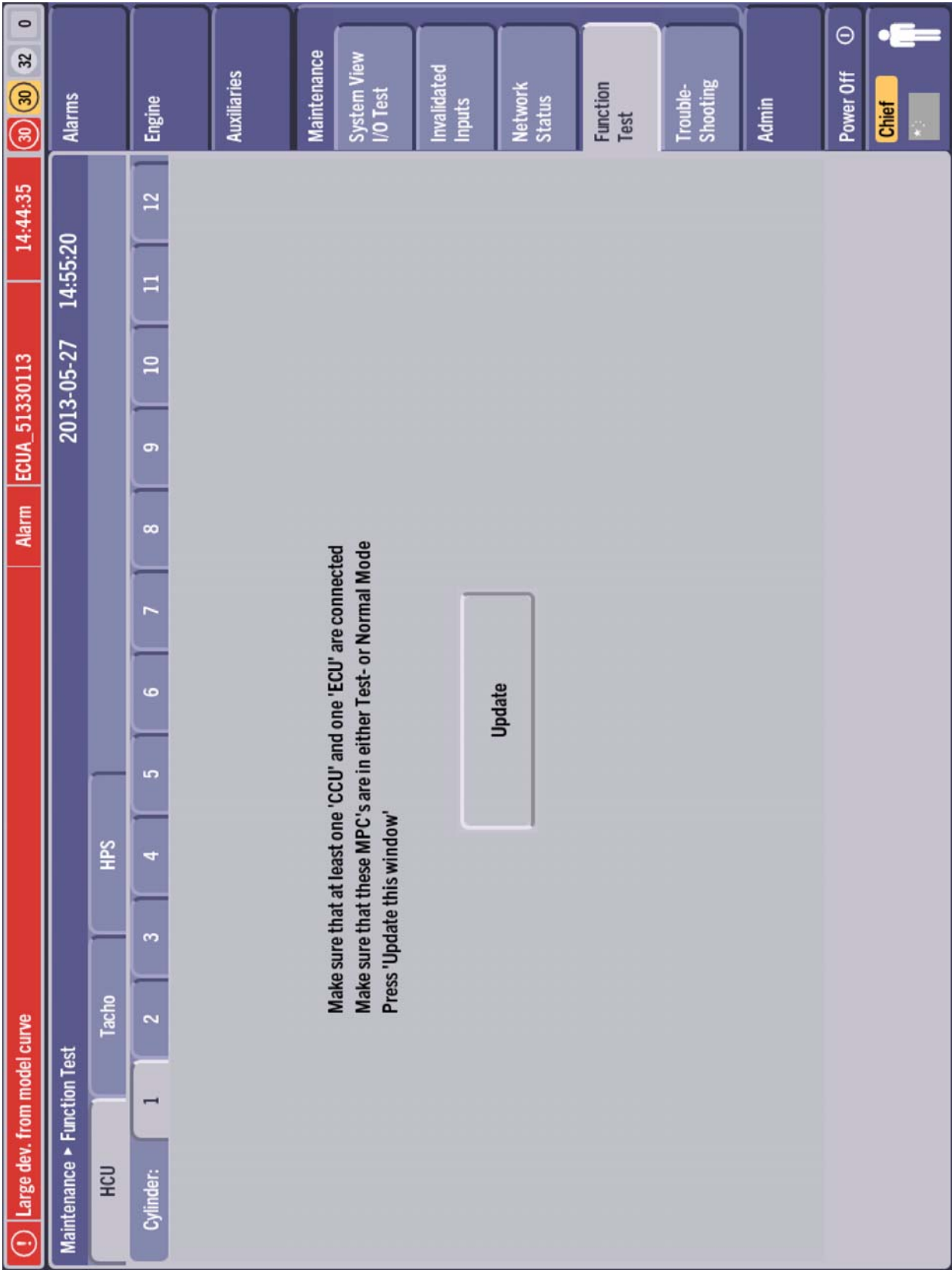


Figure 1:



Figure 2:

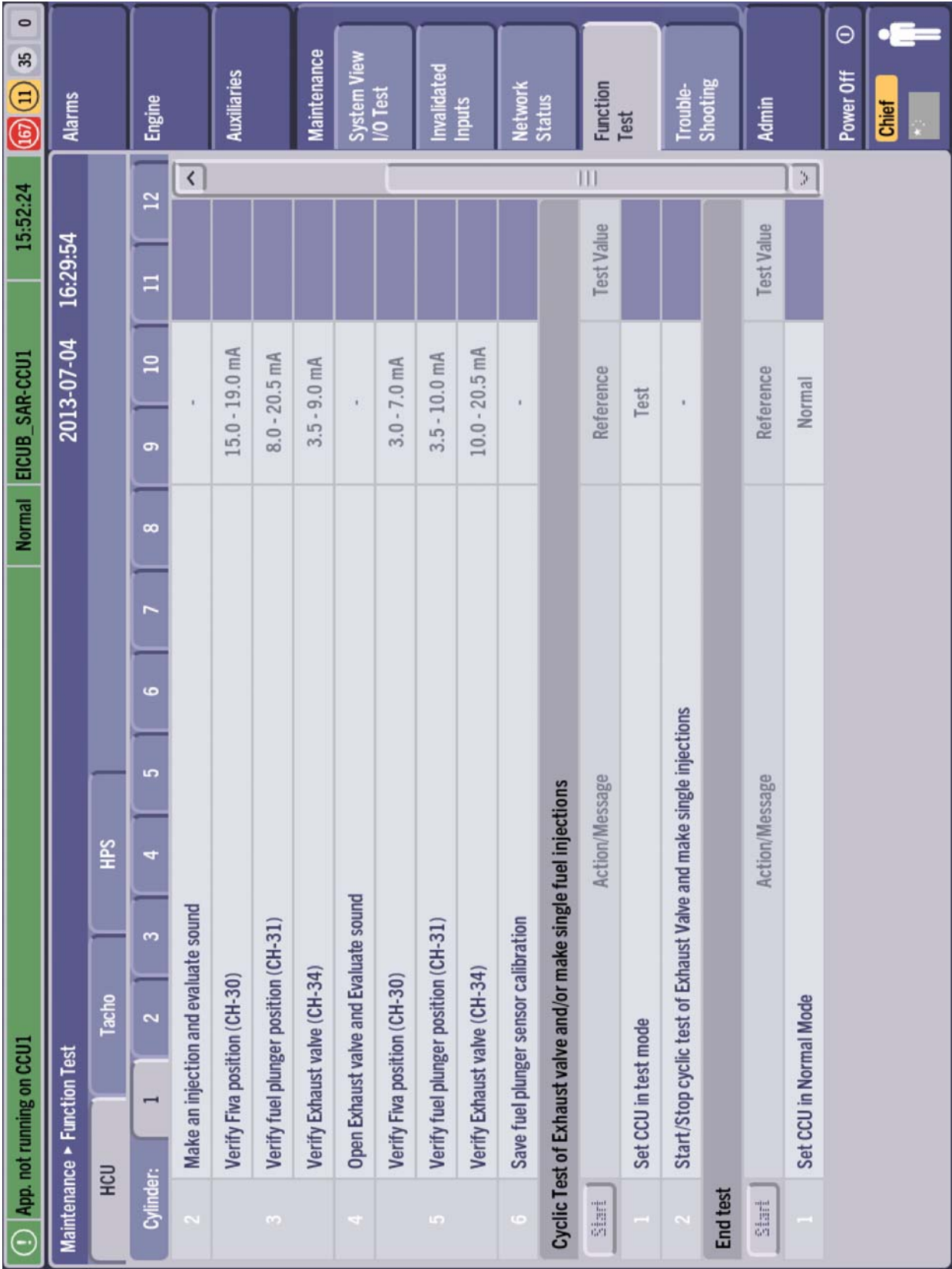


Figure 3:



Figure 4:

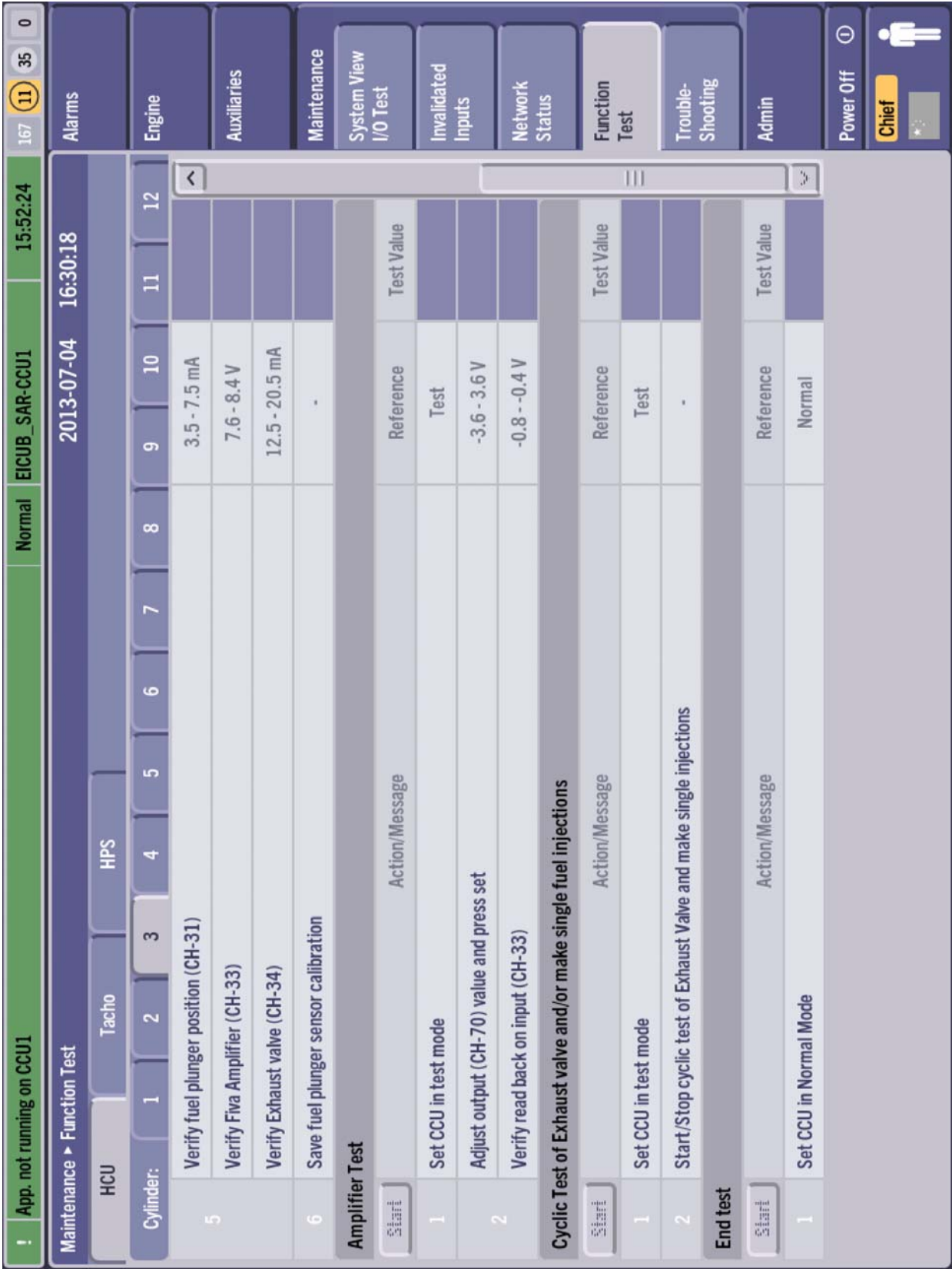


Figure 5:

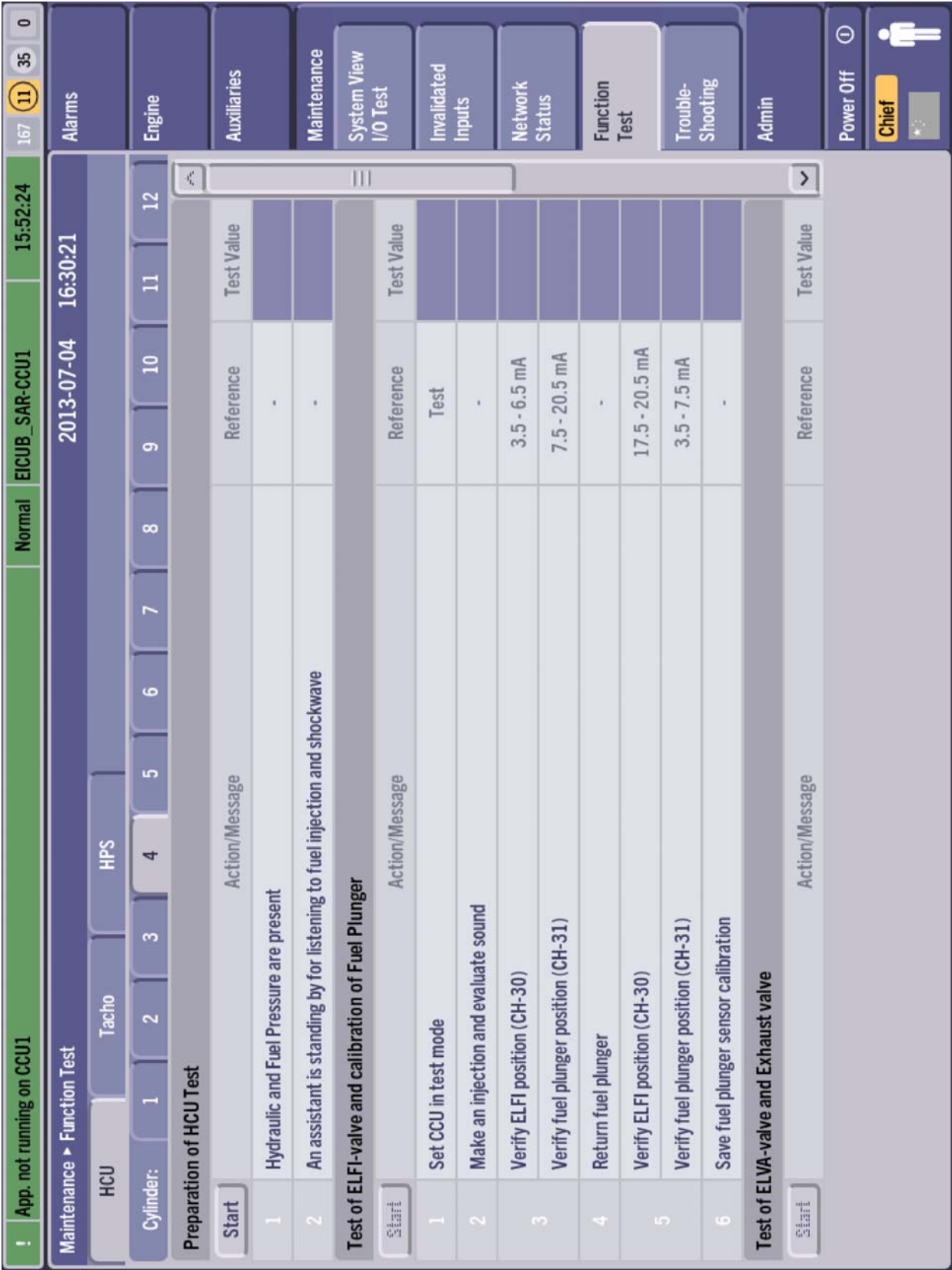


Figure 6:

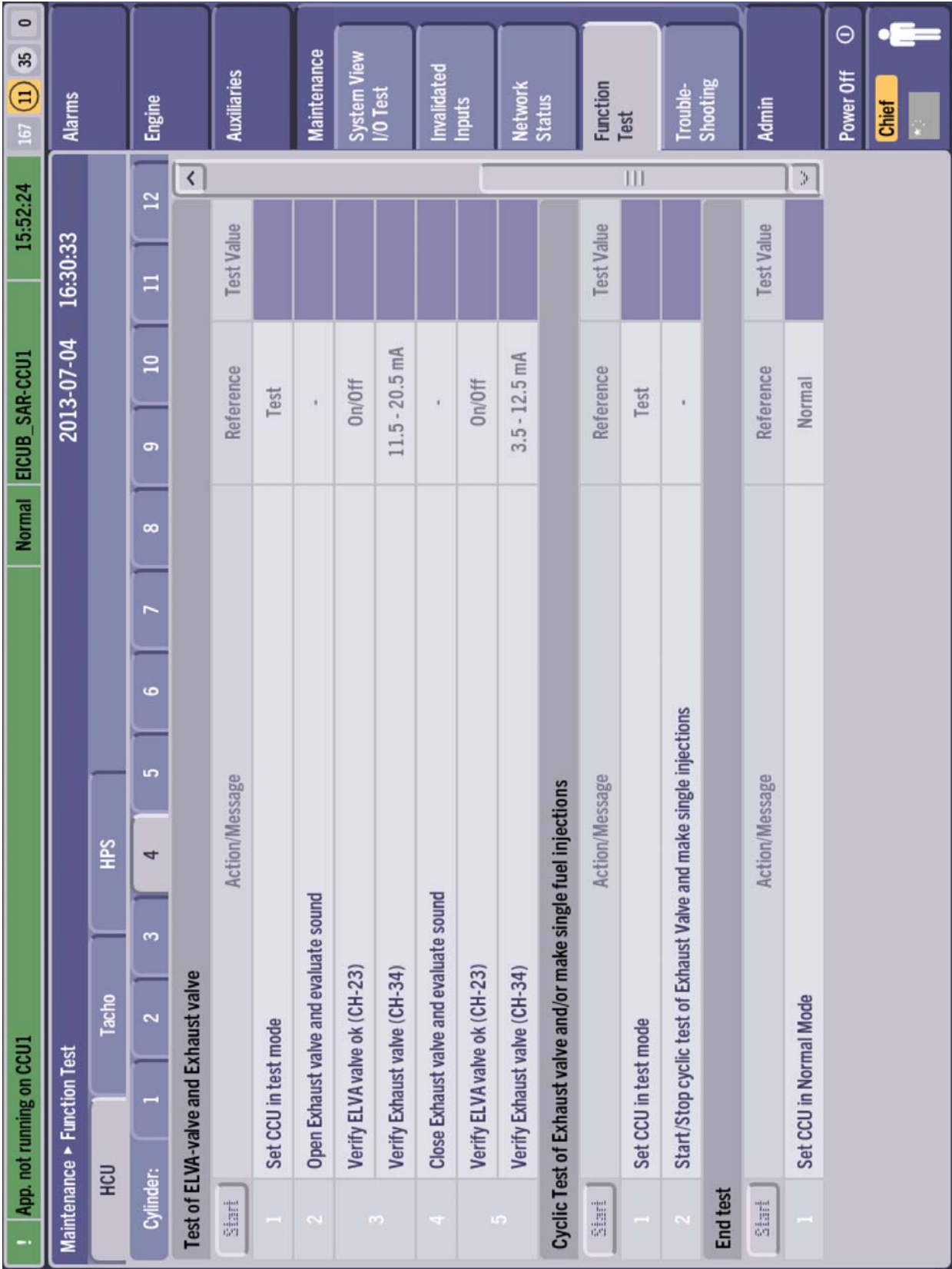


Figure 7:



! App. not running on CCU1 167 11 35 0

Maintenance ▶ Function Test 2013-07-04 16:31:05

HCU Tacho HPS

Cylinder: 1 2 3 4 5 6 7 8 9 10 11 12

Preparation of HCU Test

Start	Action/Message	Reference	Test Value
1	Hydraulic and Fuel Pressure are present	-	
2	An assistant is standing by for listening to fuel injection and shockwave	-	

Test of ELFI-valve and calibration of Fuel Plunger

Start	Action/Message	Reference	Test Value
1	Set CCU in test mode	Test	
2	Make an injection and evaluate sound	-	
3	Verify ELFI position (CH-30)	17.5 - 20.5 mA	
	Verify fuel plunger position (CH-31)	7.5 - 20.5 mA	
	Verify ELFI Amplifier (CH-33)	3.2 - 3.6 V	
4	Return fuel plunger	-	
	Verify ELFI position (CH-30)	3.5 - 6.5 mA	
5	Verify fuel plunger position (CH-31)	3.5 - 7.5 mA	
	Verify ELFI Amplifier (CH-33)	-0.2 - 0.2 V	
6	Save fuel plunger sensor calibration	-	

Alarms Engine Auxiliaries Maintenance System View I/O Test Invalidated Inputs Network Status Function Test Trouble-Shooting Admin Power Off Chief

Figure 8:

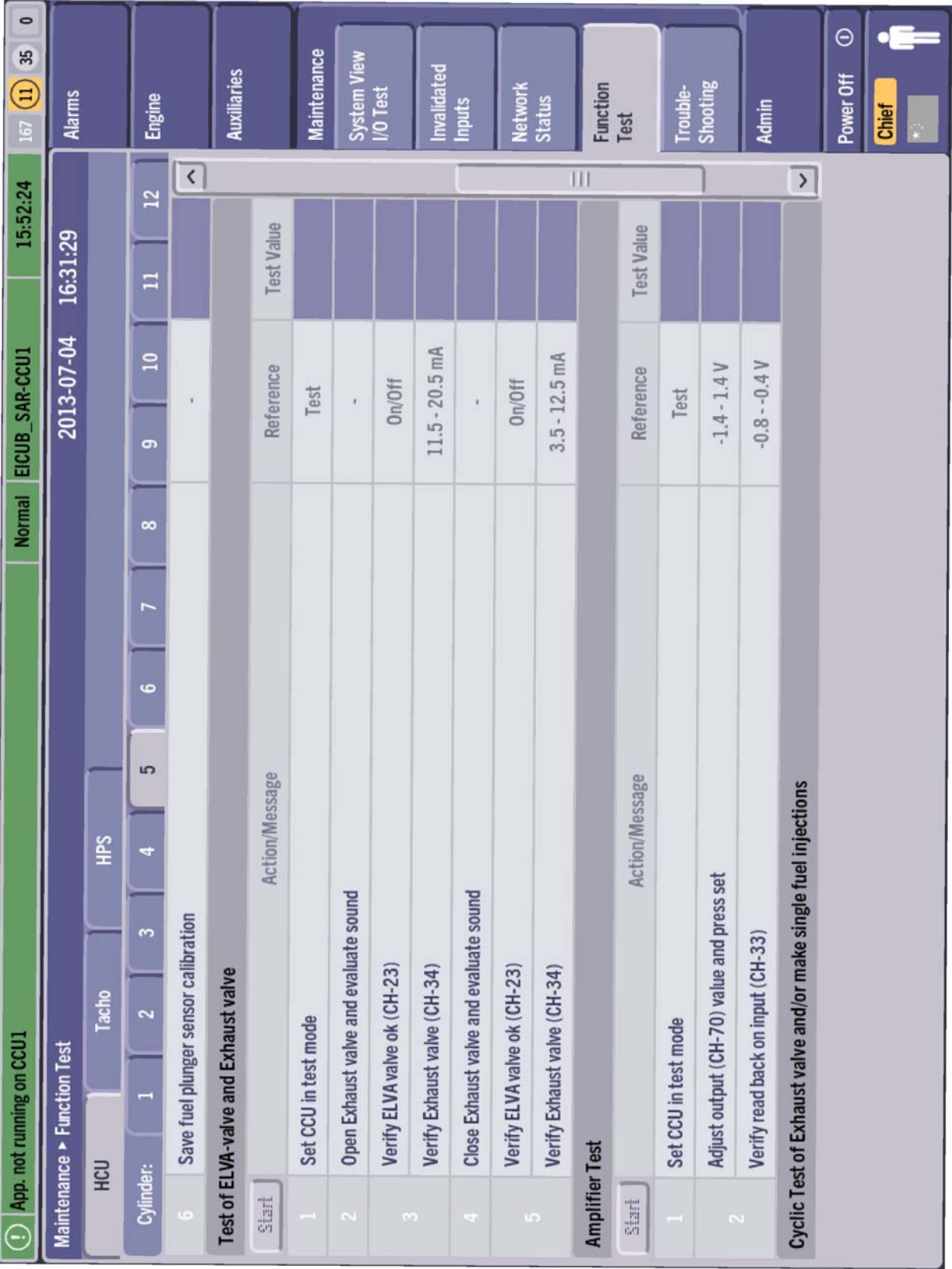


Figure 9:



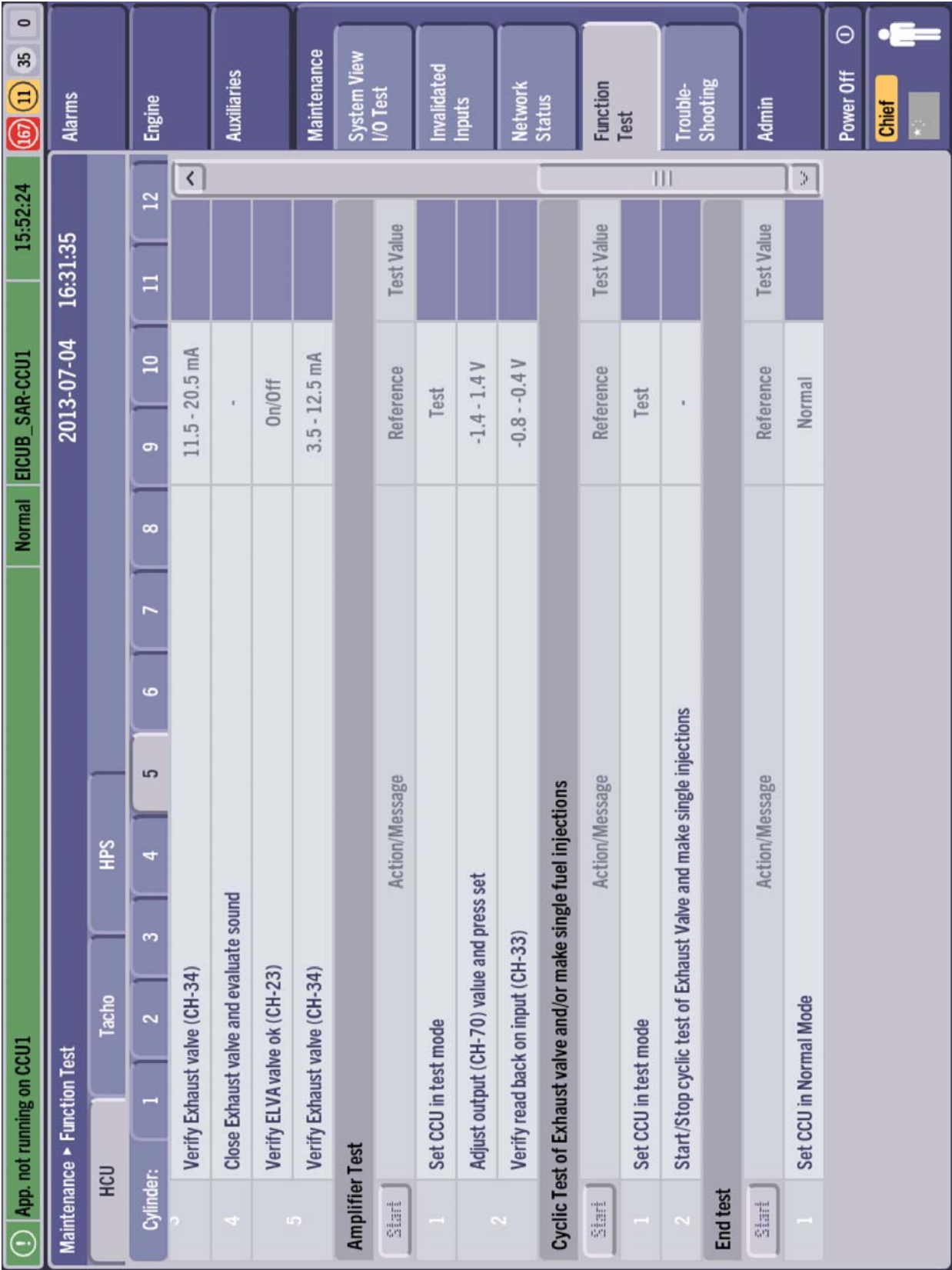


Figure 10:

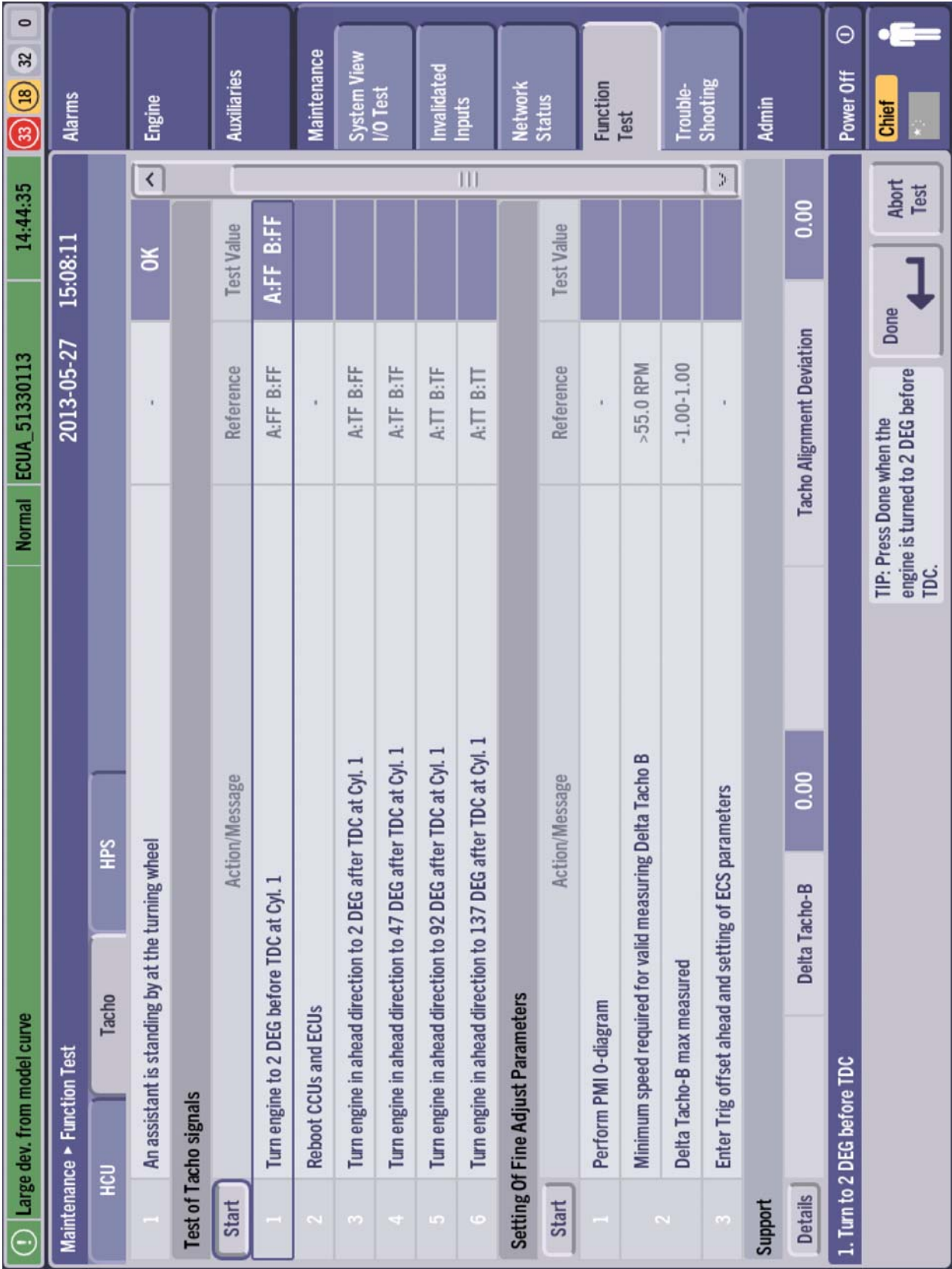


Figure 11:

MOP Function Test

Drawing

6655-0203-0005

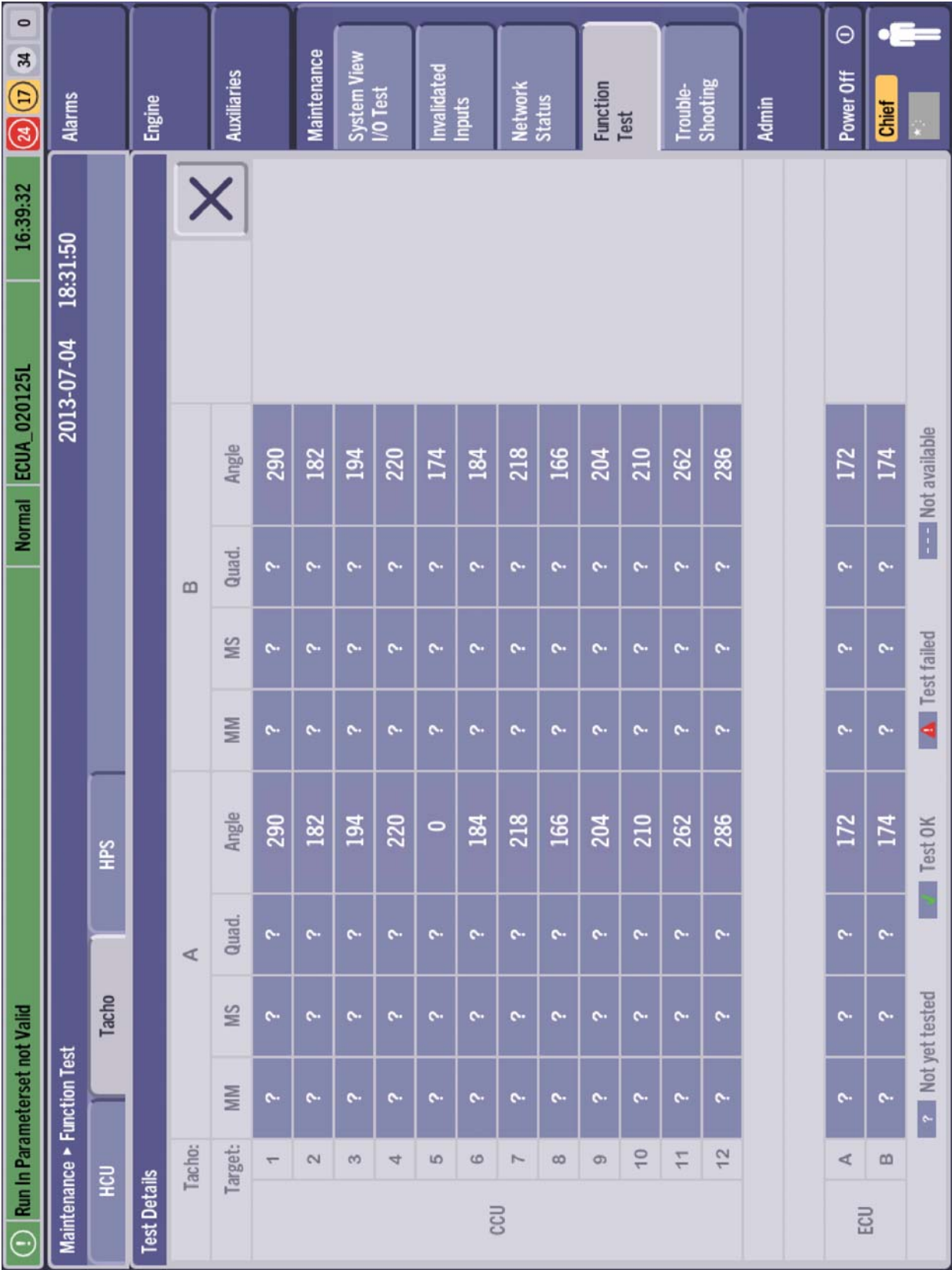


Figure 12:

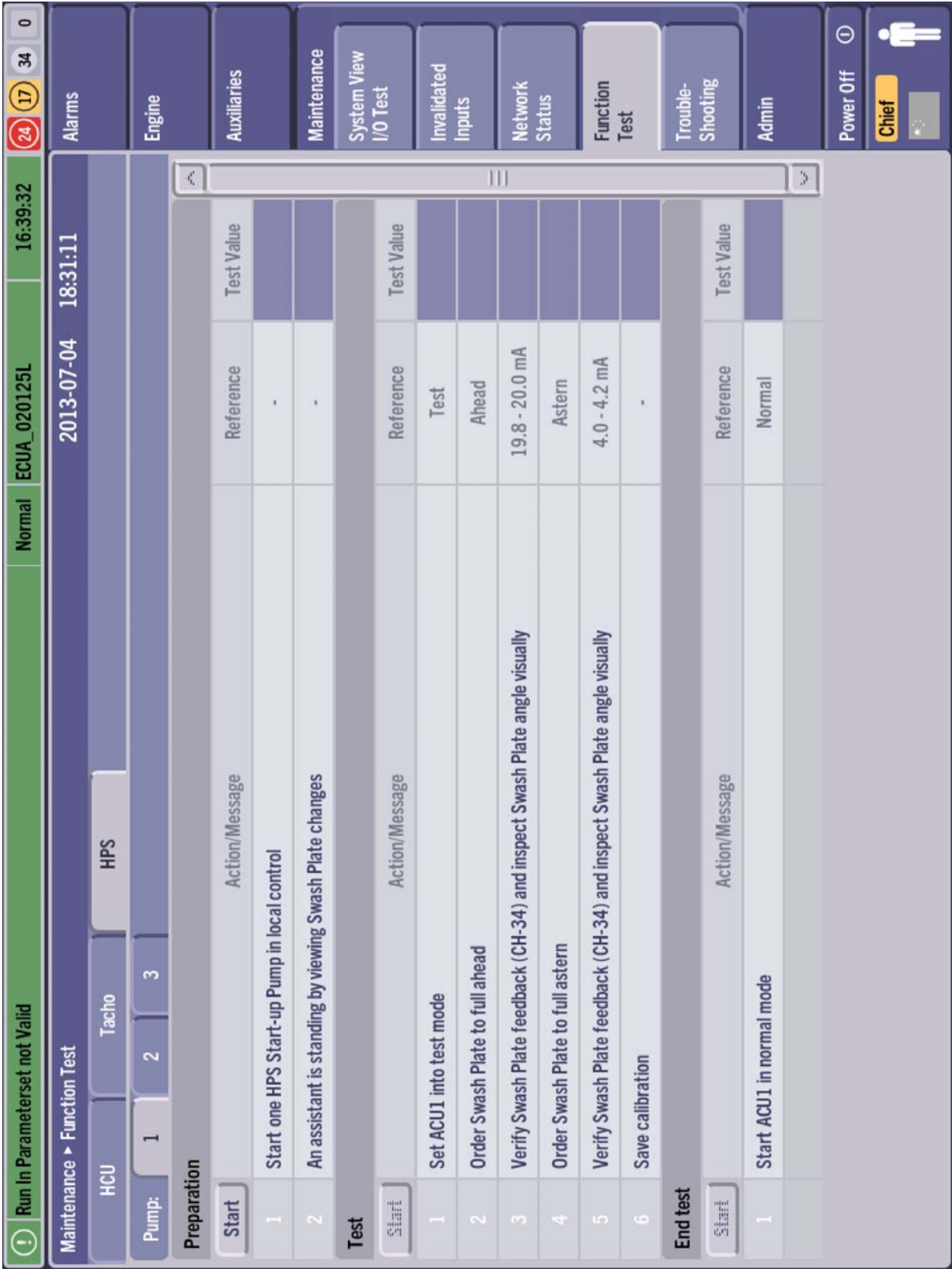


Figure 13:

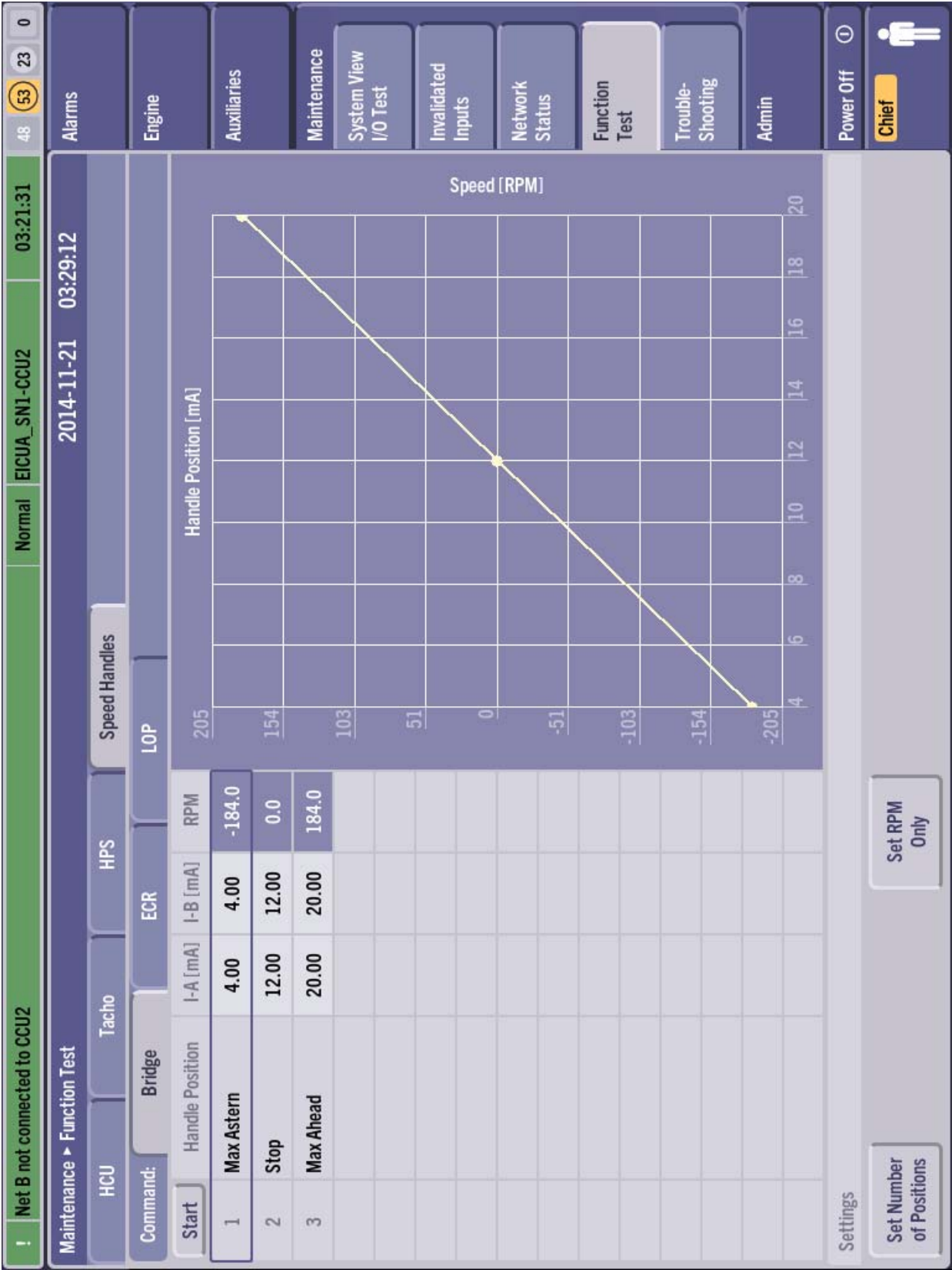


Figure 14: Calibrate Bridge handle position and RPM set point

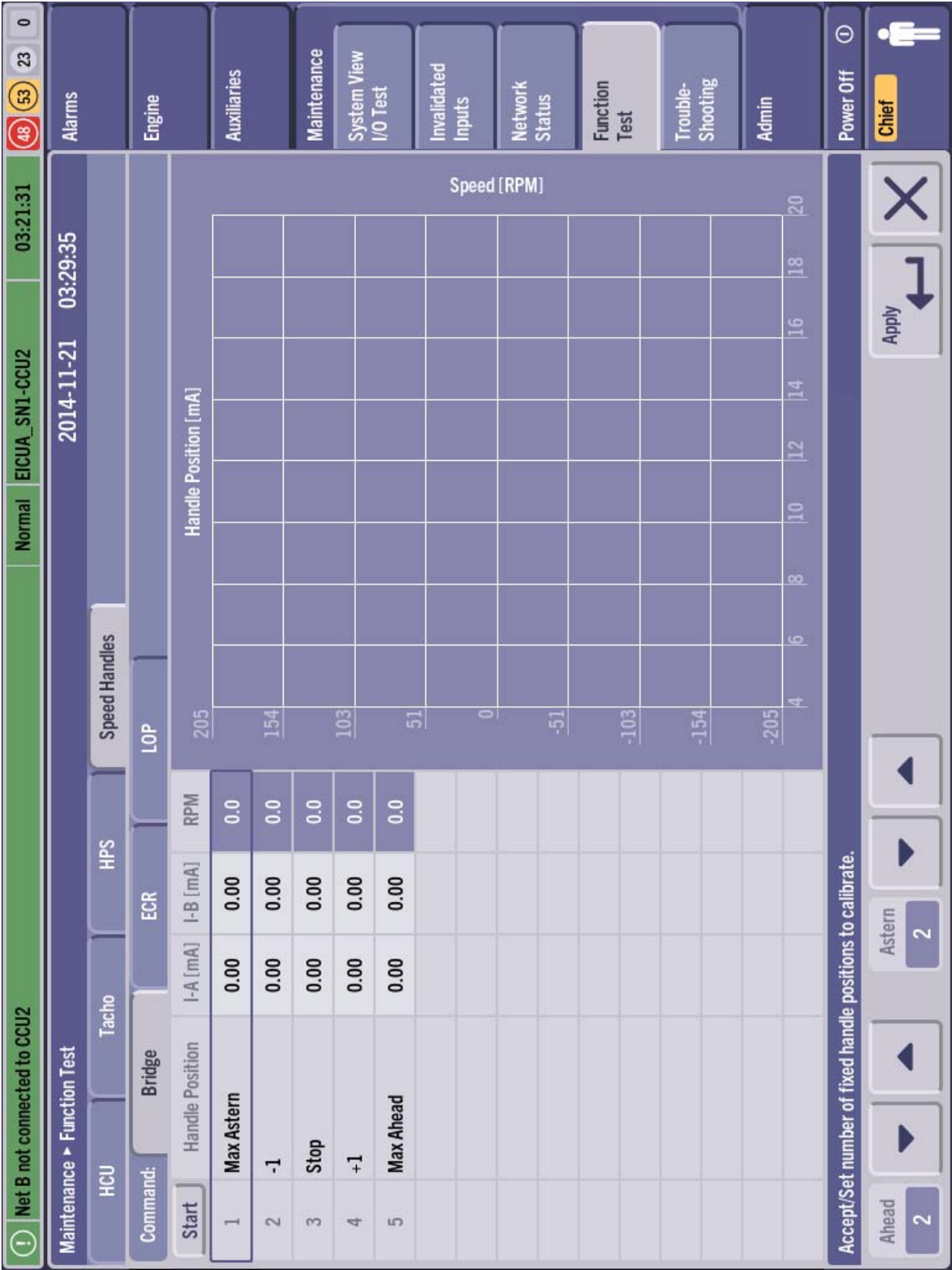


Figure 15: Calibrate Bridge handle position and RPM set point

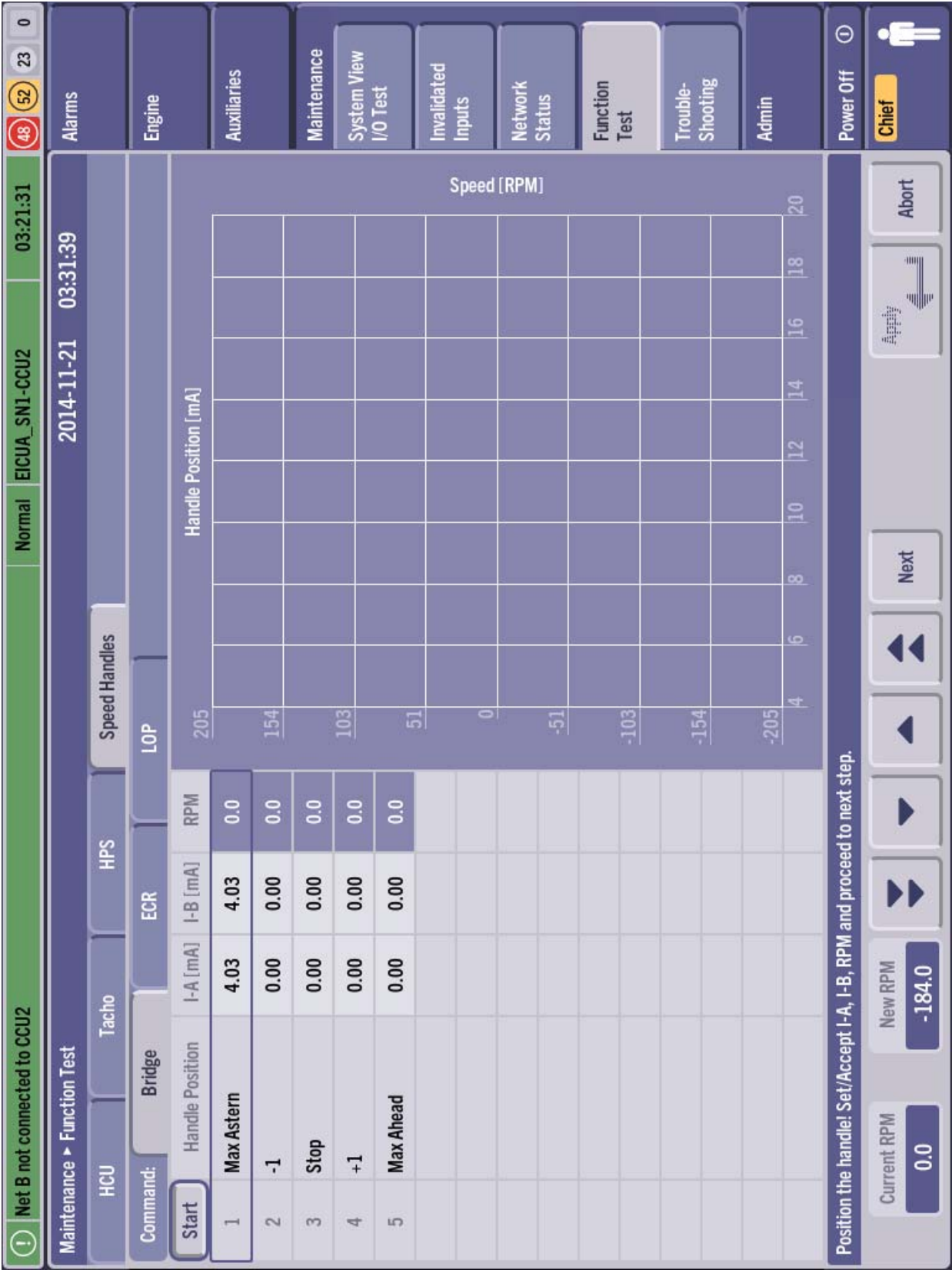


Figure 16: Calibrate Bridge handle position and RPM set point



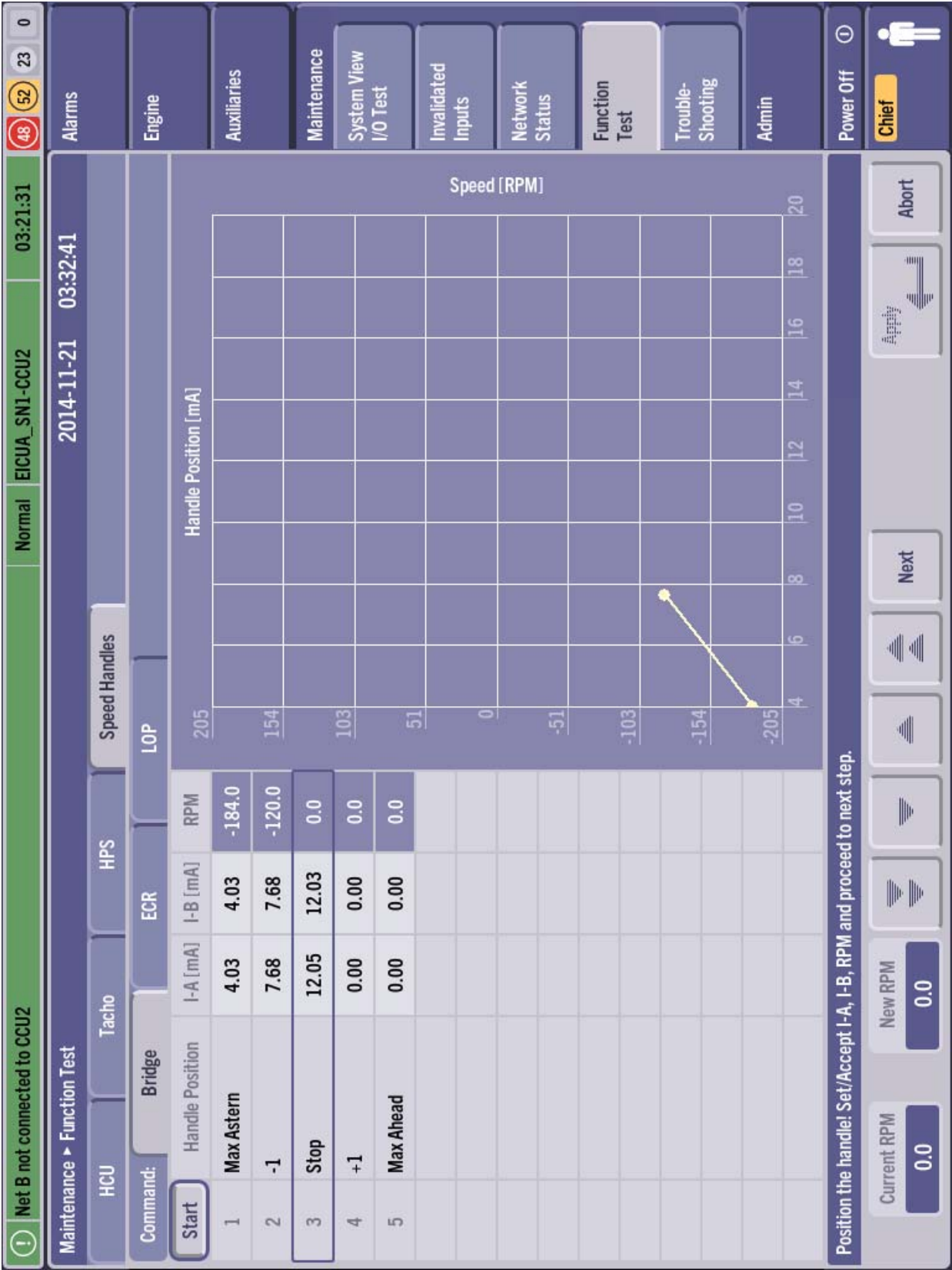


Figure 17: Calibrate Bridge handle position and RPM set point

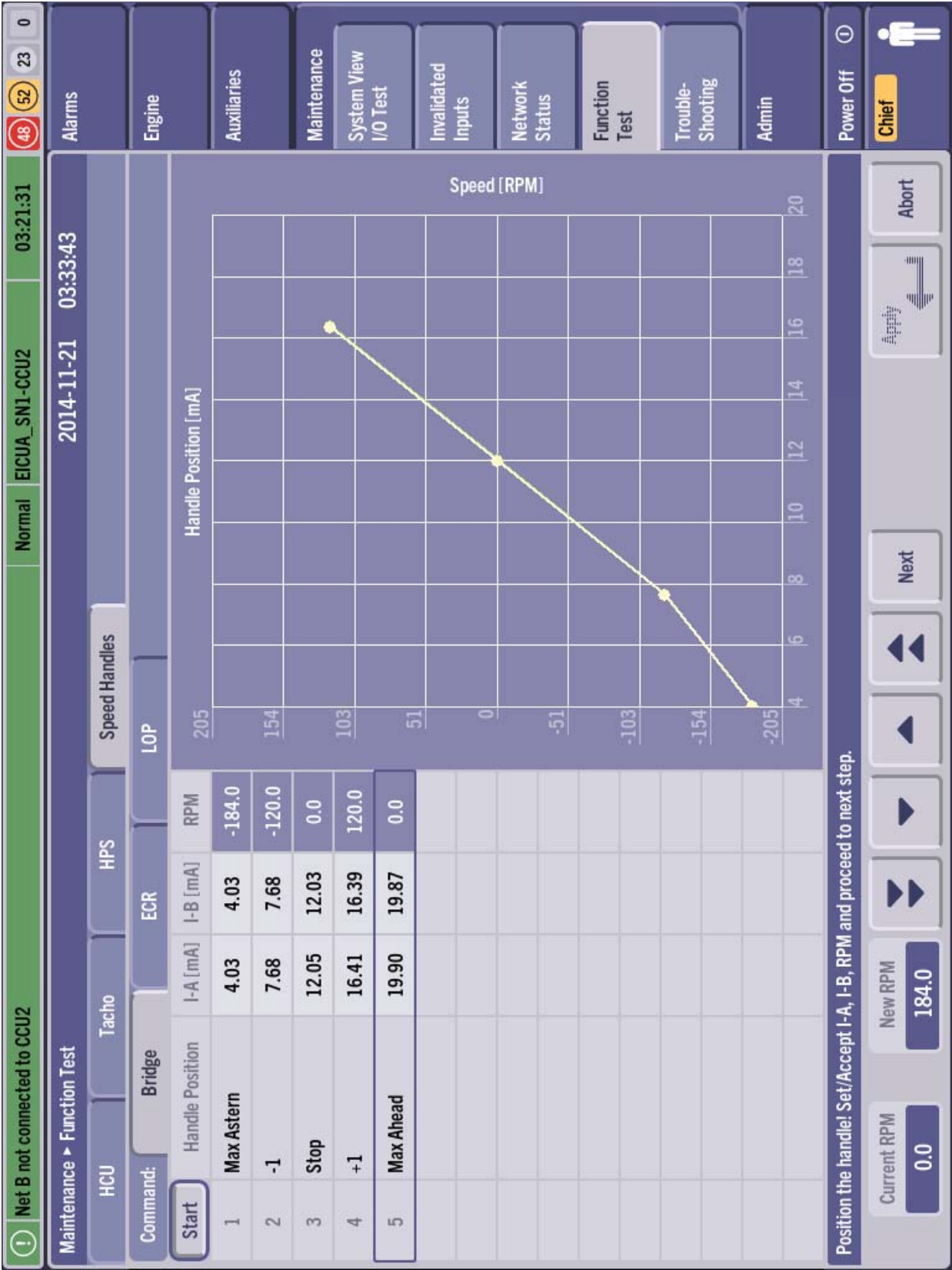


Figure 18: Calibrate Bridge handle position and RPM set point

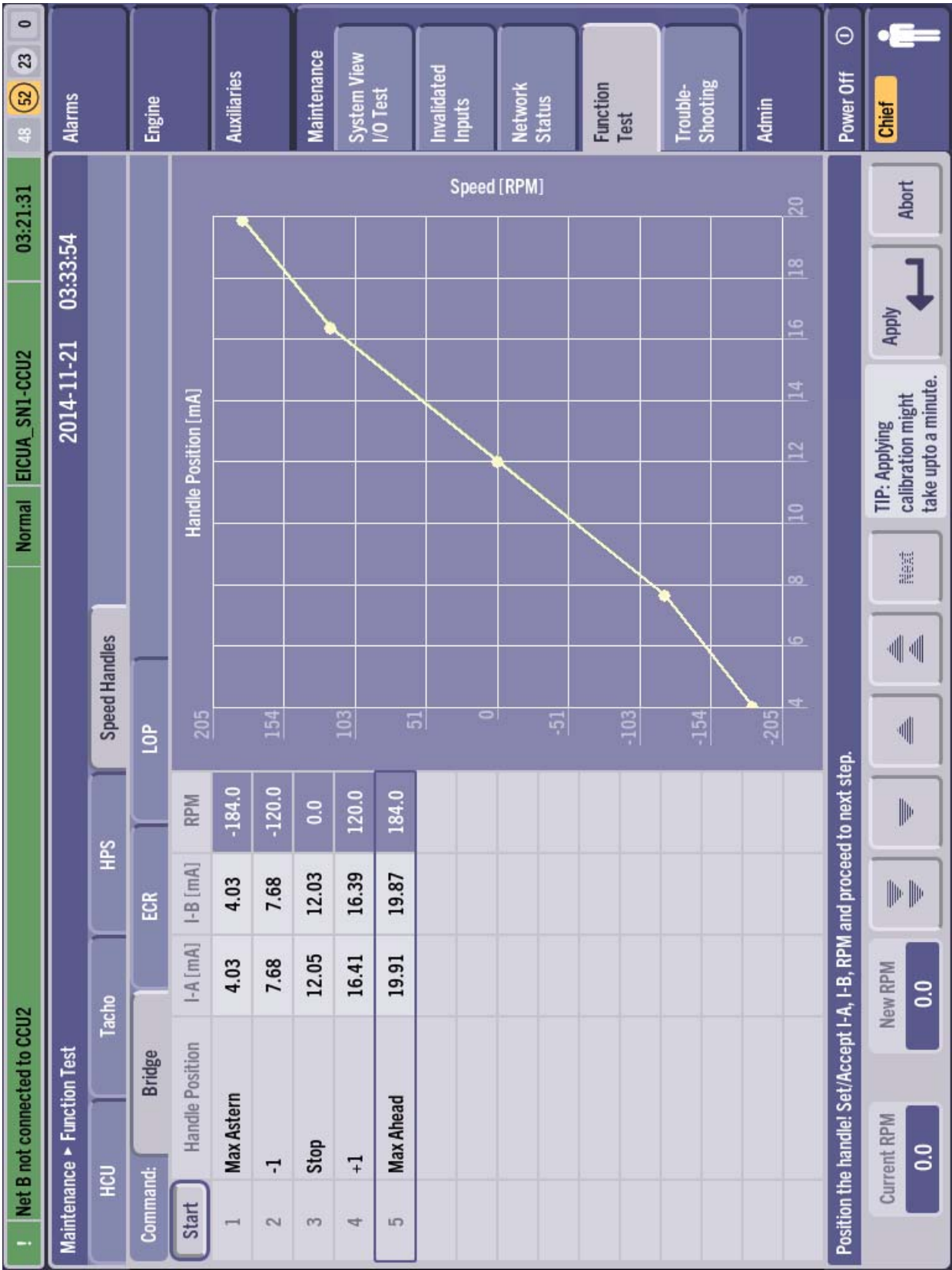


Figure 19: Calibrate Bridge handle position and RPM set point

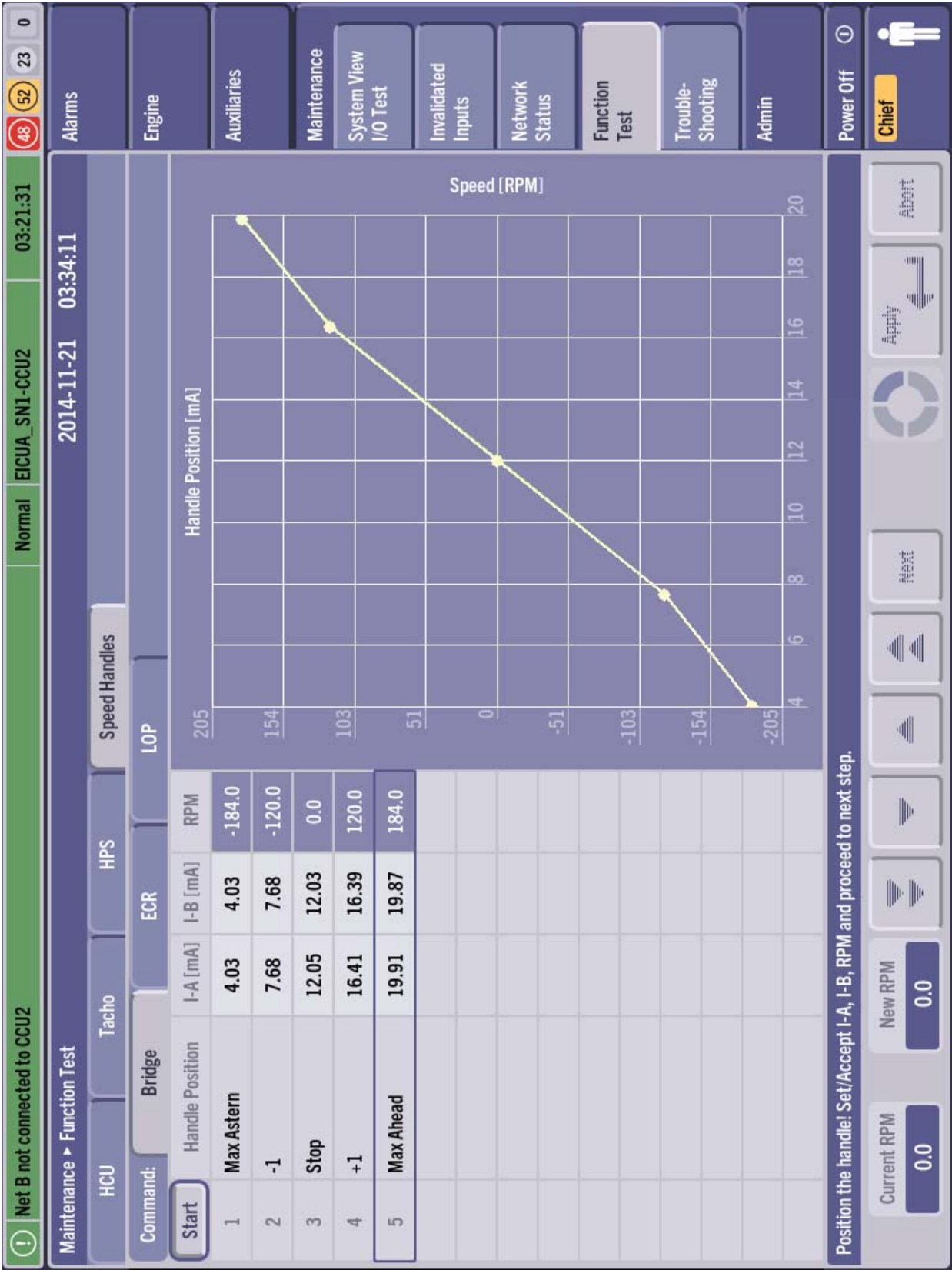


Figure 20: Calibrate Bridge handle position and RPM set point

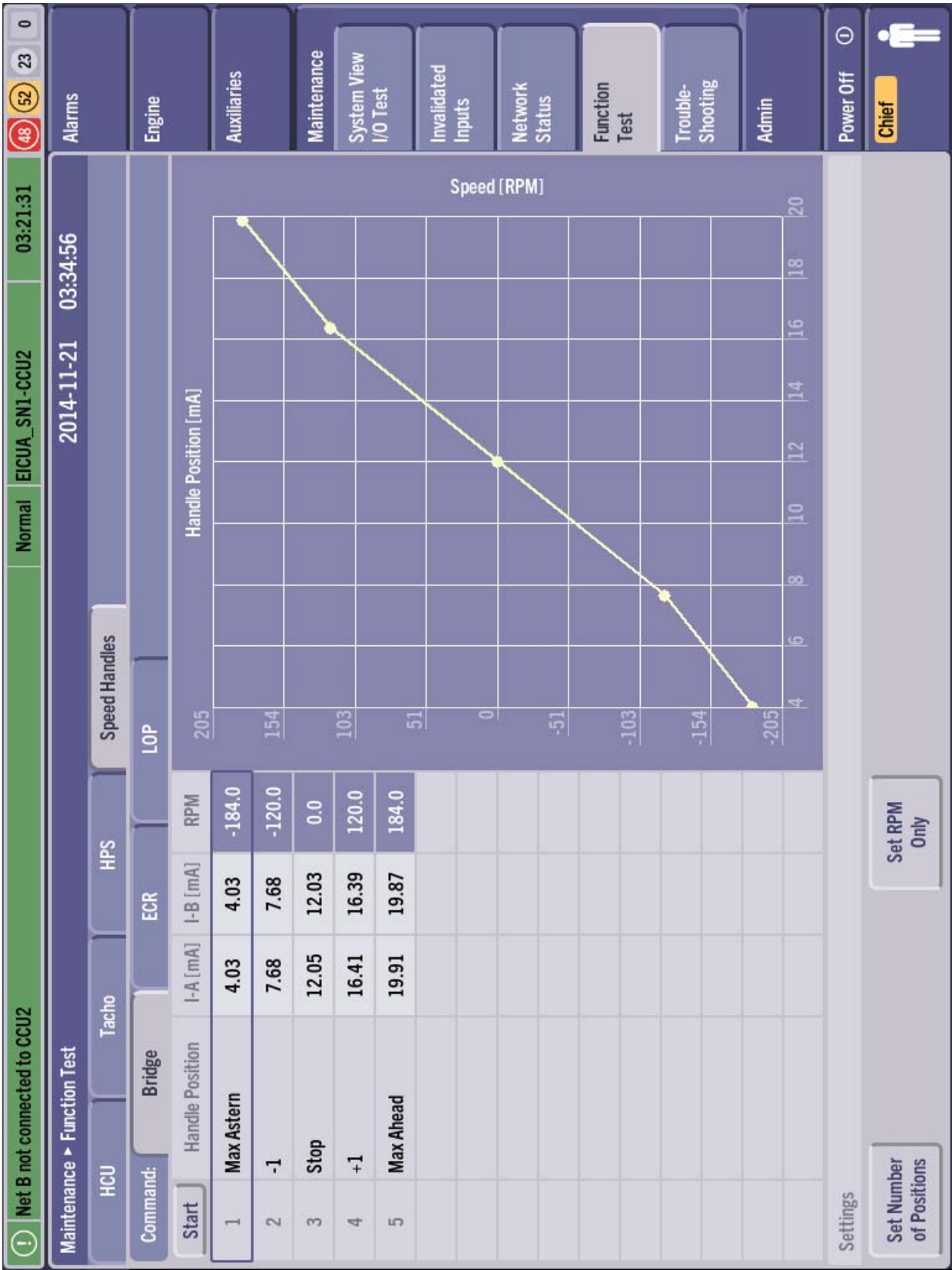


Figure 21: Calibrate Bridge handle RPM set point only

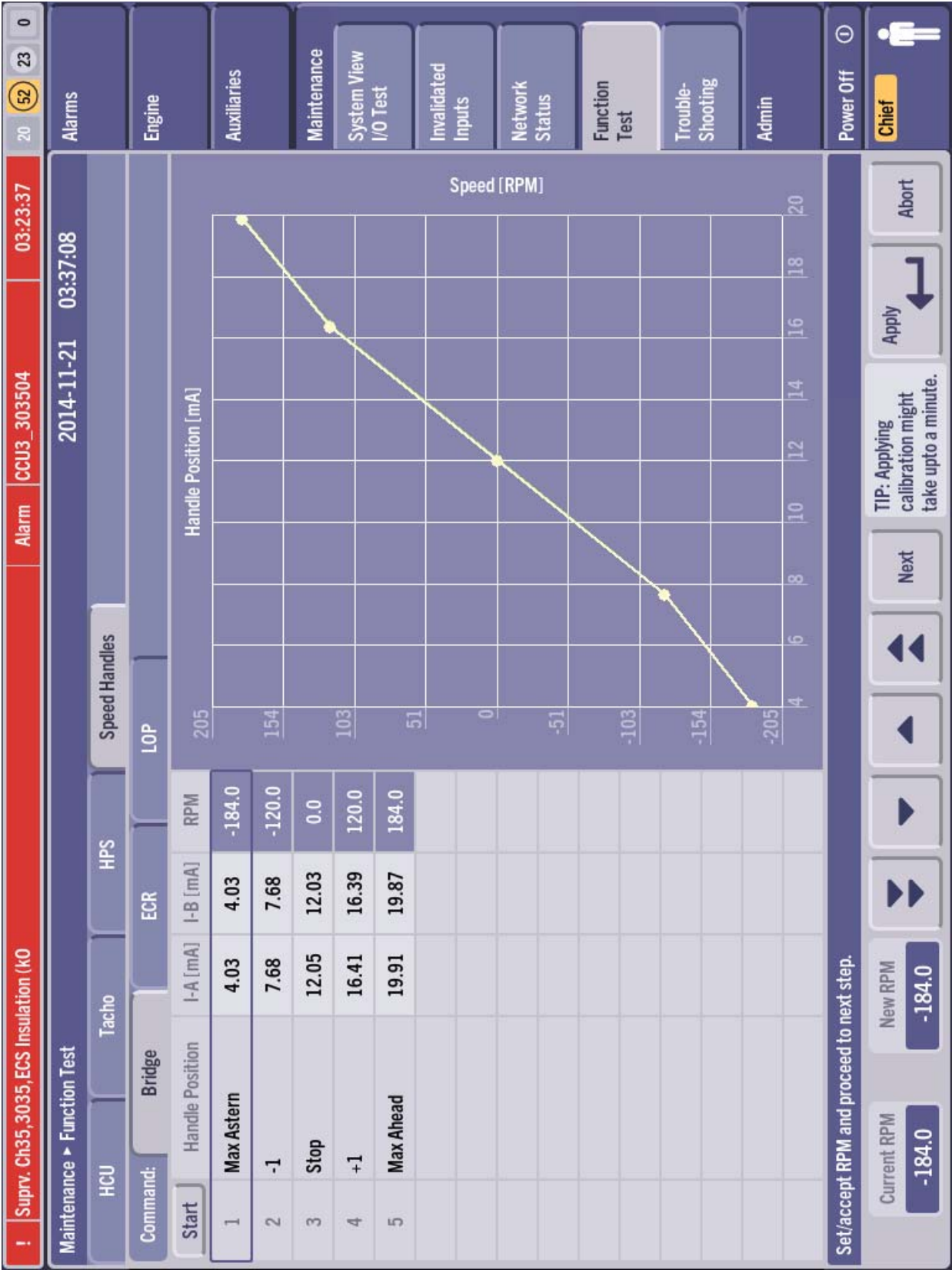


Figure 22: Calibrate Bridge handle RPM set point only

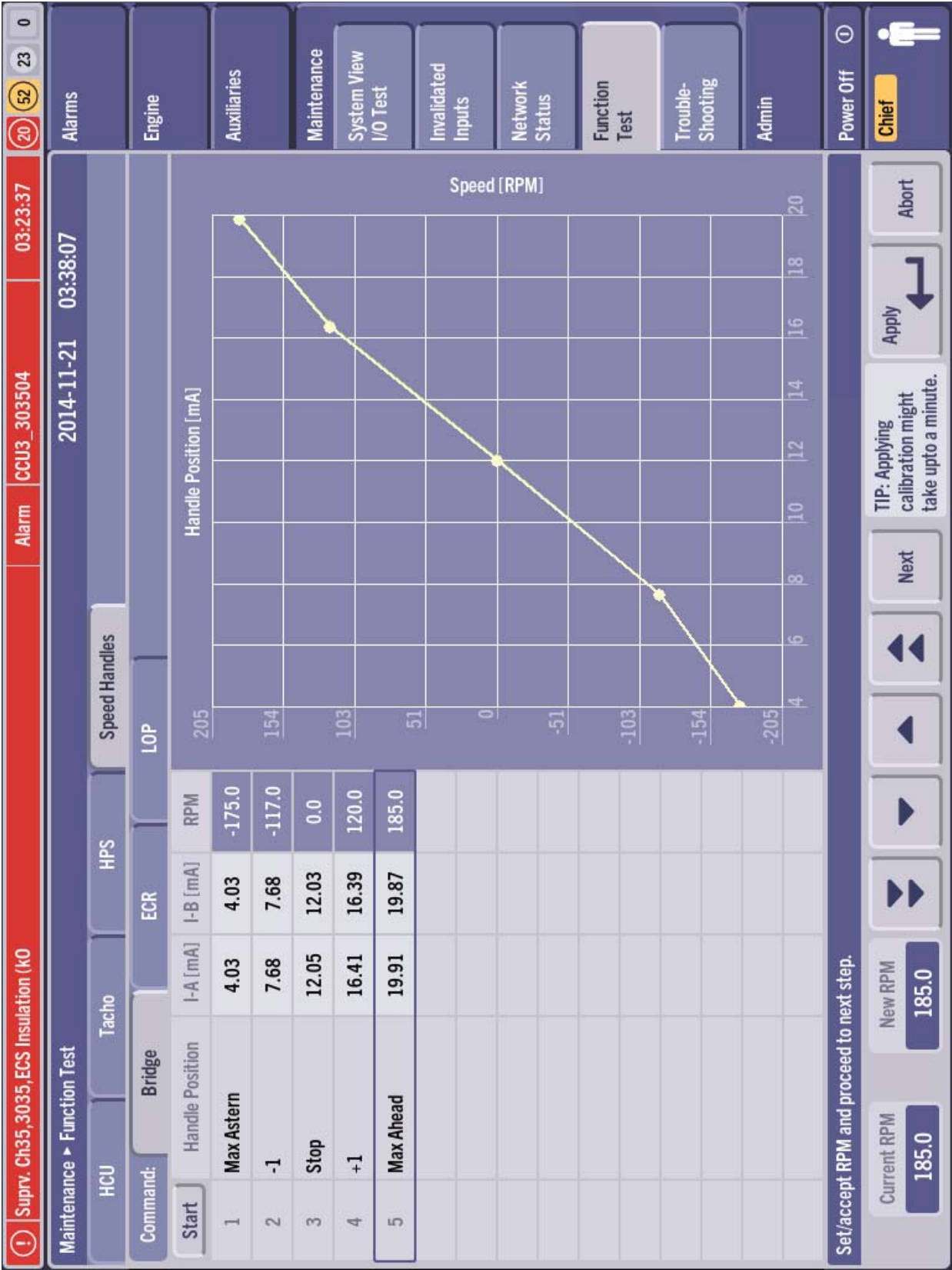


Figure 23: Calibrate Bridge handle RPM set point only

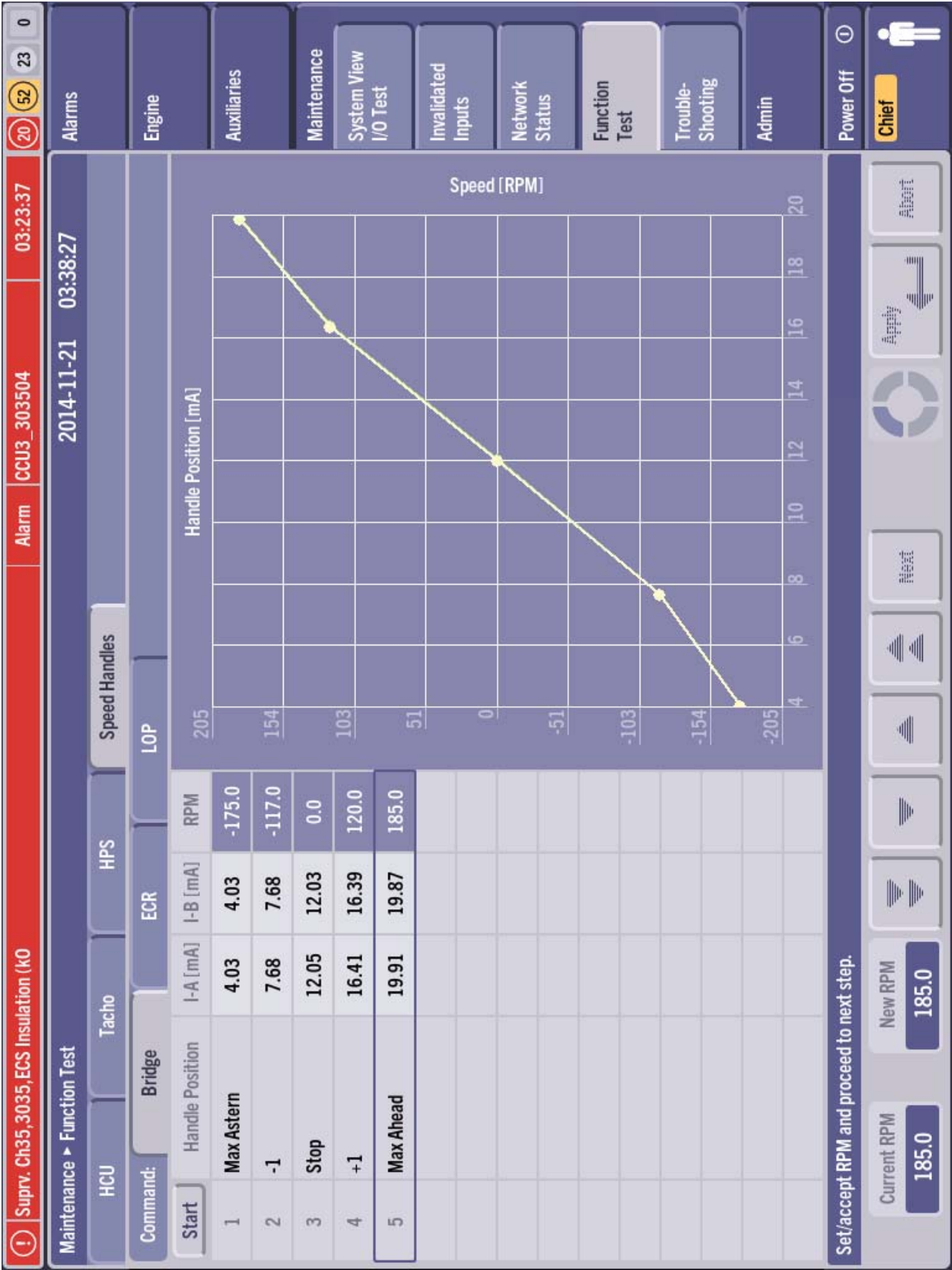


Figure 24: Calibrate Bridge handle RPM set point only

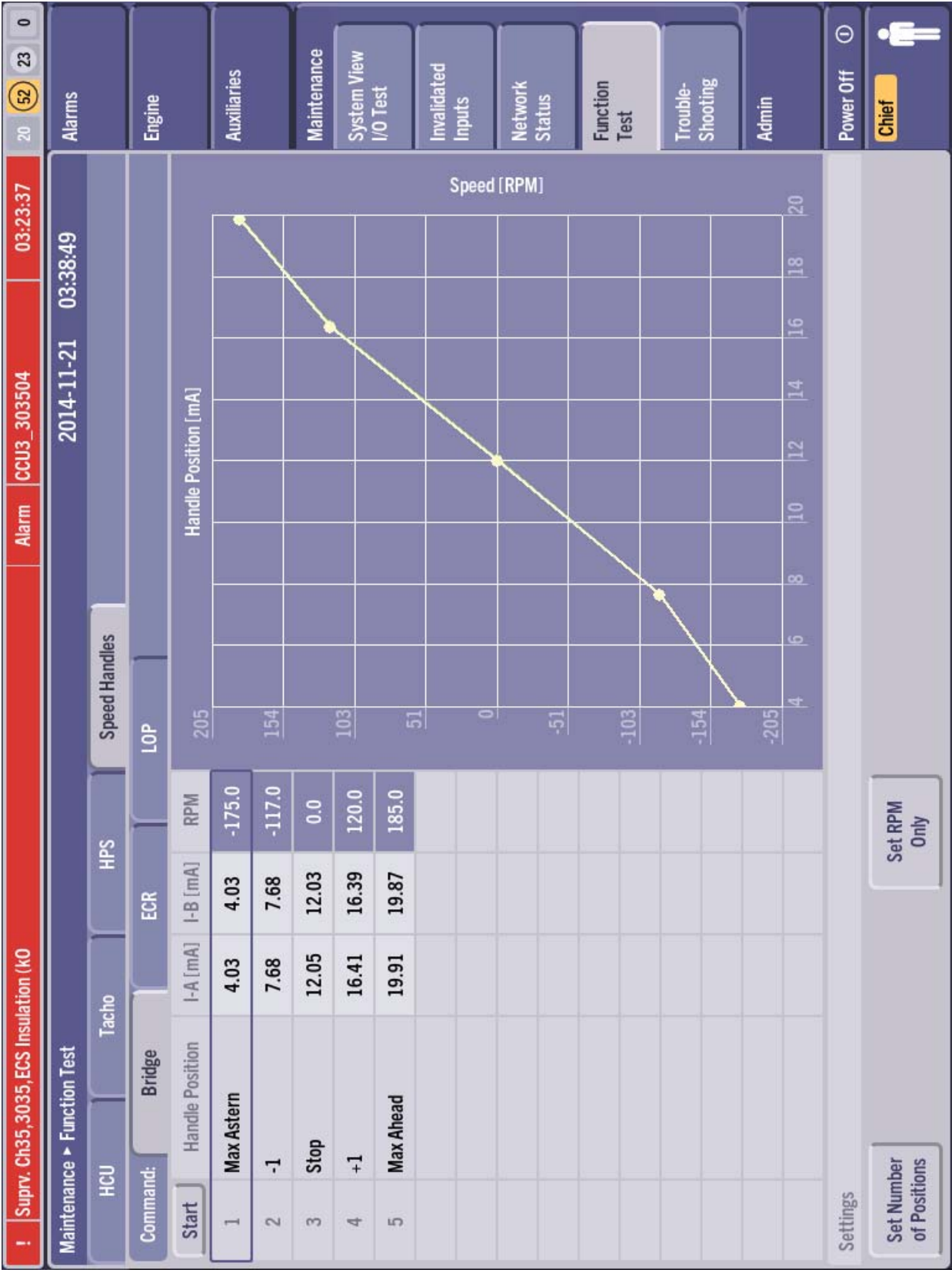


Figure 25: Calibrate Bridge handle RPM set point only

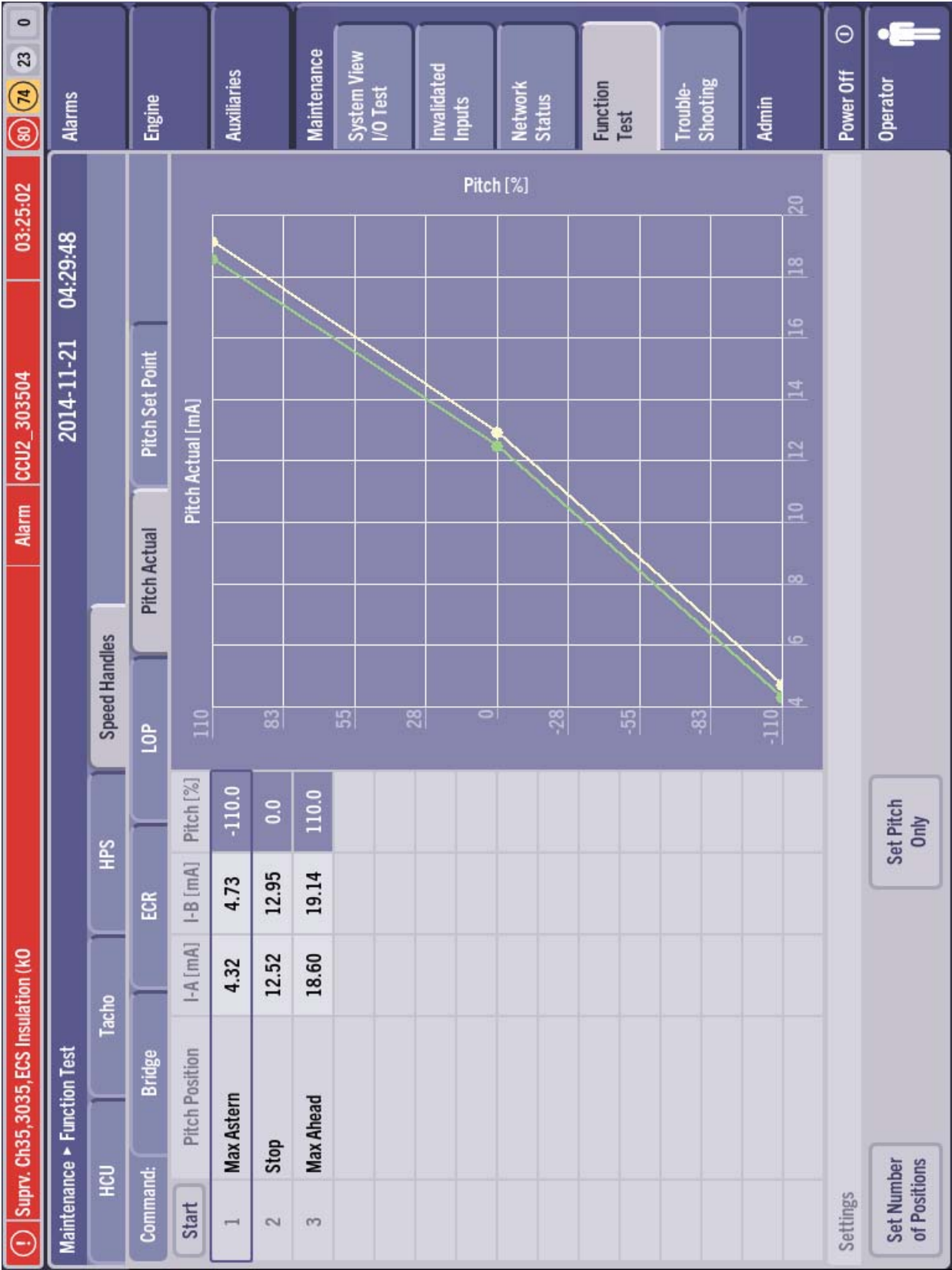


Figure 26: Calibrate Pitch Actual handle

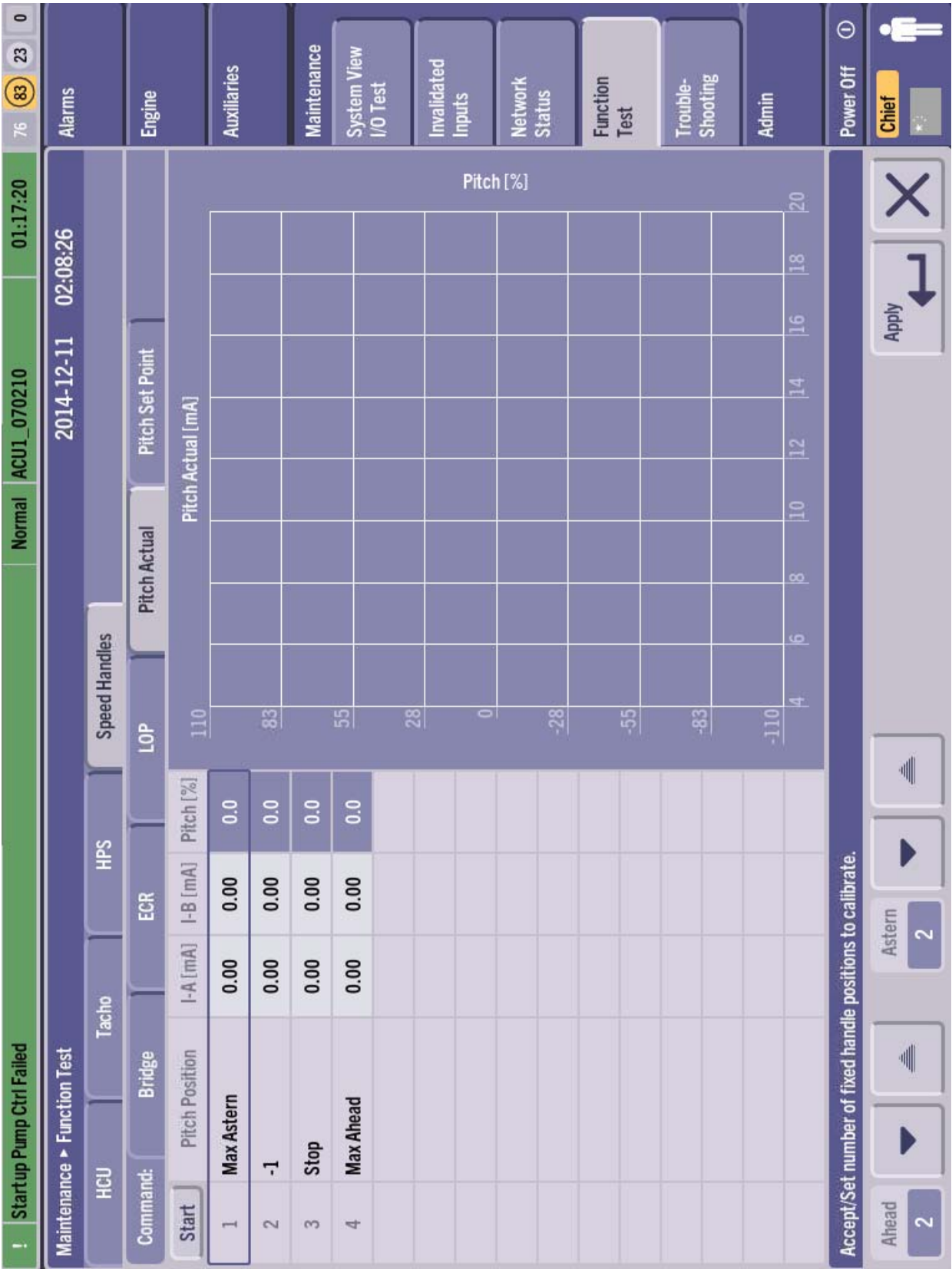


Figure 27: Calibrate Pitch Actual handle

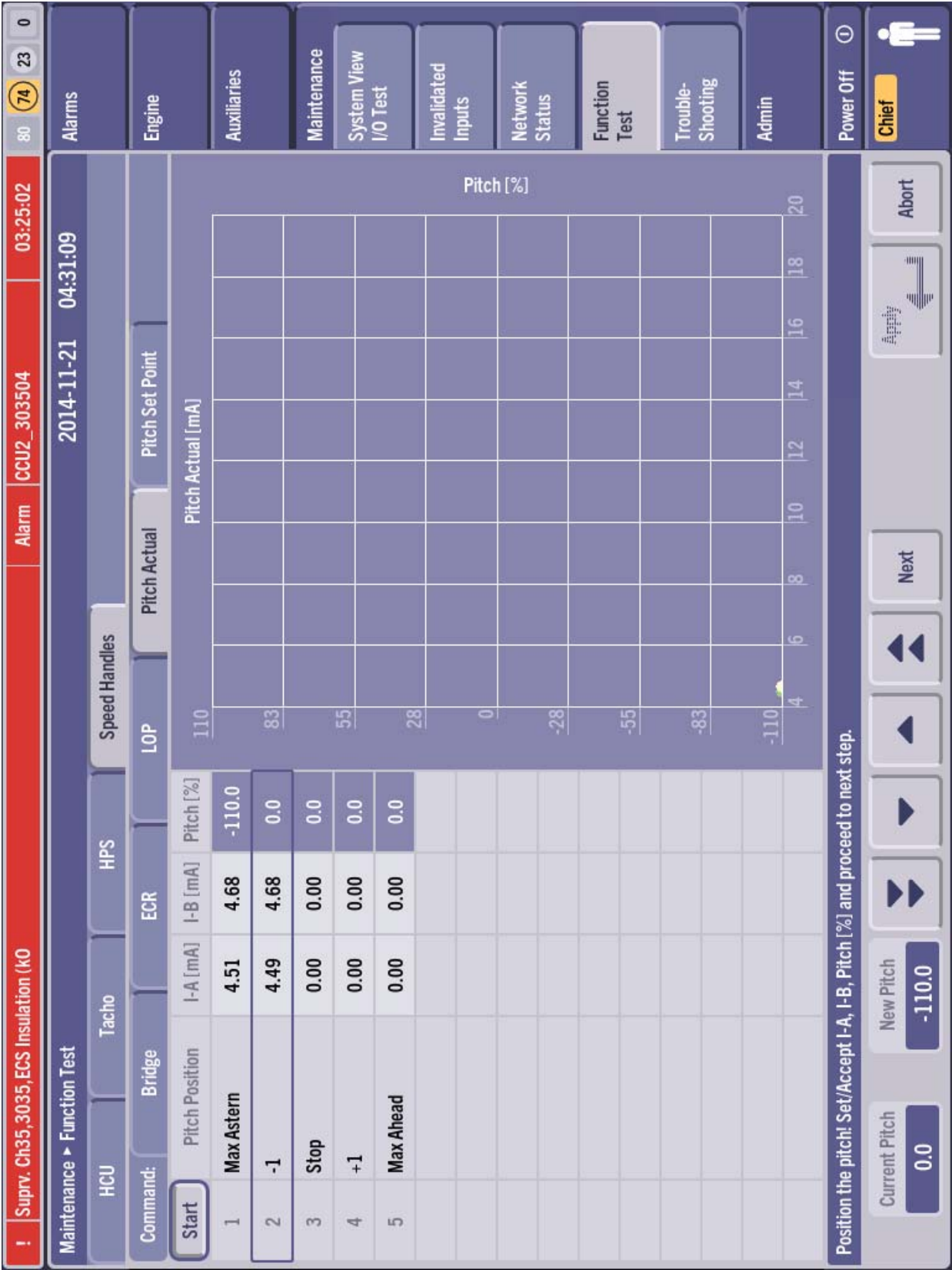


Figure 28: Calibrate Pitch Actual handle

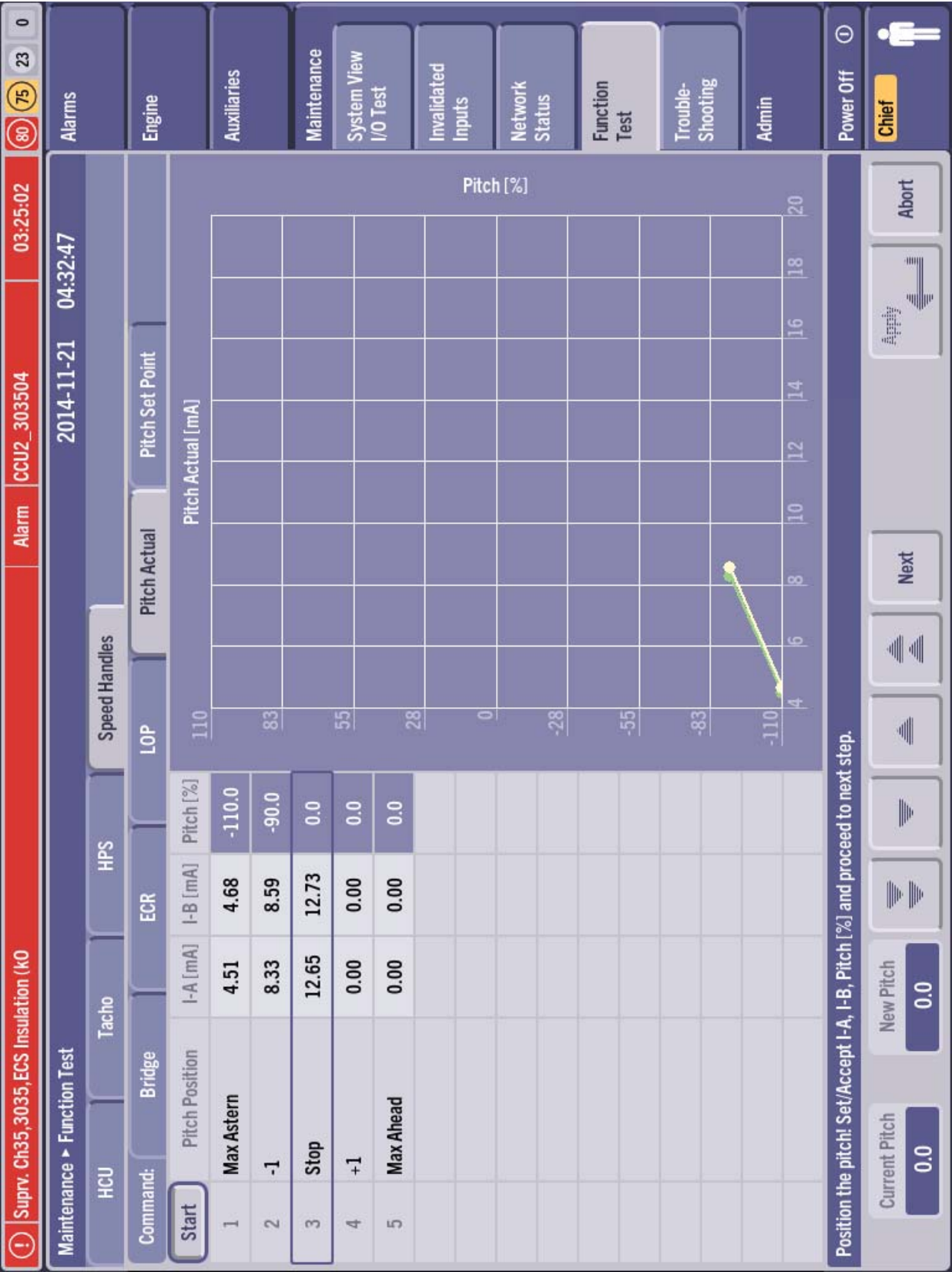


Figure 29: Calibrate Pitch Actual handle

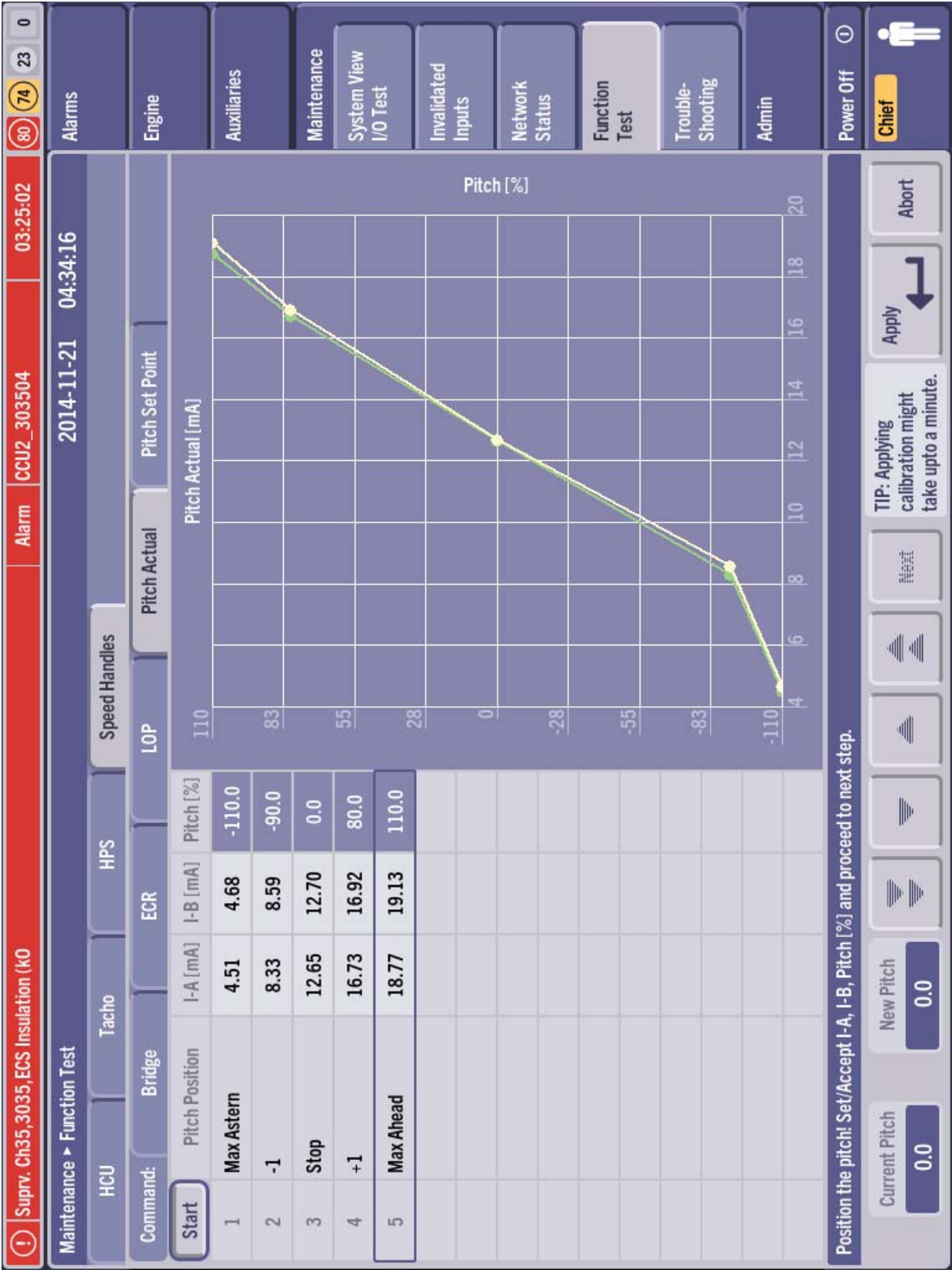
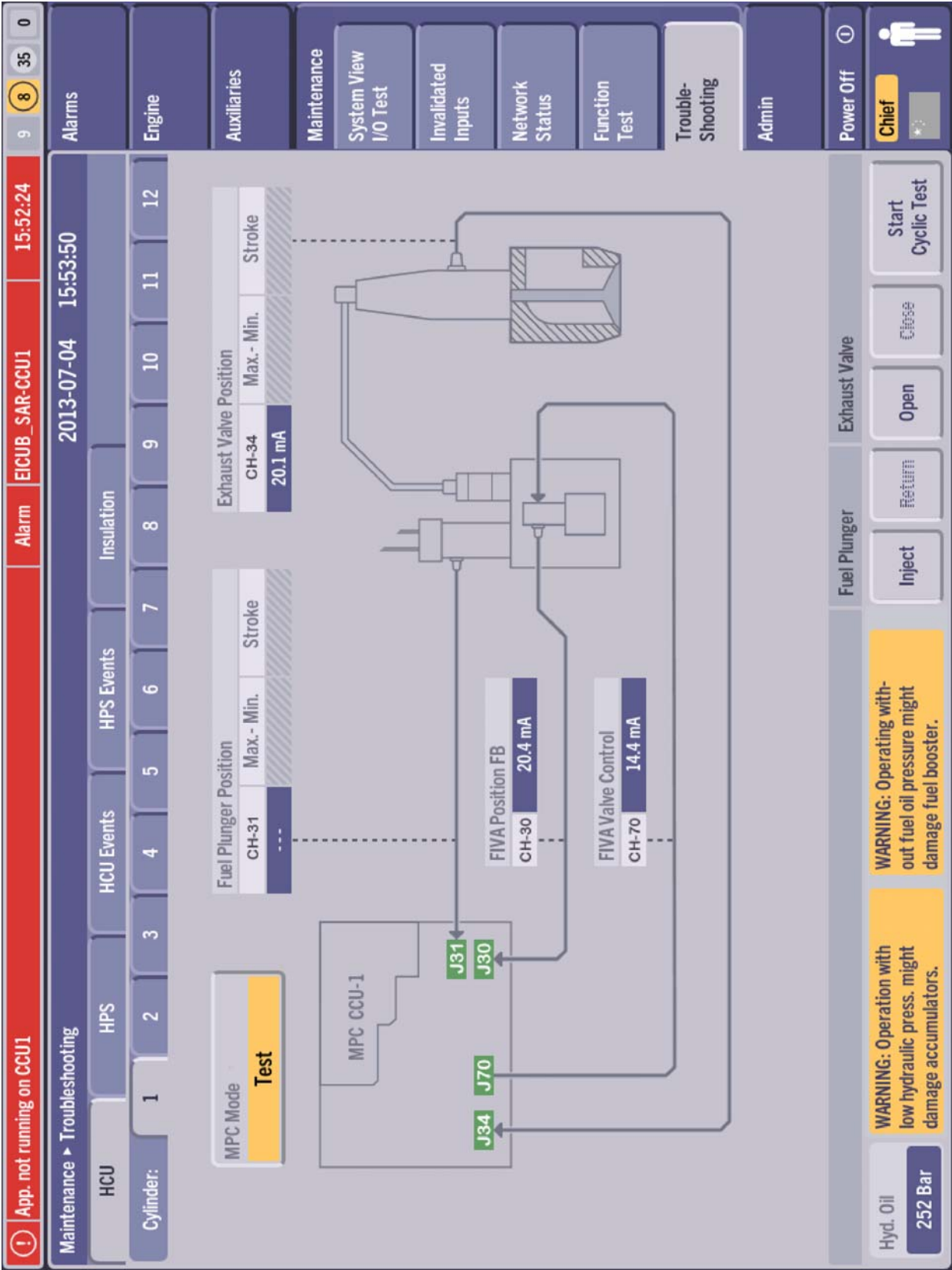
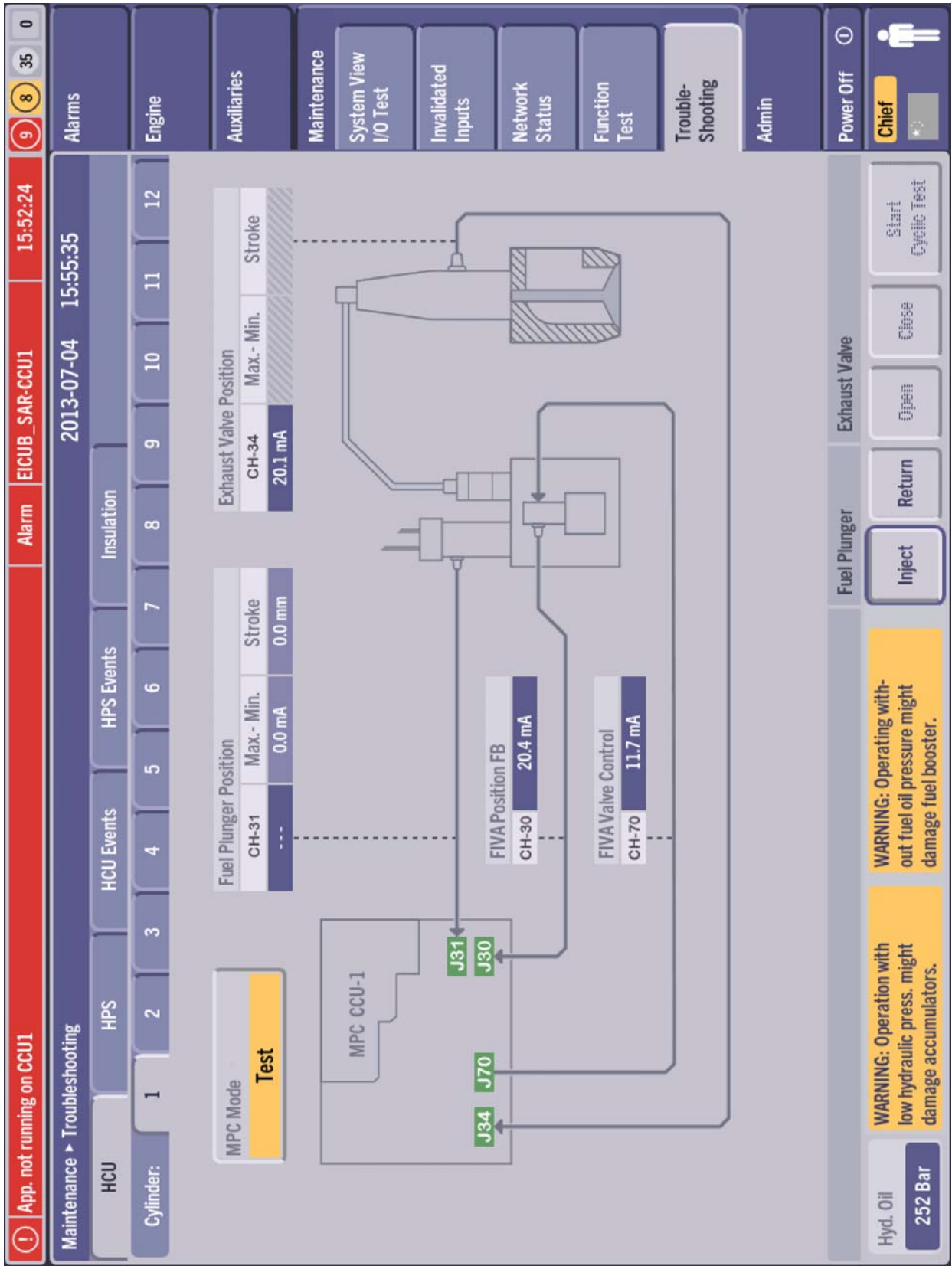


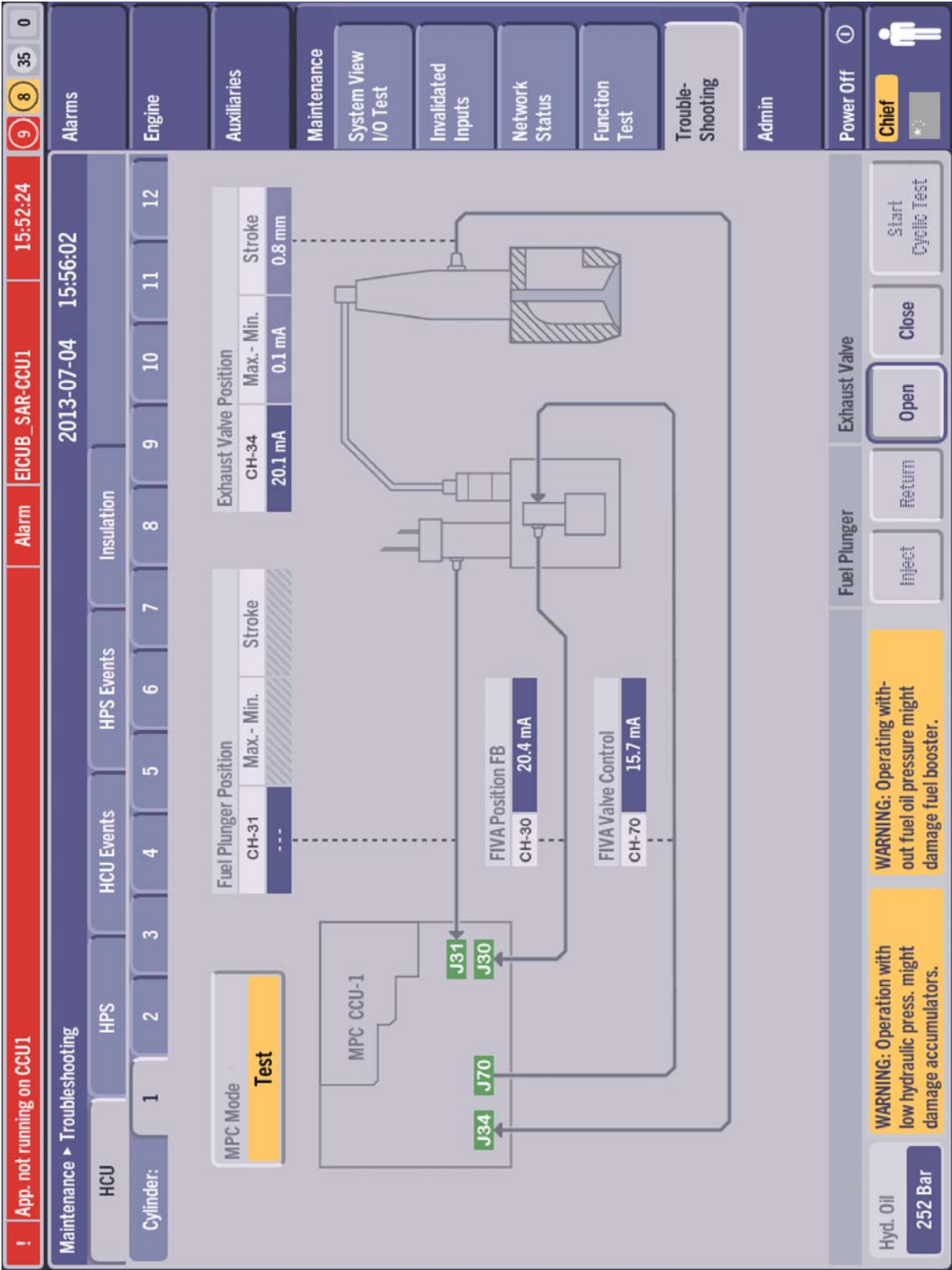
Figure 30: Calibrate Pitch Actual handle

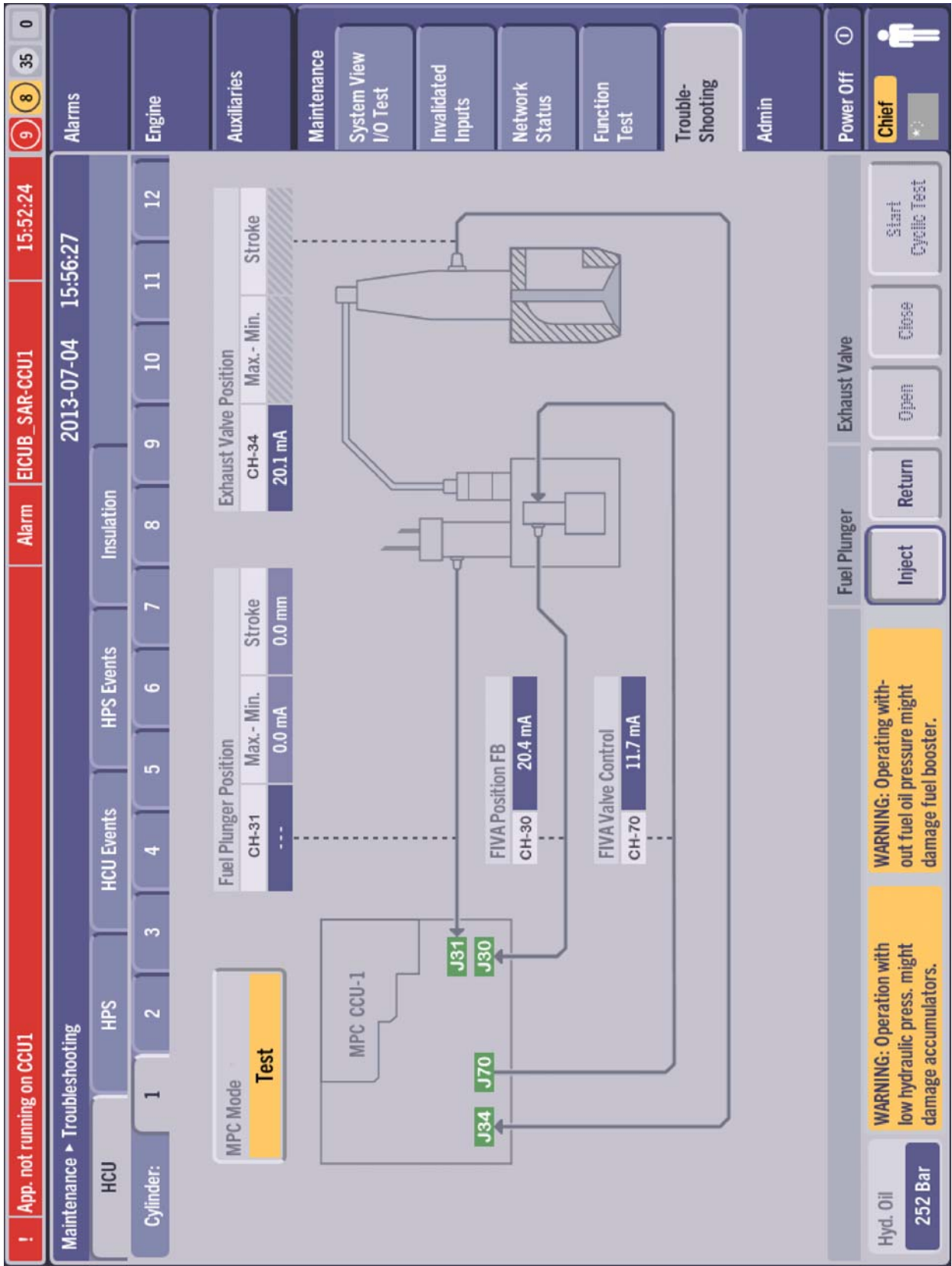


Figure 31: Calibrate Pitch Actual handle



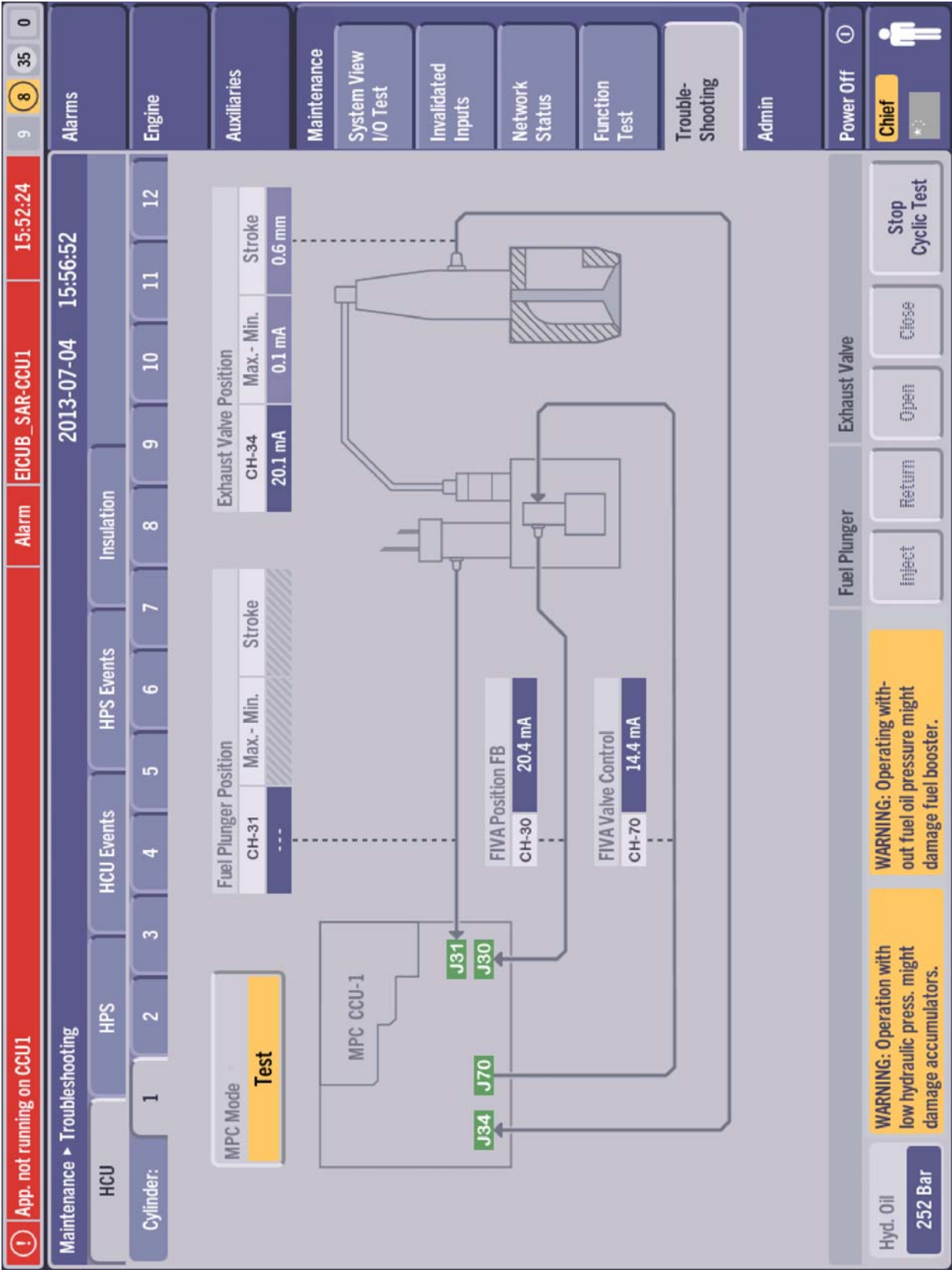


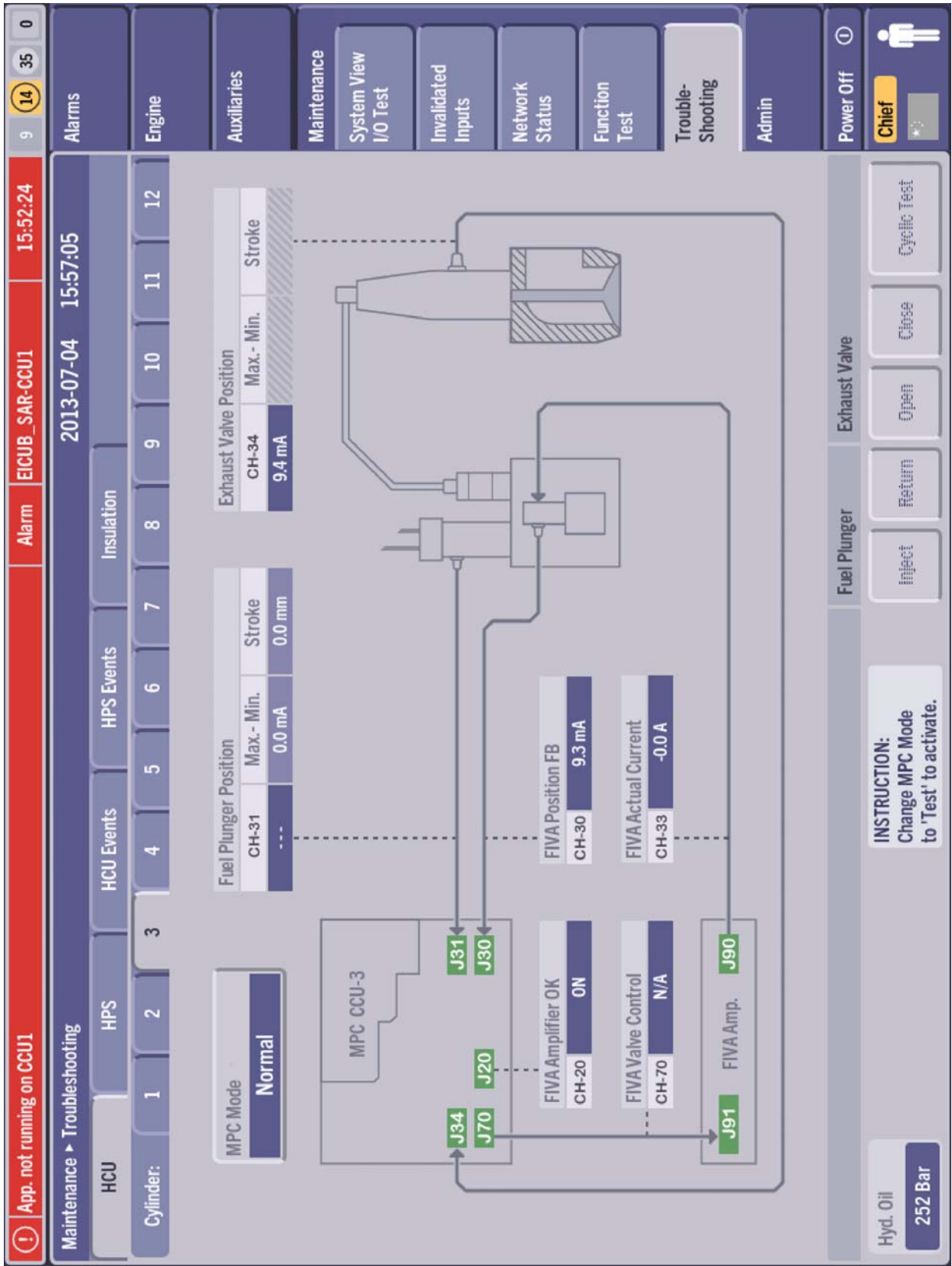


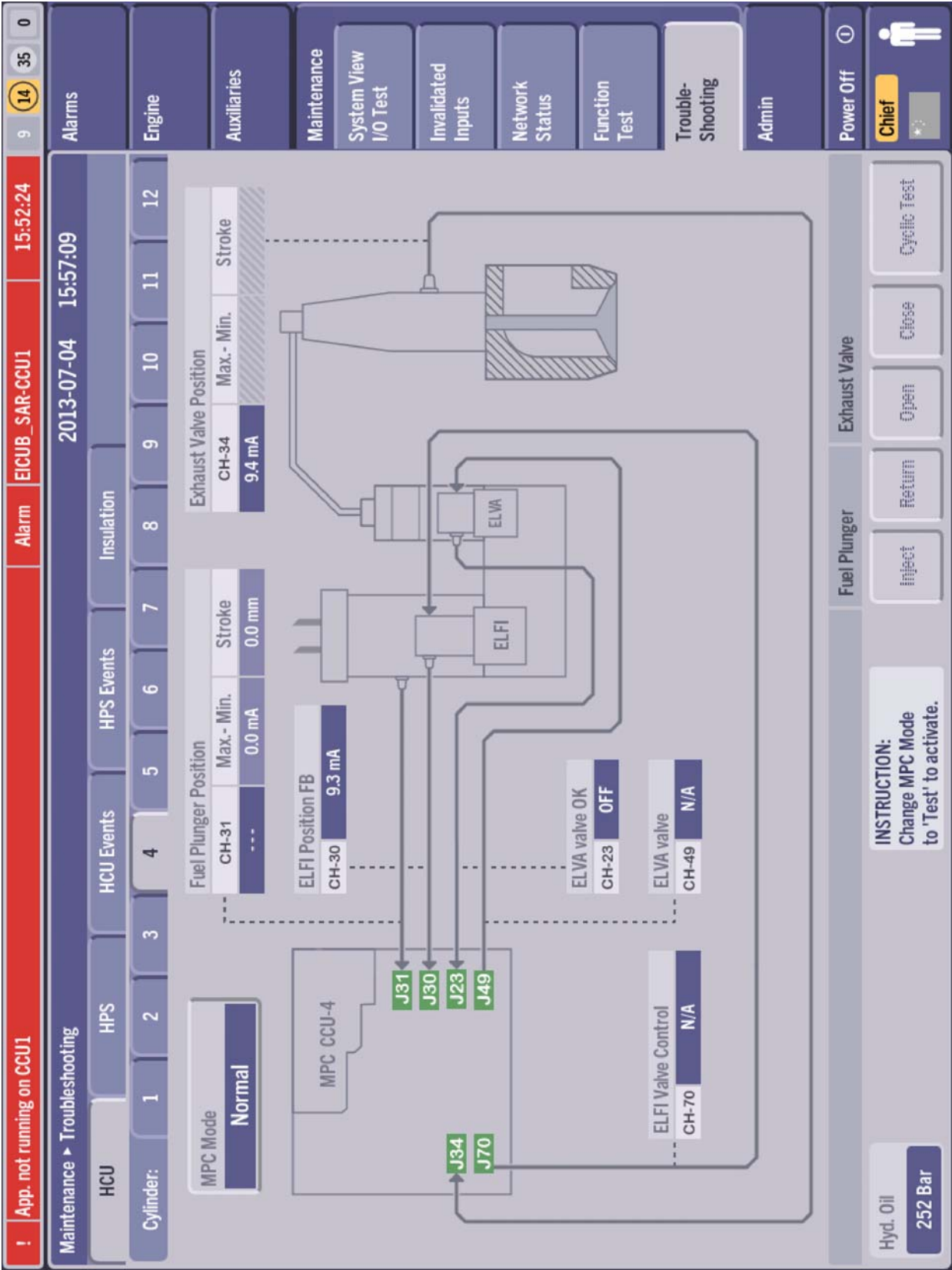


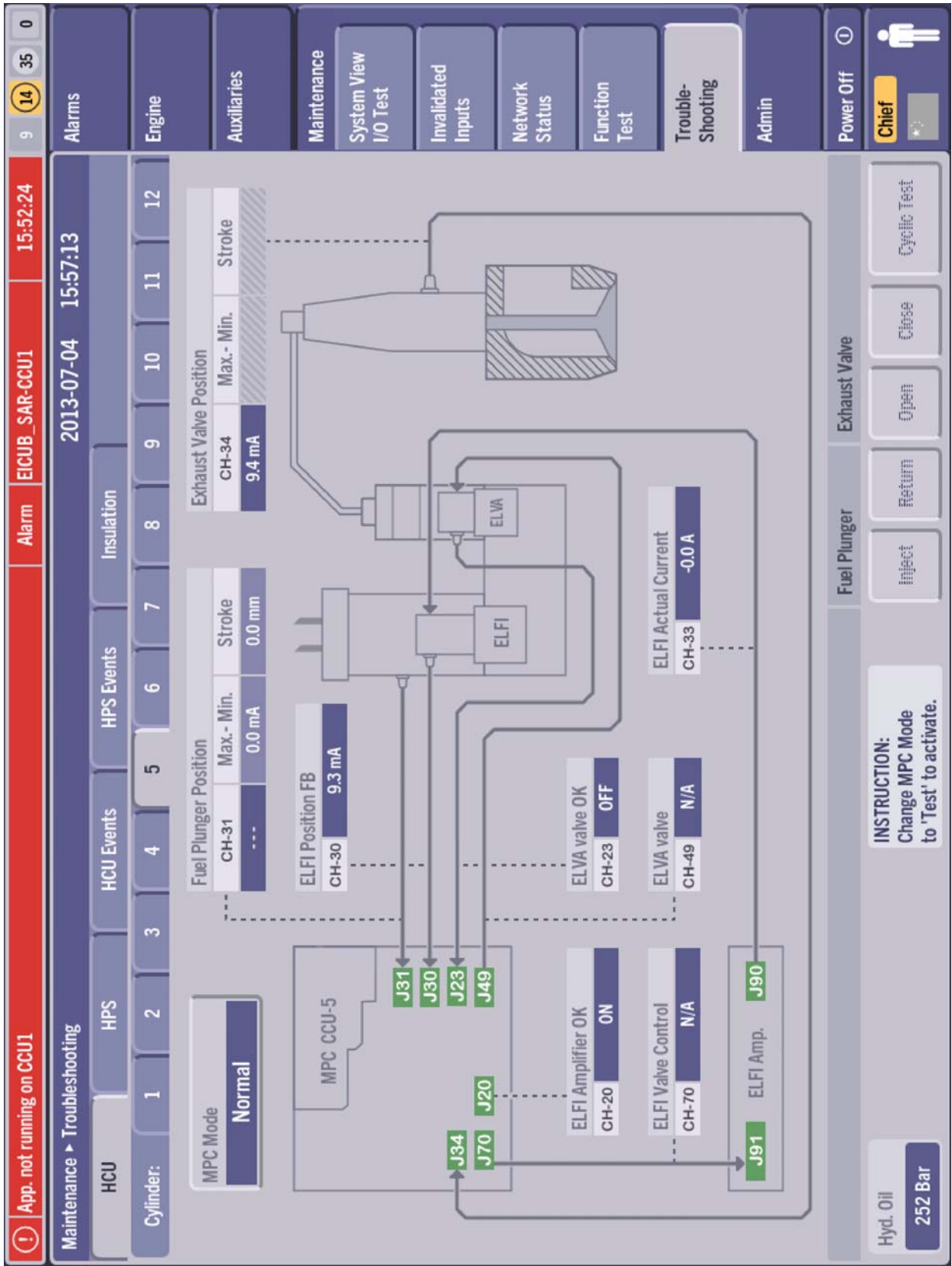
MOP Troubleshooting

Drawing
6655-0204-0003



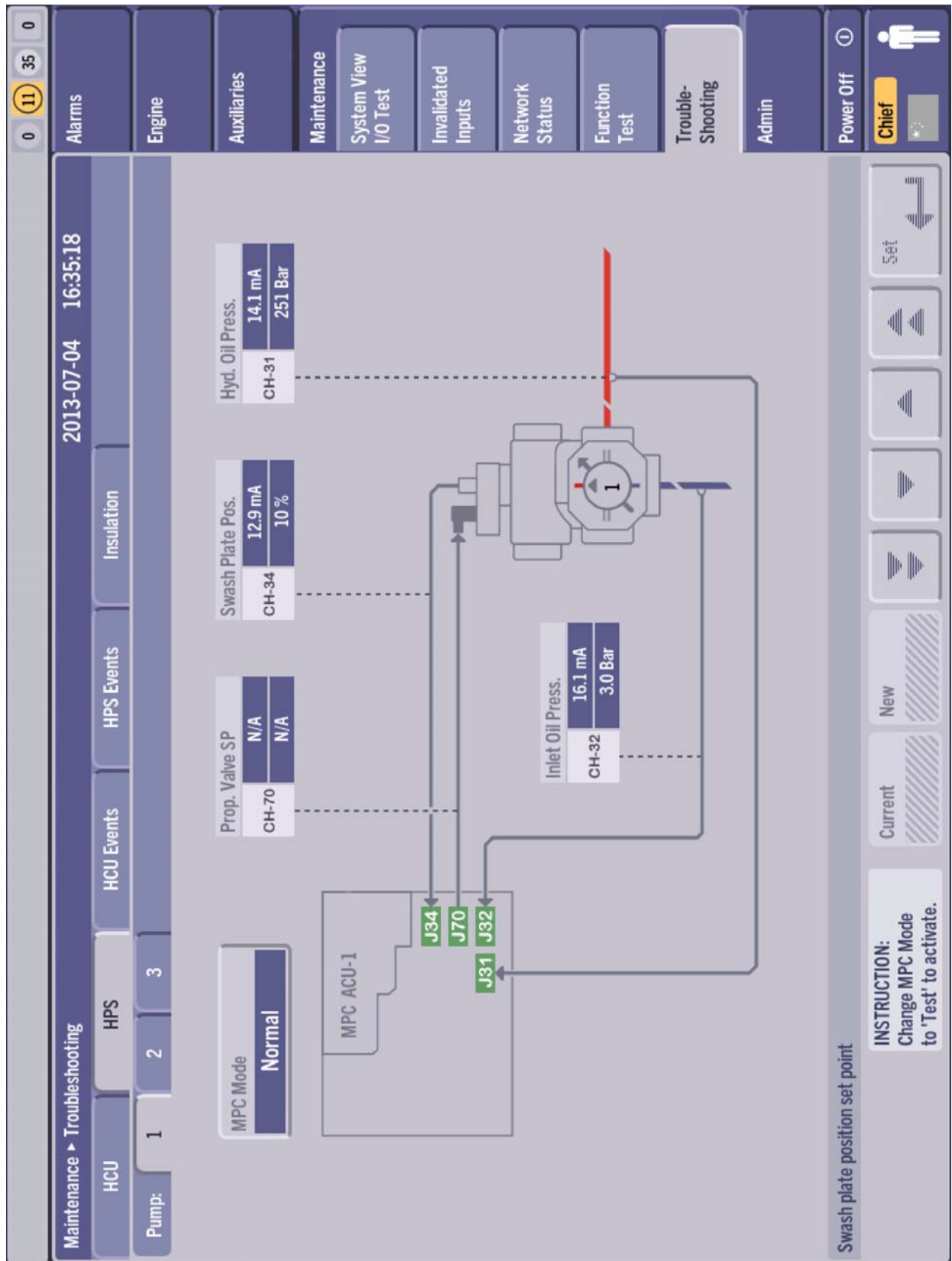


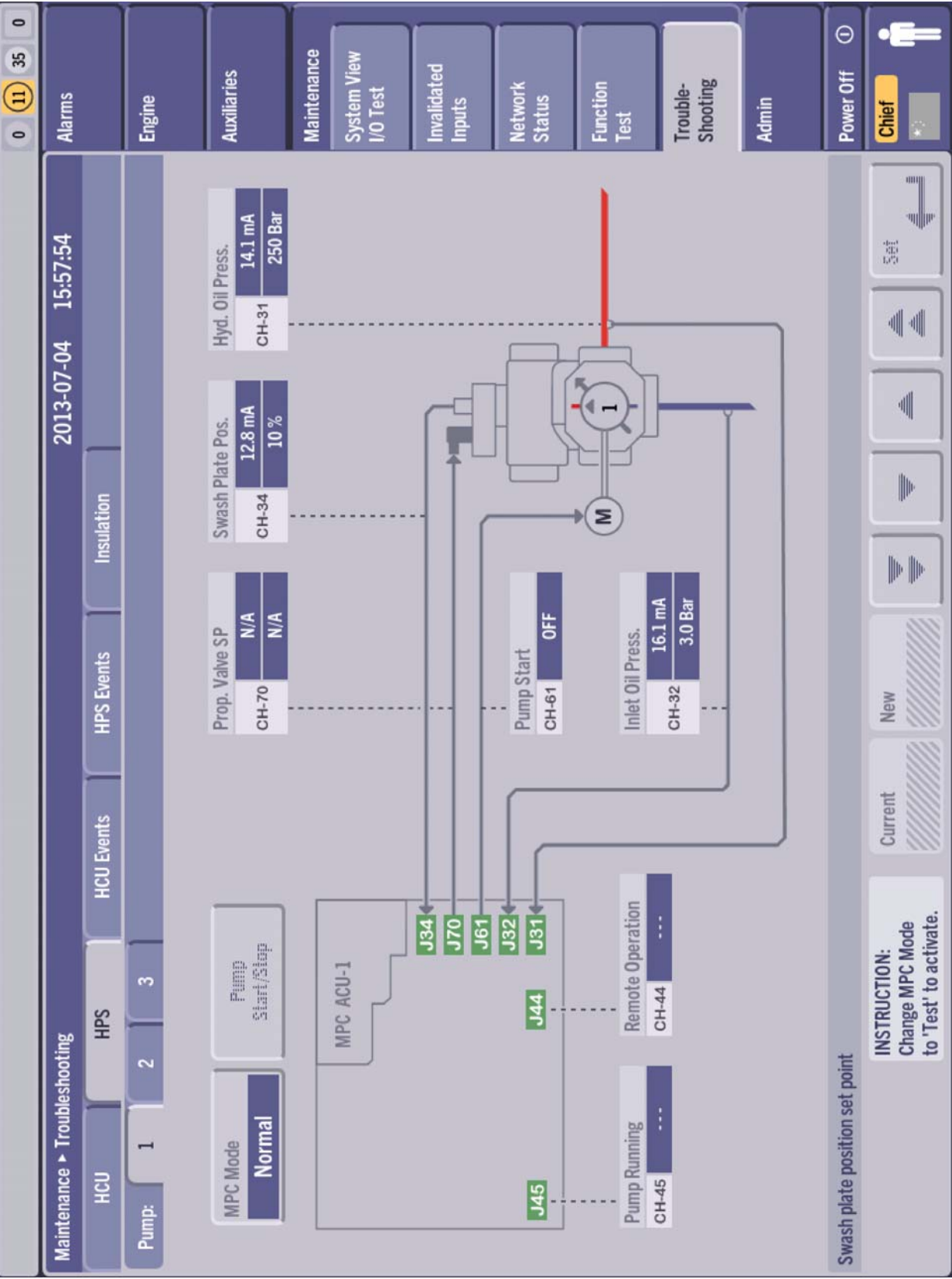




MOP Troubleshooting

Drawing
6655-0204-0003





MOP Troubleshooting

Drawing
6655-0204-0003



2013-10-21 - en



MOP Troubleshooting

! App. not running on CCU1		Normal		EICUB_SAR-CCU1	167	(11)	35	0
Maintenance ▶ Troubleshooting								
2013-07-04 16:27:42								
HCU			HPS	HCU Events	HPS Events		Insulation	
Unit ID	Insulation [kOhm]	Noise Pulse Counter	Unit ID	Insulation [kOhm]	Noise Pulse Counter			
ACU1	120	0	CCU1	120	0			
ACU2	120	0	CCU2	120	0			
ACU3	120	0	CCU3	120	0			
ECUA	120	0	CCU4	120	0			
ECUB	120	0	CCU5	120	0			
EICUA	120	0	CCU6	120	0			
EICUB	120	0	CCU7	120	0			
			CCU8	120	0			
			CCU9	120	0			
			CCU10	120	0			
			CCU11	120	0			
			CCU12	120	0			
Alarms								
Engine								
Auxiliaries								
Maintenance								
System View I/O Test								
Invalidated Inputs								
Network Status								
Function Test								
Trouble-Shooting								
Admin								
Power Off ⓘ								
Chief								

Run In Parameterset not Valid

!

Normal

ECUA_020125L

16:39:32

24

17

34

0

Admin ▶ Set Time

2013-07-04 18:30:44

Alarms

Engine

Auxiliaries

Maintenance

Admin

Set Time

Version

UTC Date/Time

2013-07-04 18:30:44

UTC Time Displayed

Local Date/Time

2013-07-04 18:30:44

Local Time Displayed

Power Off

Chief

①

Drawing

6655-0205-0006

MOP Set Time

1 (3)

Run In Parameterset not Valid

Normal

ECUA_020125L

16:39:32

24

17

34

0

Admin ▶ Set Time

Alarms

Engine

Auxiliaries

Maintenance

Admin

Set Time

Version

Power Off ⓘ

Chief ⓘ

2013-07-04 18:30:56

Local Date/Time

2013-07-04 18:30:56

Local Time Displayed

UTC Date/Time

2013-07-04 18:30:56

UTC Time Displayed

UTC Date/Time

New Date/Time

2013-07-04 18:30:00

Set

⌂

✕

! Run In Parameterset not Valid

Normal

ECUA_020125L

16:39:32

24

17

34

0

Admin ▶ Set Time

2013-07-04 18:31:02

Alarms

Engine

Auxiliaries

Maintenance

Admin

Set Time

Version

UTC Date/Time

2013-07-04 18:31:02

UTC Time Displayed

Local Date/Time

2013-07-04 18:31:02

Local Time Displayed

Local Date/Time

2013-07-04 18:30:58

Offset

00:00

Hours

-1

+1

Minutes

-15

-5

+5

+15

Set

X

Power Off

Chief

Set Time



0

5

28

0

Admin ▶ Version

2000-02-09 21:03:17

Alarms

Product Name & Version

Engine Group No.

Engine Builder

Eng. No.

ME-ECS-SW-1312-1.9

Simulator

MD-CPH

8

IMO No.

Sim 8

Controller Unit

Parameters Check Sums

ID	Addr.	Type	User	Chief	Service	Design	IMO Design	IMO Chief
ACU1	224	ACU	0	131	29939	4166	0	0
ACU2	225	ACU	0	130	29938	4169	0	0
ACU3	226	ACU	0	172	29217	4145	0	0
CCU1	240	CCU	0	2	43913	67121	16685	17222
CCU2	241	CCU	0	1	48560	65594	16685	14325
CCU3	242	CCU	0	1	48560	65594	16685	14325
CCU4	243	CCU	0	636	48950	65595	16685	14958
CCU5	244	CCU	0	239	48896	65595	16685	14561
CCU6	245	CCU	0	238	48896	65595	16685	14561
CCU7	246	CCU	0	286	48786	65595	16685	14609
CCU8	247	CCU	0	511	48971	65595	16685	14834
CCU9	248	CCU	0	608	48975	65595	16685	14931
CCU10	249	CCU	0	512	48778	65595	16685	14835
CCU11	250	CCU	0	6	48800	65596	16685	14329
CCU12	251	CCU	0	612	48803	65595	16685	14935
ECUA	208	ECU	0	16189	109034	60071	43940	22401
ECUB	209	ECU	0	16191	109245	60071	43940	22401

Refresh

Export Version

Export SPAF

▶

⏏

Power Off

Chief

Suprv. Ch31,1201-3,Hydraulic Pressu

Normal

ACU3_1201-304

00:10:41

53

22

28

0

Admin ▶ Version

2000-05-17 20:27:05

Product Name & Version
ME-ECS-SW-1312-1.9

Engine Group No.
Simulator

IMO No.
Sim 8

Engine Builder
MD-CPH

Eng. No.
8

Parameters Check Sums									
Controller Unit	ID	Addr.	Type	User	Chief	Service	Design	IMO Design	IMO Chief
	ACU1	224	ACU	0	132	29939	4166	0	0
	ACU2	225	ACU	0	130	29938	4169	0	0
	ACU3	226	ACU	0	172	29218	4145	0	0
	---	240	---	---	---	---	---	---	---
	CCU2	241	CCU	0	1	48940	65594	16685	14325
	CCU3	242	CCU	0	1	48940	65594	16685	14325
	CCU4	243	CCU	0	636	49330	65595	16685	14958
	CCU5	244	CCU	0	239	49276	65595	16685	14561
	CCU6	245	CCU	0	238	49276	65595	16685	14561
	CCU7	246	CCU	0	286	49166	65595	16685	14609
	CCU8	247	CCU	0	511	49351	65595	16685	14834
	CCU9	248	CCU	0	608	49355	65595	16685	14931
	CCU10	249	CCU	0	512	49158	65595	16685	14835
	CCU11	250	CCU	0	6	49180	65596	16685	14329
	CCU12	251	CCU	0	612	49183	65595	16685	14935
	ECUA	208	ECU	0	12831	108856	60071	43940	21894
	ECUB	209	ECU	0	13340	109067	60071	43940	22401

Export Version

TIP: Remove USB storage to save to HDD

USB & HDD E:\

Ready to save

Save

X

Alarms

Engine

Auxiliaries

Maintenance

Admin

Set Time

Version

Power Off

Operator

0

5

28

0

Admin ▶ Version

2000-02-09 21:03:17

Alarms

Engine

Auxiliaries

Maintenance

Admin

Set Time

Version

Power Off ⓘ

Chief 

Product Name & Version

ME-ECS-SW-1312-1.9

Engine Group No.

Simulator

IMO No.

Sim 8

Engine Builder

MD-CPH

Eng. No.

8

Controller Unit

Parameters Check Sums

ID	Addr.	Type	User	Chief	Service	Design	IMO Design	IMO Chief
ACU1	224	ACU	0	131	29939	4166	0	0
ACU2	225	ACU	0	130	29938	4169	0	0
ACU3	226	ACU	0	172	29217	4145	0	0
CCU1	240	CCU	0	2	43913	67121	16685	17222
CCU2	241	CCU	0	1	48560	65594	16685	14325
CCU3	242	CCU	0	1	48560	65594	16685	14325
CCU4	243	CCU	0	636	48950	65595	16685	14958
CCU5	244	CCU	0	239	48896	65595	16685	14561
CCU6	245	CCU	0	238	48896	65595	16685	14561
CCU7	246	CCU	0	286	48786	65595	16685	14609
CCU8	247	CCU	0	511	48971	65595	16685	14834
CCU9	248	CCU	0	608	48975	65595	16685	14931
CCU10	249	CCU	0	512	48778	65595	16685	14835
CCU11	250	CCU	0	6	48800	65596	16685	14329
CCU12	251	CCU	0	612	48803	65595	16685	14935
ECUA	208	ECU	0	16189	109034	60071	43940	22401
ECUB	209	ECU	0	16191	109245	60071	43940	22401

Export SPAF

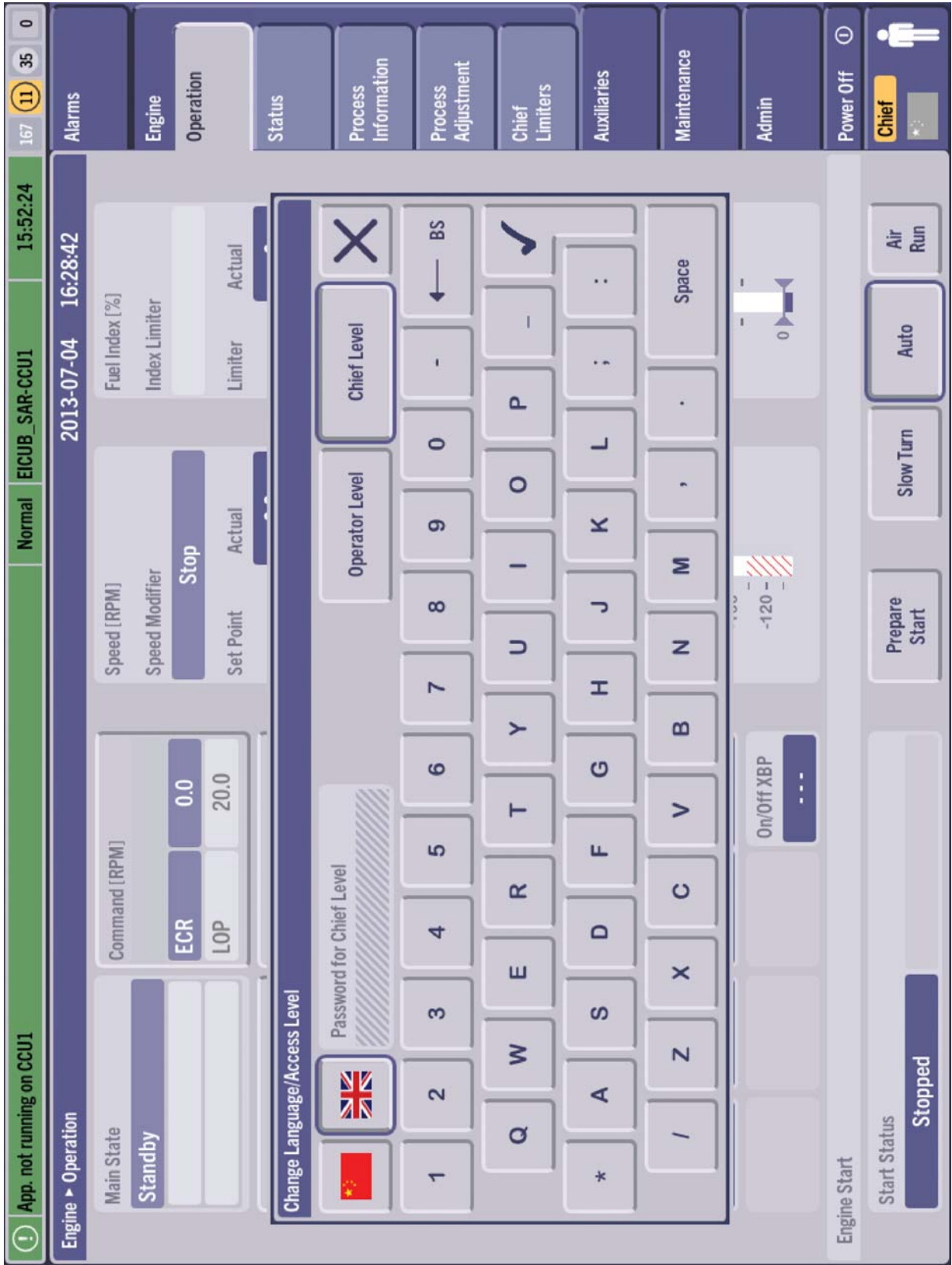
TIP: Remove USB storage to save to HDD

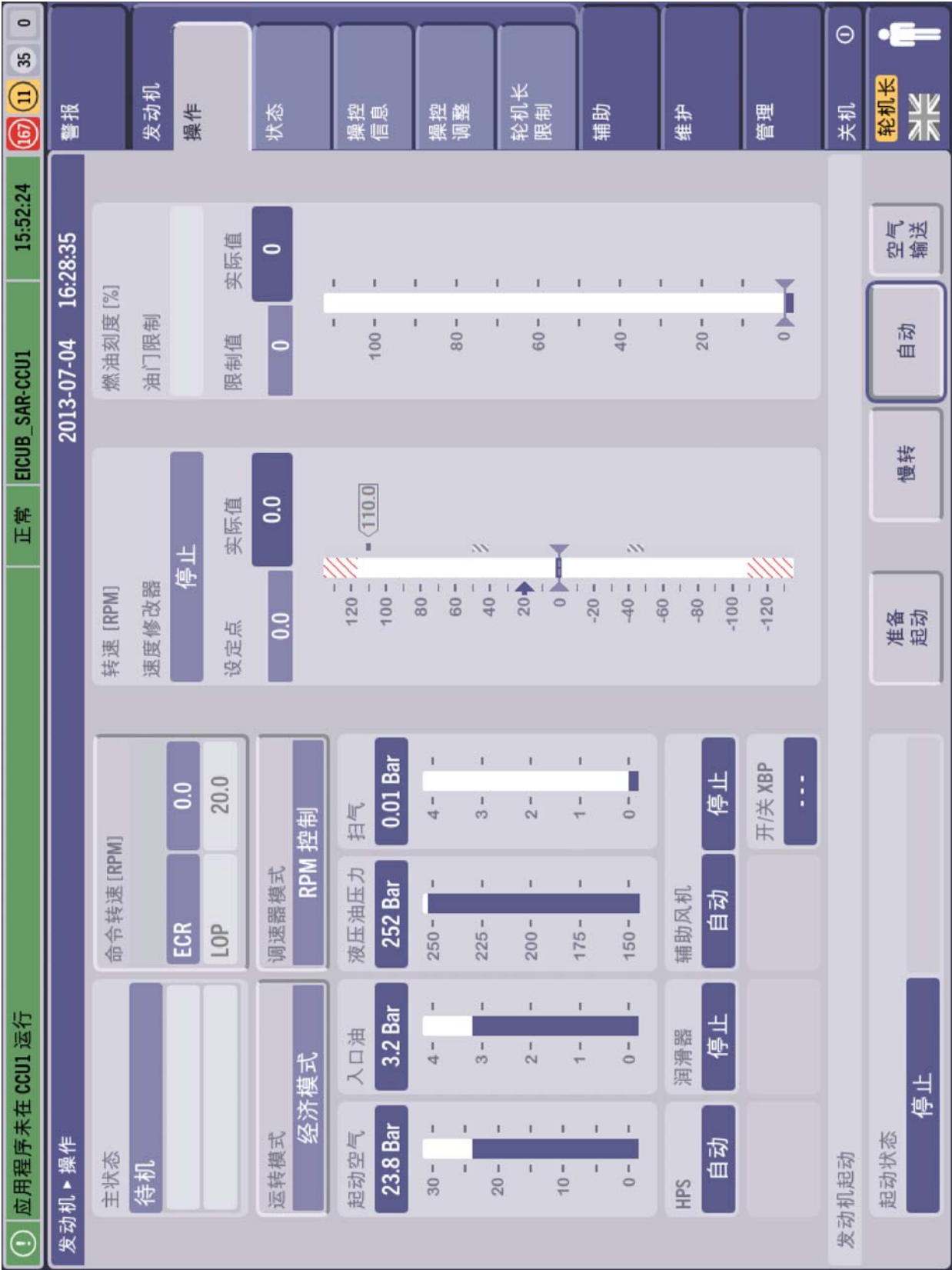
USB & HDD E:\

Ready to save

Save

✕





Case X - Z

Component	Case X		Case Y ¹⁾			Case Z
	Engines with one T/C	Engines with two or more T/C	Engines with one T/C		Engines with two or more T/C	(Engines with two or more T/C)
			With by-pass	Without by-pass		
Rotor ²⁾	Locked	Locked	Locked	Removed	Locked	
Nozzle ring ²⁾				Removed		
Compressor outlet		Orifice plate			Orifice plate	Blanking plates
Turbo inlet					Orifice plate	Blanking plates
Turbo outlet						Blanking plates
Compensator after compressor outlet	Removed		Removed	Removed		
By-pass blanking plate			Removed			
T/C housing ²⁾				Blanking plates		
Max % of MCR load/ (speed):						
1 T/C of 1	15/(53) ³⁾	-	20-/(58) ⁴⁾ 20-25 ⁴⁾ (58-63)	15/(53) ³⁾	-	-
1 T/C of 2 ⁹⁾	-	15/(53) ^{3) 5)}	-	-	50/(79) ^{3) 6)}	50/(79) ^{3) 6)}
1 T/C of 3*	-	20/(58) ^{3) 5)}	-	-	66/(87) ^{3) 6)}	66/(87) ^{3) 6)}
1 T/C of 4*	-	20/(58) ^{3) 5)}	-	-	75/(91) ^{3) 6)}	75/(91) ^{3) 6)}
1 Aux.bl. of 2 ⁷⁾	10/(46) ⁴⁾	10/(46) ⁴⁾	15/(53) ⁴⁾	10/(46) ⁴⁾	8)	8)
1 Aux.bl. of 3 ^{7) *}	-	15/(53) ⁴⁾	-	-	8)	8)
1 Aux.bl. of 4 ^{7) *}	-	15/(53) ⁴⁾	-	-	8)	8)

*) These items are NOT valid for engines 26-46 bore.

1) The engine builder will, in each specific case, be able to give further information about engine load possibilities and temperature levels.

2) See T/C manual.

3) The exhaust temperatures must not exceed the value(s) stated in *description 7045-0100*. Also see the note in *description 6645-0320, Item 1, 'General'*.

4) The exhaust temperature must not exceed a) 430°C b) 400°C for 26 - 46 bore engines.

5) This is due to the loss of exhaust gas through the damaged turbocharger.

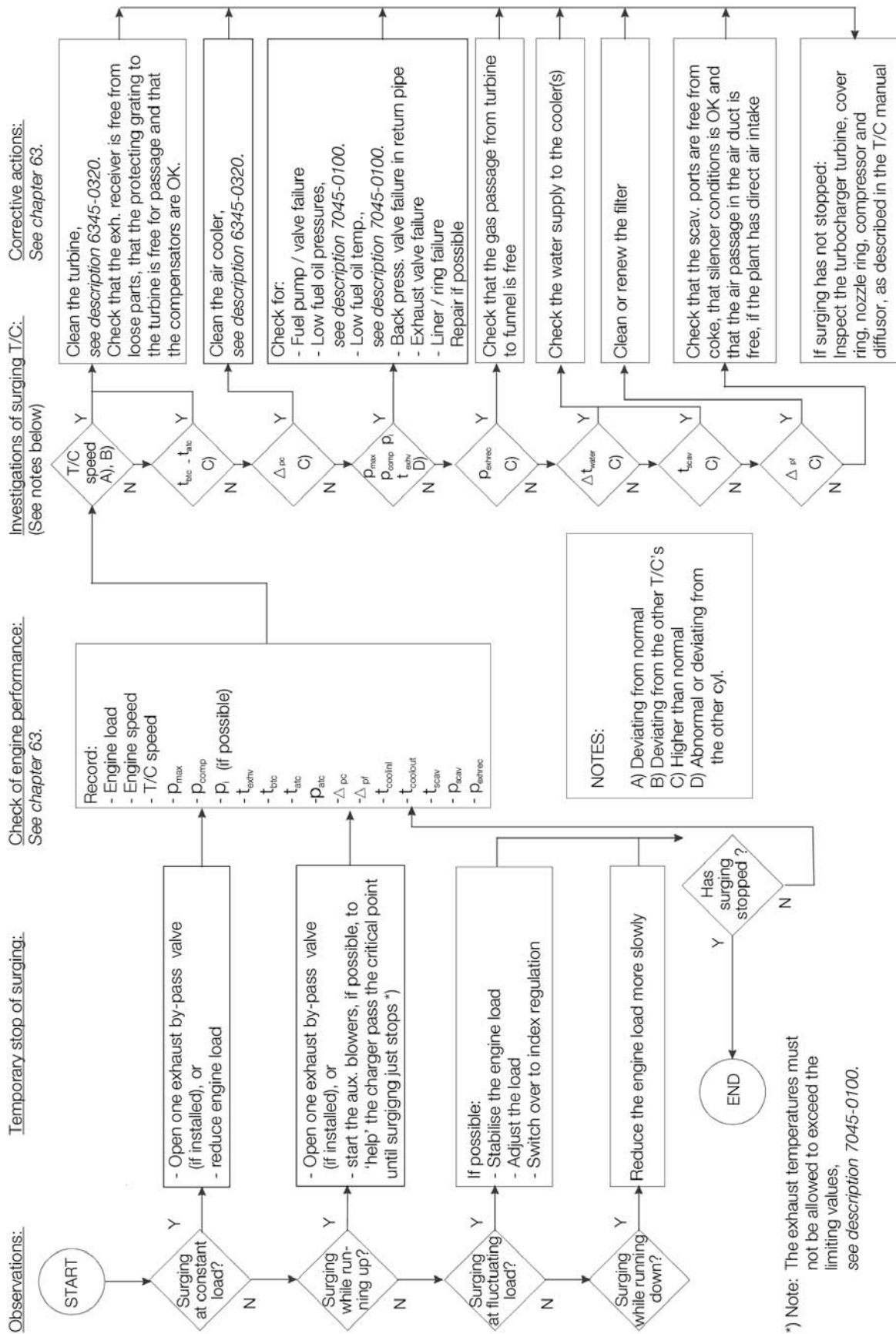
6) The mentioned exhaust temperature limit is an average value for the whole load range.

7) Simultaneous with 1 T/C out of operation. There are no load restrictions with 1 aux. blower out of operation and all T/C's in operation.

Cutting turbochargers out of action

Drawing
6655-0220-0003

- 8) See the limits given under '1 T/C of 2', '1 T/C of 3', and '1 T/C of 4', above.
- 9) Running with one T/C out of two increases the cylinder pressure at low load and may increase the torsional stresses with approx. 30%. The torsional vibrations in the shafting system should therefore be evaluated with this increase. Engines with barred speed range can be operated below the barred speed range. In case of emergency running it can be necessary to pass the barred speed range. To protect the intermediate shaft, the number of passages should be kept to a minimum – preferably one time up and one time down.
Once the vessel gets close to port - speed should be kept below the barred speed range.



Safety**Precautions**

For detailed sketch
see 0545-0100

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off control air supply
☐	Shut off air supply to exhaust valve - Only when stopped lubricating oil pumps
☐	Shut off fuel oil

**Data**

Ref.	Description	Value	Unit
-	Table is empty on purpose. No Data needed.	-	-

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

Plate	Item No.	Description
2270-0200	125	Tool for emergency opening exhaust valve
2270-0200	174	Lifting tool for roller guide
6670-0100	013	Cable, complete

For all special running conditions, see description 6645-0320.

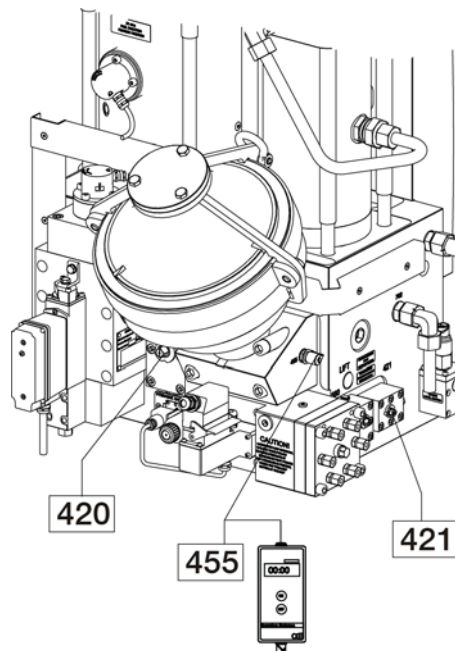
Under conditions where it is necessary to run the engine with an open exhaust valve, an exhaust emergency opening tool must be mounted as follows.

1. **Stop the engine**

Mount a pressure gauge at minimess point No. **455**. Check the pressure.

Close valve **420** and open valve **421** on the hydraulic block for the cylinder concerned.

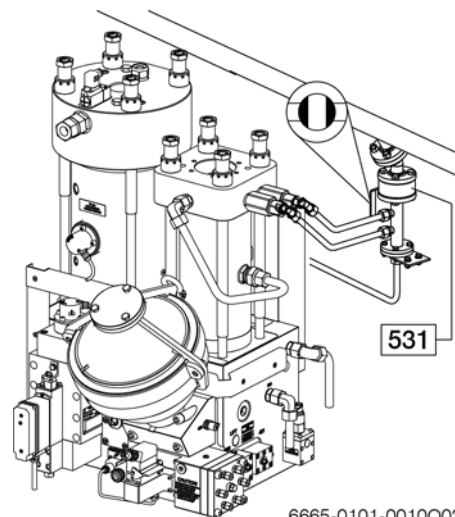
Check that the hydraulic cylinder unit is depressurised.



4565-0501-0010C01

2. **Close off oil supply**

Shut off the oil damper oil supply by closing valve **531** on the hydraulic cylinder unit.

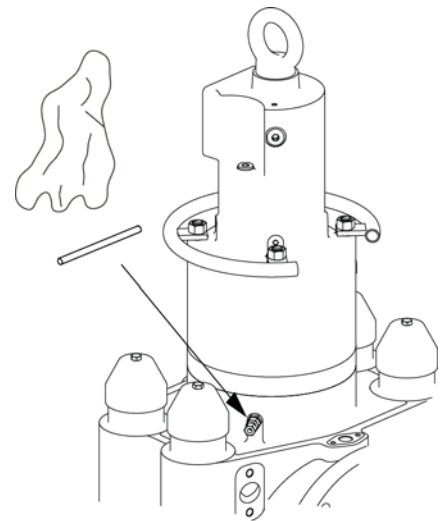


6665-0101-0010002

3. Disconnect the exhaust valve air supply

Shut off and disconnect the exhaust valve air supply.

Use a mandrel to puncture the non-return valve. Cover the valve with a cloth to protect against oil spray.



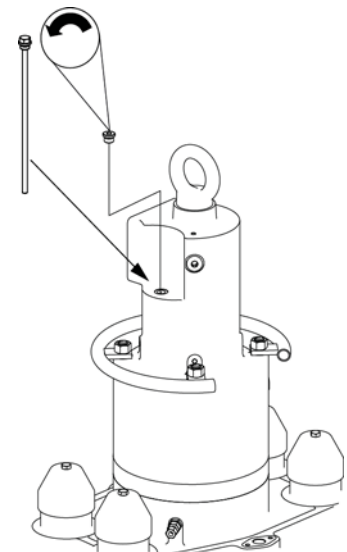
6665-0101-0010003

4. MOP panel

Check on the MOP panel that the exhaust valve spindle has moved to the open position.

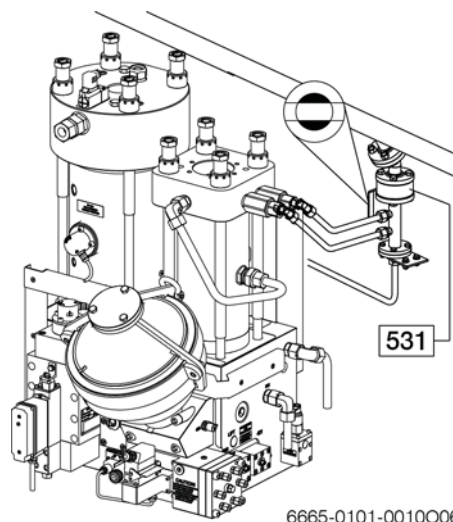
5. Mount the emergency opening tool

Remove the plug screw and mount the tool for emergency opening of exhaust valve.

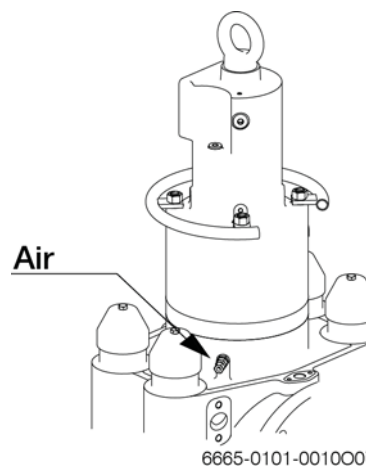


6665-0101-0010005

6. Open oil damper oil supply Open the oil damper oil supply by opening valve **531** on the hydraulic block.



7. Reconnect air supply Reconnect the exhaust valve air supply.



8. CCU Failure: In case of CCU failure (and the CCU can not be changed immediately), activation of the ME lubricator can be achieved as follows.

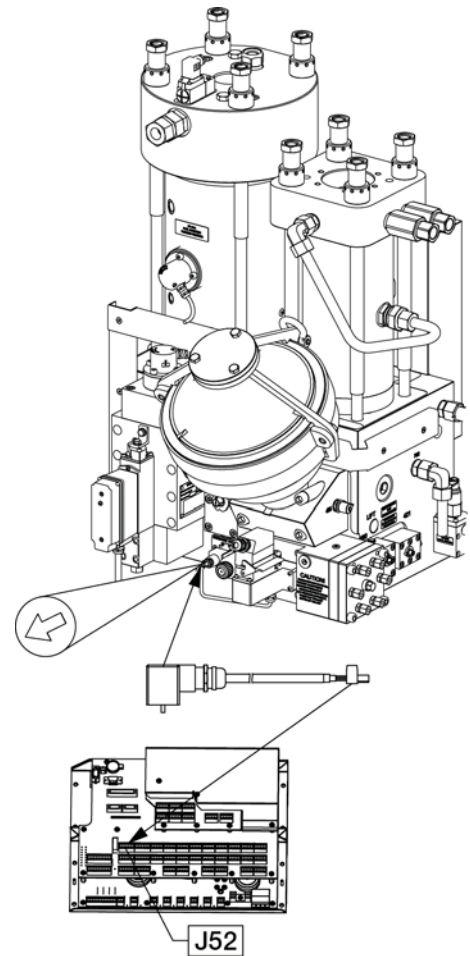
NOTICE

In case of CCU failure, the engine is running in "Slow Down" mode.

9. Temporary backup cable

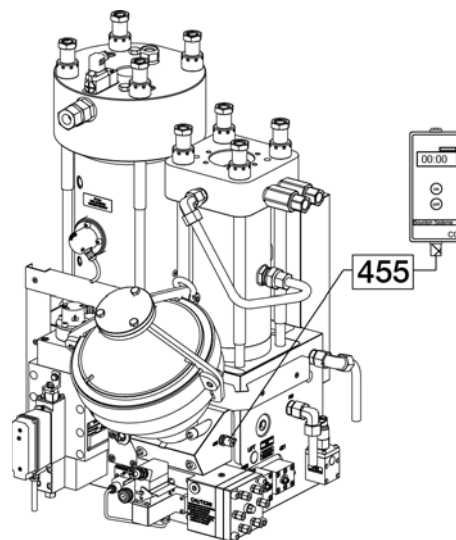
Remove the plug from the cylinder lubricator solenoid valve. Connect the plug on the ECU temporary backup cable for lubricator with the solenoid valve.

Connect the other end of the ECU temporary backup cable with the ECU **A** or **B** MPC board.



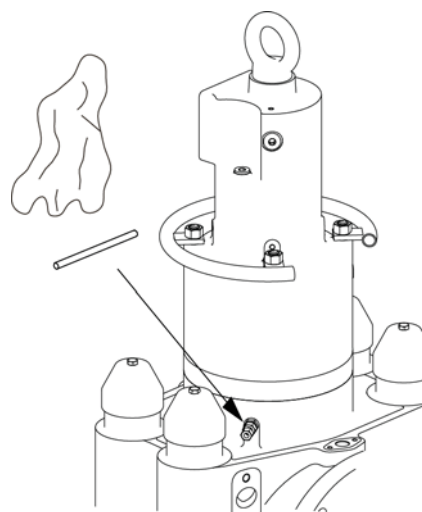
6665-0101-0010009

10. Return to normal When the special running with open exhaust valve is finished, the engine must be brought back to normal operation condition.
11. Stop the engine Mount a pressure gauge at minimess point No. **455**. Check that the hydraulic cylinder unit is depressurised.
- Check that valve **531** is closed.



6665-0101-0010010

12. Shut off and disconnect the exhaust valve air supply Use a mandrel to puncture the non-return valve. Cover the valve with a cloth to protect against oil spray.



6665-0101-0010003

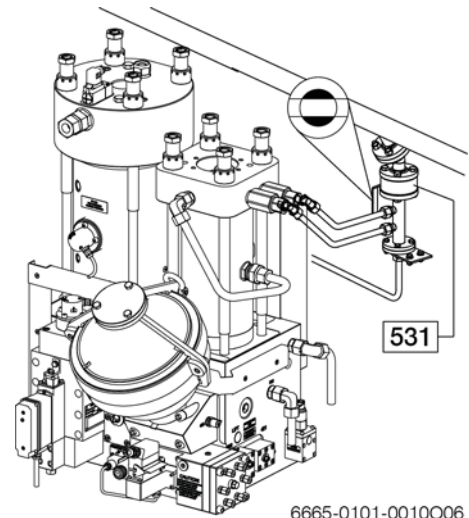
13. Check exhaust valve spindle Check that the exhaust valve spindle has moved to the open position.
14. Remove the tool for emergency opening of exhaust valve and remount the plug screw. Remove the tool for emergency opening of exhaust valve and remount the plug screw.

15. Open valve 531

Open the oil damper oil supply by opening valve **531** on the hydraulic block.

Reconnect the exhaust valve air supply.

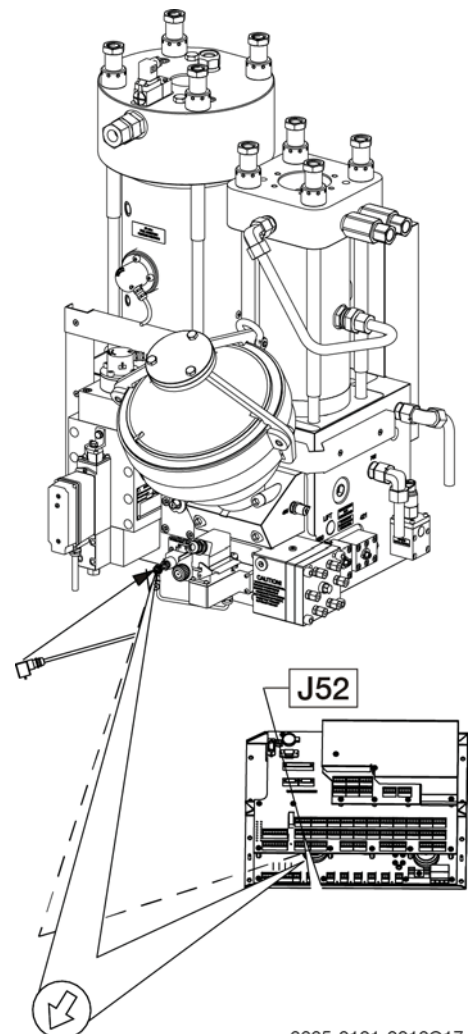
Close valve **421** and open valve **420** on the hydraulic block for the cylinder concerned.



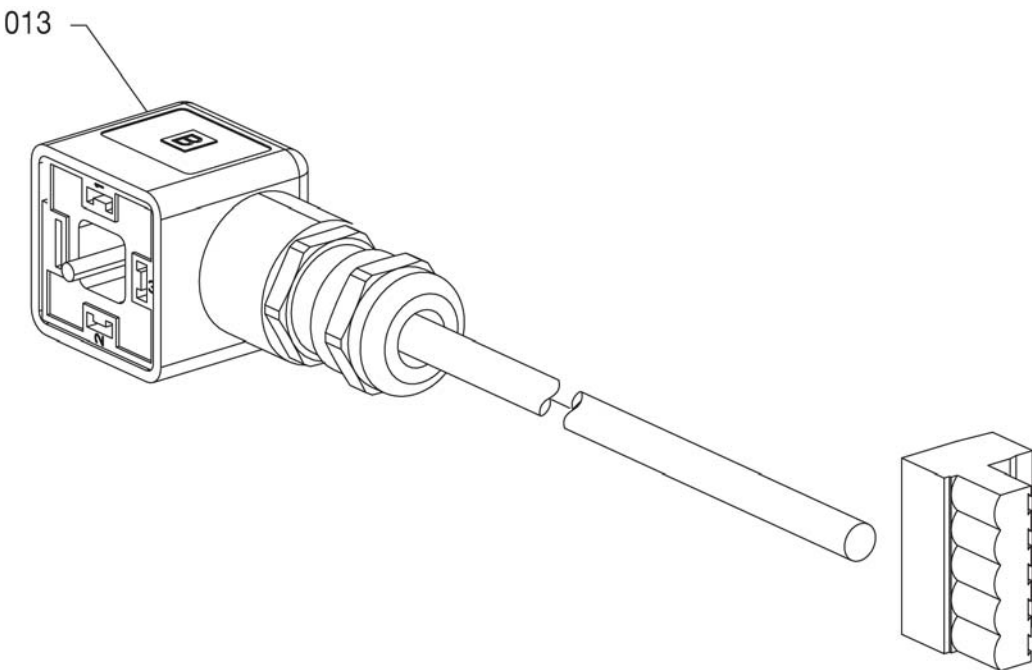
6665-0101-0010006

16. Remove cable between the CCUs

When the CCU has been replaced, restore the cylinder lubricator to normal by removing the ECU temporary backup cable and reconnecting the normal plug with the cylinder lubricator solenoid valve.



6665-0101-0010017

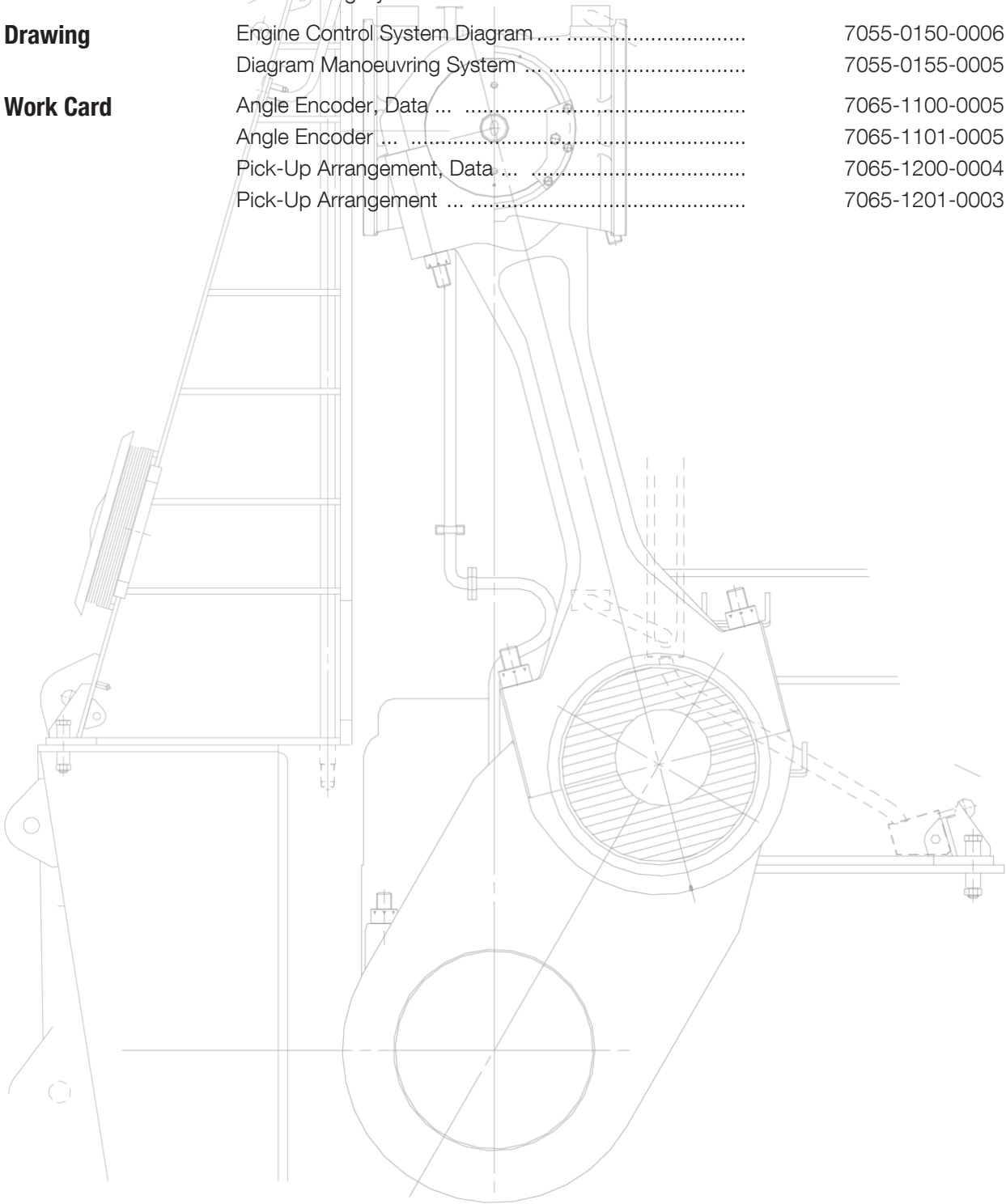


Plate

6670-0100-0001.0

[illegible]

Preface Chapter	Control System	7040-0100-0001
Description	Guidance Value Automation	7045-0100-0011
	Instrumentation	7045-0200-0005
	Manoeuvring System	7045-0300-0001
Drawing	Engine Control System Diagram	7055-0150-0006
	Diagram Manoeuvring System	7055-0155-0005
Work Card	Angle Encoder, Data	7065-1100-0005
	Angle Encoder	7065-1101-0005
	Pick-Up Arrangement, Data	7065-1200-0004
	Pick-Up Arrangement	7065-1201-0003



PMI-System

See separate instructions for operating the PMI-system (option).

1 General Basis for Guidance Values

The values stated in the list on the following pages refer to layout point L1, (Nominal max. continuous rating "MCR" and are for engines running with UNI-Lubricating oil system without lubricating oil booster pump and with common turbocharger lubricating oil system.

Furthermore, the lubrication oil inlet pressure sensors Nos. 8108 and 8109, refer to a level 1800 mm above crankshaft centre line. In case sensor(s) is(are) placed at a different level the alarm slow down and shut down setpoints are to be corrected correspondingly.

NOTICE

The values are for guidance only, in connection with the 'List of Capacities of Auxiliary Machinery' for dimensioning of auxiliary systems, and must not be used for determining the extent of the alarms or actions.

The item numbers refer to the drawings showing the extent and placement of sensors for standard alarms and indicators on the engine, if the signal equipment is fitted. *See description 7045-0200*, further on.

For sensors placed in the systems outside the engine, see the actual pipe arrangements in the appropriate chapters.

If the engine is provided with special equipment, some values may differ from this list. The correct values shall in such a case be obtained from the Plant Installation Drawings.

The engine slow-down level corresponds to 40% of nominal MCR r/min.

Unless otherwise specified, the pressures are stated in bar gauge.

Engines specified and optimised at derated power may have other normal service values depending on layout power/revolutions and application.

For derated engines, the testbed/trial values should be used.

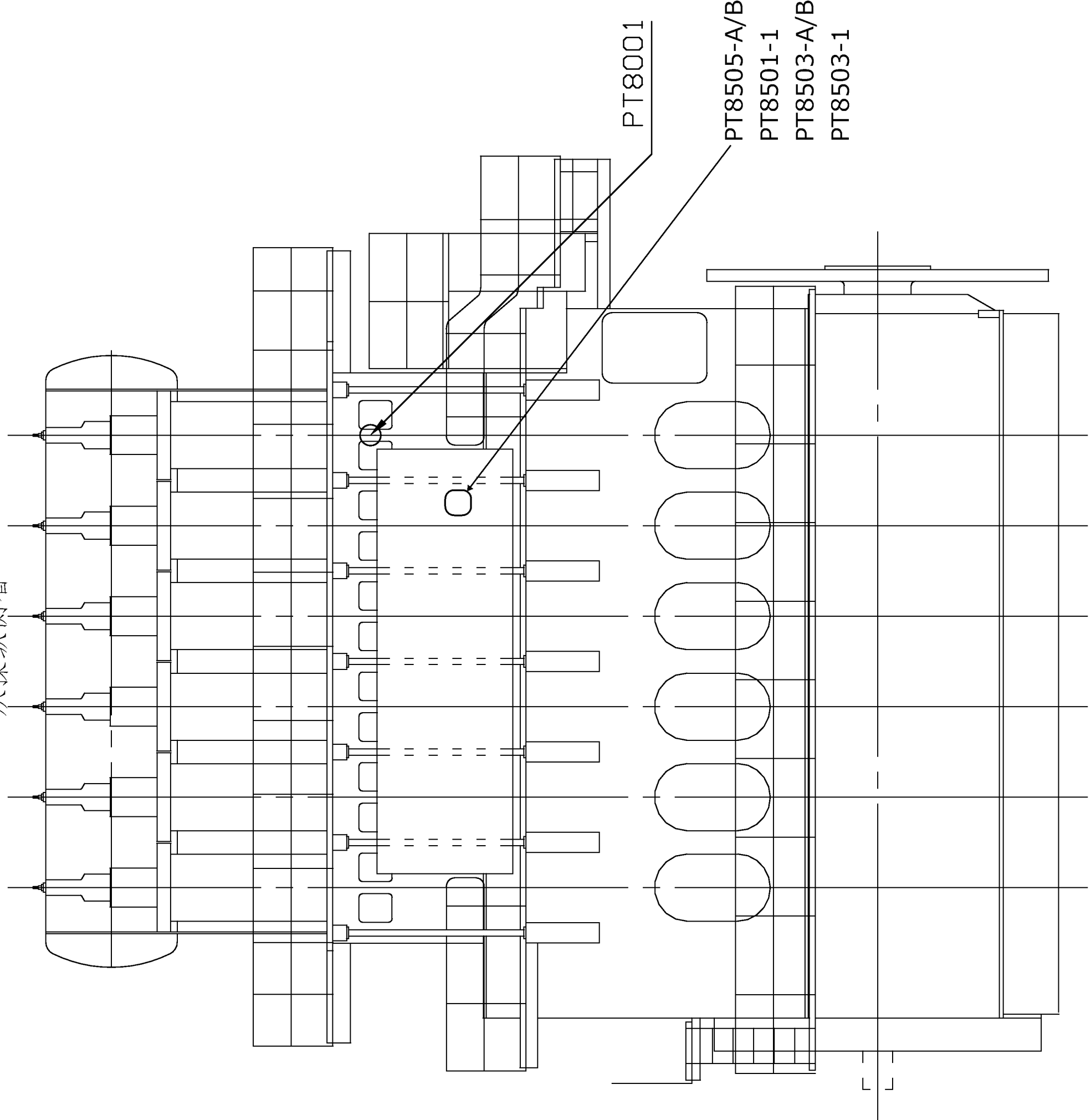
CAUTION

Attention must be paid to the temperature levels stated under Nos. 8120 to 8125 (incl.), as two different values have been indicated, one value for **metal temperature** and another for **oil outlet temperature**.

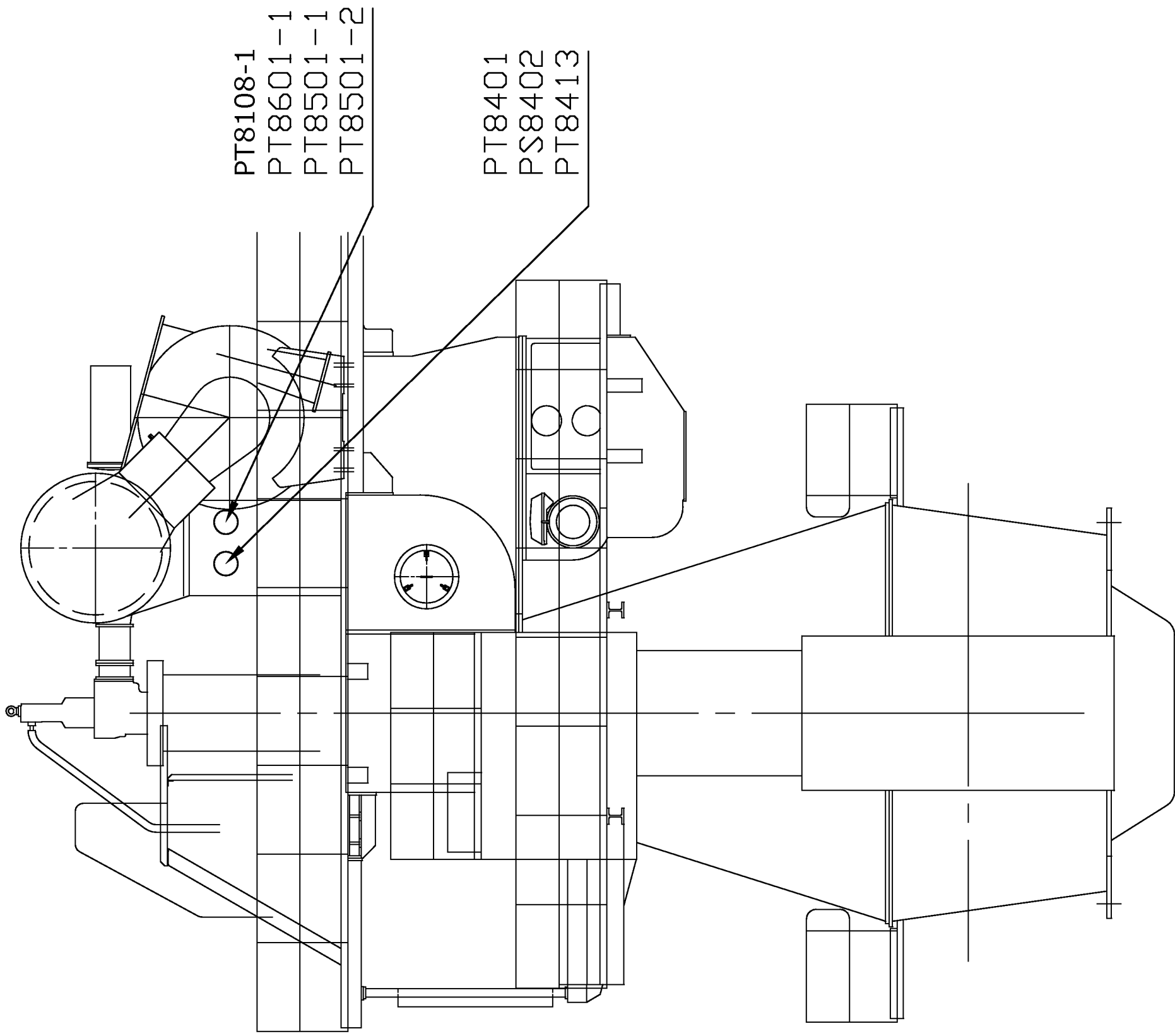
When setting the limits, maximum limits must be set at rising parameter and minimum limits at falling parameter.

文件说明 Document Remarks		机 型 Eng. Type		CMD-MAN-B&W 6G60ME-C9.5		
		台 份 Set No.				
		工程编号 Engine No.				
		船 厂 Shipyard		NTS		
		船 号 Hull No.		0311113/14/15/16/17/18/19/20		
		船级社 Classification Society		ABS		
CMD-MAN B&W 6G60ME-C MK9.5 GUIDANCE VALUE AUTOMATION M-6 运行参数表						
						5
						4
						3
						2
TE8423-1, TE8701, TE8702, ZT8420, ST8801-1 are updated according to MDT's drawing. Add the sensors (PDT8606, TE8612, PT8706, PT8708, TT 8818, PT 8802, XT 8819) for EMS.						1
修 改 说 明 Corrected Description						
						5
						4
						3
						2
王勇 20171106	魏守刚 20171106	刘闯 20171106				1
易志银 20170308	王勇 20170308	杜清 20170308				0
编 制 Compiled	校 对 Checked	审 核 Confirmed	审 定 Approved	会 签 Countersigned	批 准 Authorized	版本号 C.No.
被替代文件编号 Replace No.		设计参考文件编号 Reference No.		页 数 Pages	1	总页数 Total Pages
 上海中船三井造船柴油机有限公司 CSSC-MES Diesel Co., Ltd.				文件编号 Document No.	D6519785-8.	

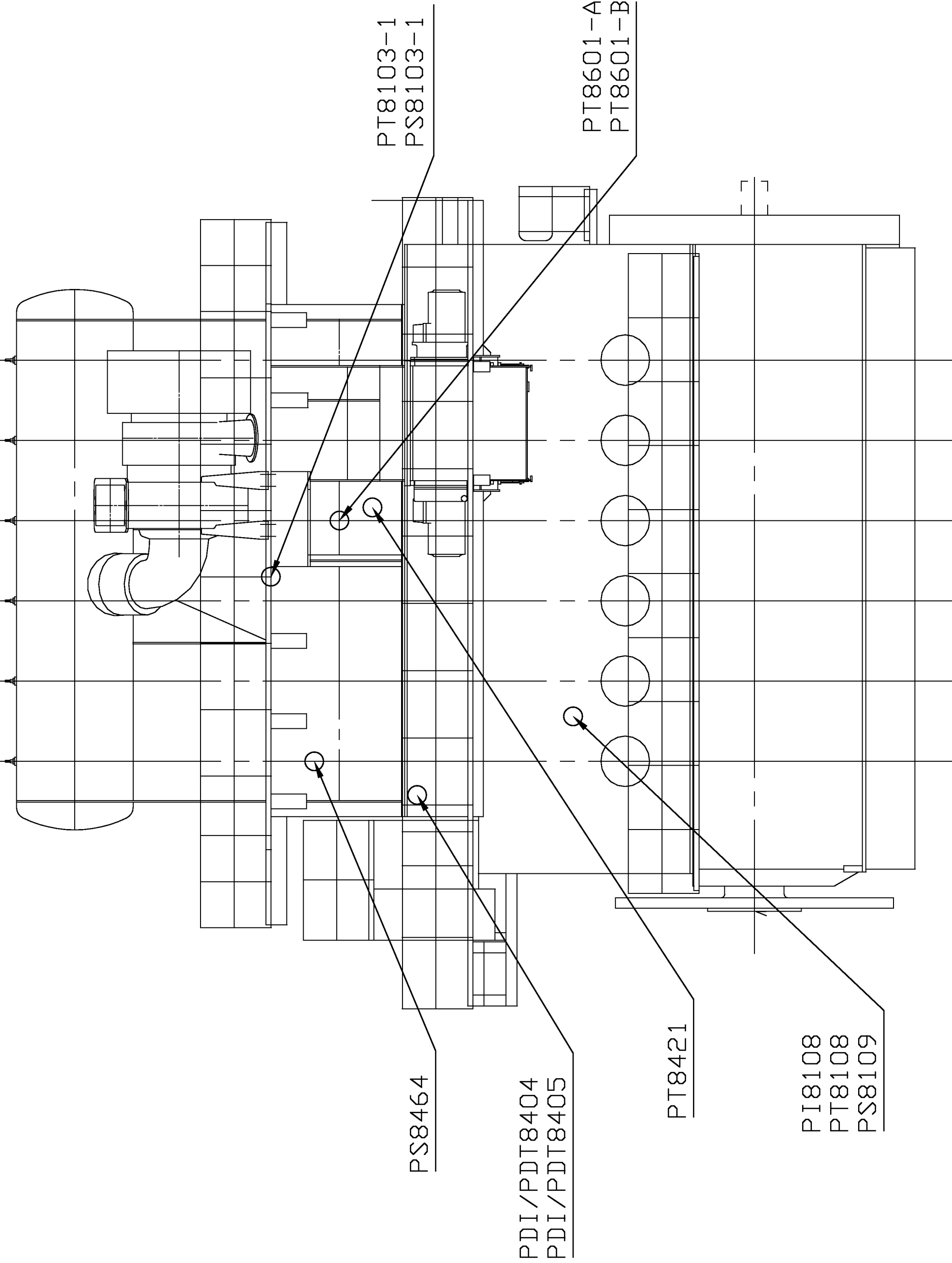
SEE FROM MANOEUVRE SIDE
从操纵侧看



SEE FROM AFTER
从推力端看

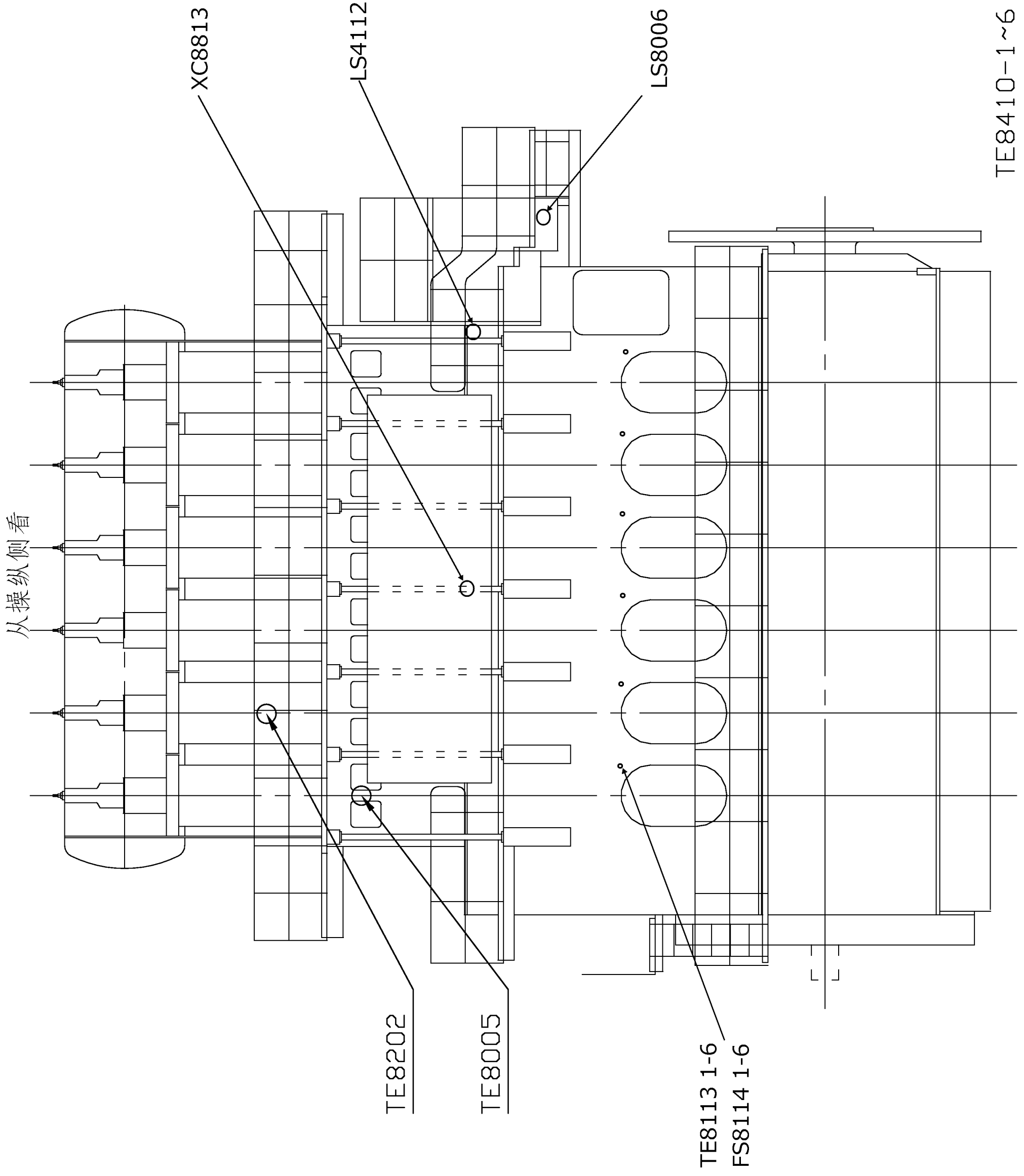


SEE FROM EXHAUST SIDE
从排气侧看

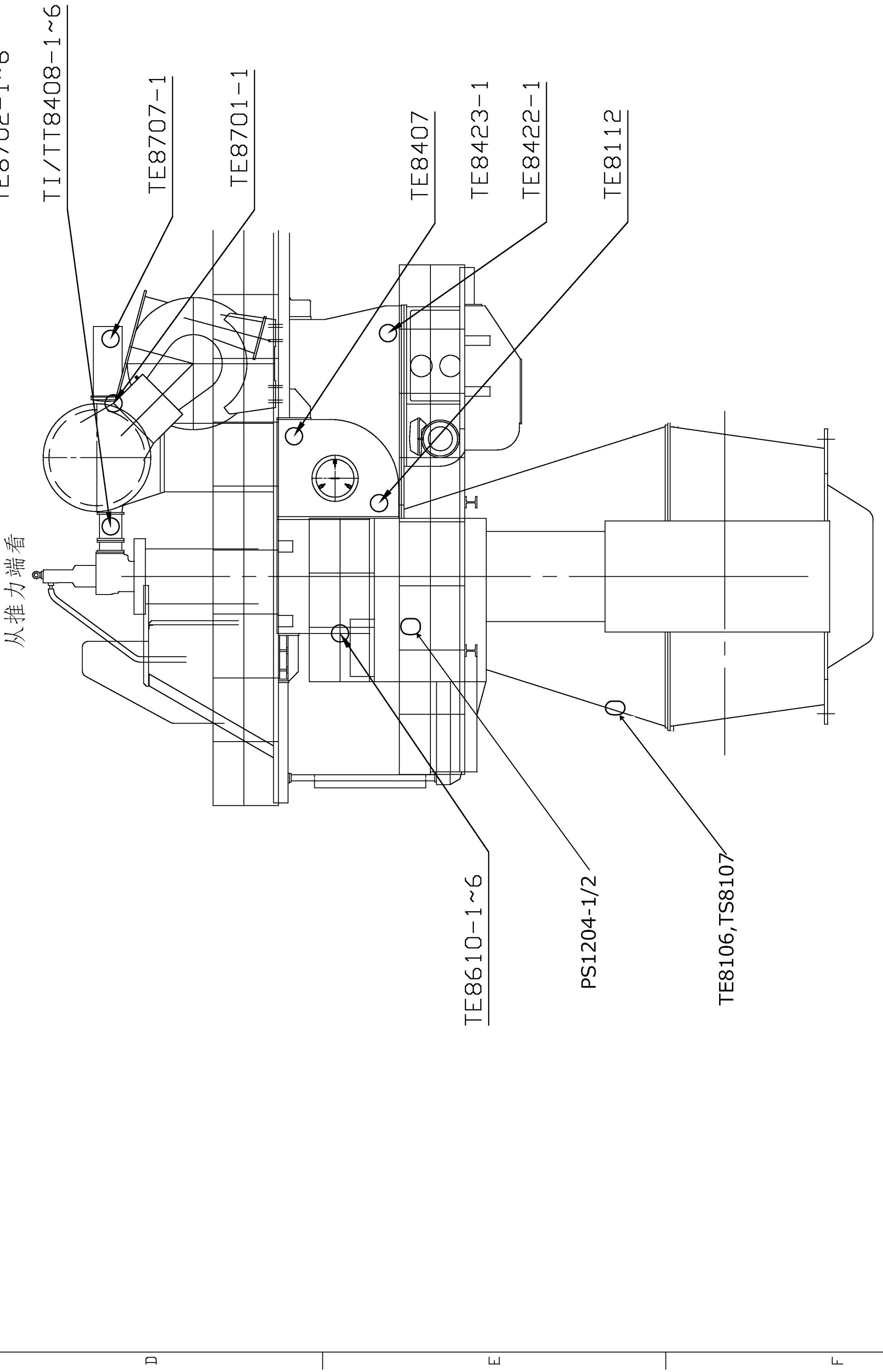


Basic Standards (M&B S&B & Suppl. Drawing No.)		EN21C Surf. roughness		Projection		Material / Blade	
		EN21F-m Tolerances		Mass (kg)		Final User Material	
Date		Des.		Appr.		Change / Replacement	
		CHK.		A. C.		Replaced by Ident. No.	
						No	
						5	
						4	
						3	
						2	
						1	
						0	
20140819		丁超 宁军		✱		CSD05446A.442[B]位置修改	
20140419		丁超 宁军		✱		CE0317T	
Similar Drawing No.		Replacement For Ident. No.		Page No.		CSCC-MES	
Scale		Type		01 < 01 >		Ident. No.	
~		A1		6G60ME-C9.2		Ident. No.	
Trnfo. No.		Description		Final User Ident. No.		Final User Ident. No.	
442j		压力开关布置		3H-17913		3H-17913	

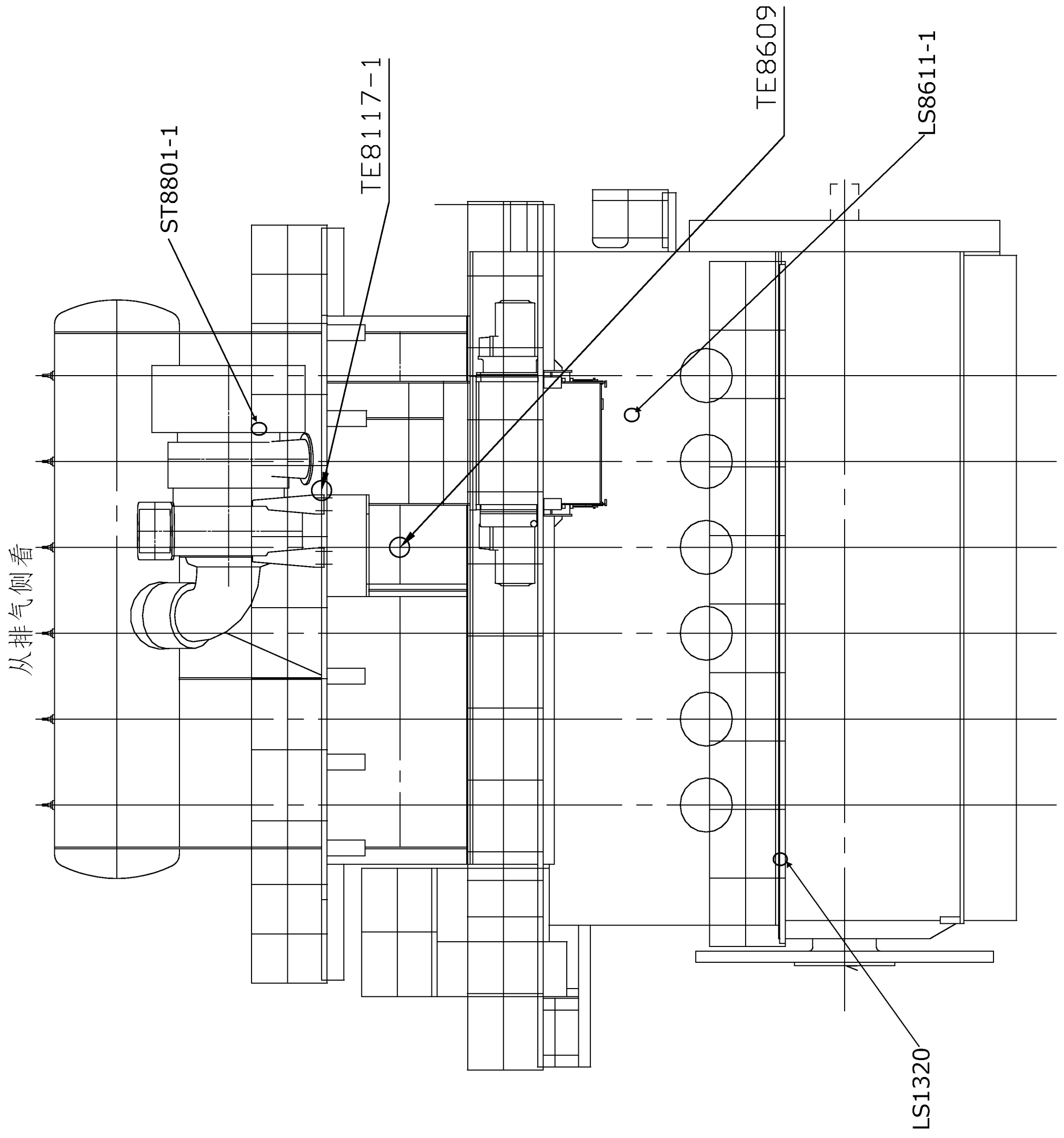
SEE FROM MANOEUVRE SIDE



SEE FROM AFTER



SEE FROM EXHAUST SIDE



Basic Standards (MBD S3D & Suppl. Drawing No.)			EN21C Surf. roughness				Material / Blank		
			EN21F-m Tolerances				Final User Material		
Date	Des.	CHK.	Appr.	A. C.	Change / Replacement				
					Replaced by Ident. No.				
					No				
					5				
					4				
					3				
					2				
					1				
					0				
20131213	丁超 宁军				CE0294Y				
Similar Drawing No.		Type		Replacement For Ident. No.					
Scale ~	Size A1			Page No. 01 < 01 >		 CS5C-MES			
Info. No.	Description		Ident. No.						
Final User Info. No. 442V		Final User Description		Final User Ident. No.		3H16540			
		温度传感器布置							

2

3

4

5

6

A - A

PT8706

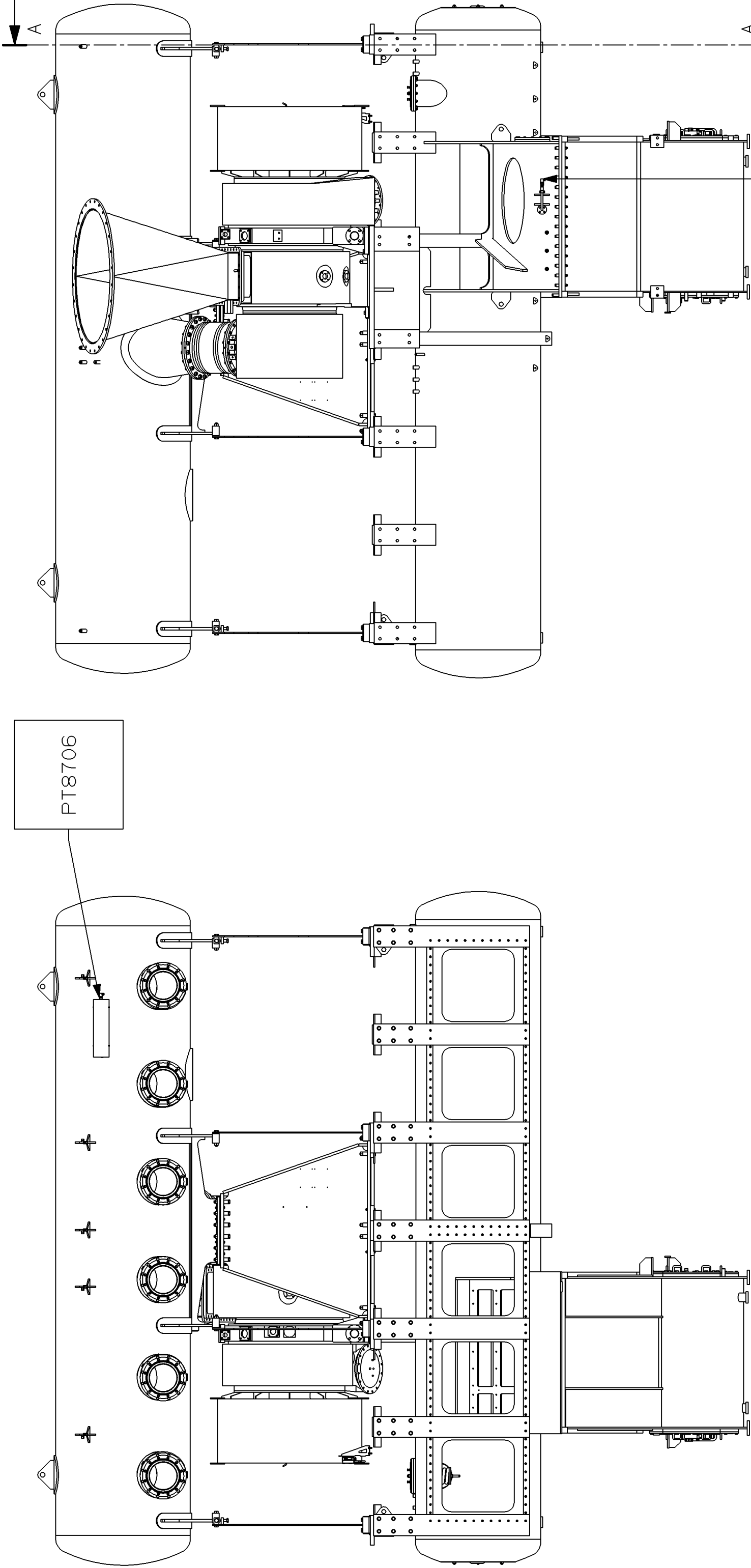
A

F

B

C

D



PT8708

TE8612

PT8802

TT8818

XT8819

PDT8606-M

PDT8606-S

**Placed in SF21-5642 on SCR engines

PDT8606-M/S

M=Master/S=Slave

Date	Des.	Chk.	A.C.	Revision change	Rev.
					03
					02
					01
					00
20170908STRASSTB					
Basic Standards IMB0 SBI:					
EN21F-m Tolerances EN21CA Surf. roughness					
Material / Blank:					
Suppl. Drawing No.:					
Final User Material:					
Mass (kg):					
*					
Scale:	Size:	Product Type:	EXTENDED INSTRU.		
1:40	A2				
Info. No.:		Item Name:	INSTRUMENTATION		
335200					
Final User Info. No.:		Final User Description:			
Projection:		Page No.:	01 (01)		
Item Id.:					
5809882-0					
Final User Ident. No.:					

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F

F

A2p11604

CAD Drawing - do not correct by hand - NX Drawing

ITEM	DESCRIPTION	QUATITY	类型	工作范围 (service)	报警值 (alarm)		降速 (slow down)		停车 (shut down)		量程/设定值范围	Remark
					low	high	low	high	low	high		
PT8505-1	Air inlet to air cylinder for exhaust valve	1	4-20mA	0.65~0.75	0.55		0.5				0~1	Unit: Mpa
PT8501-1	Starting air inlet	1	4-20mA	1.5~3.0	1.5						0~4	FOR ALARM, Unit: Mpa
PT8501-2	Starting air inlet	1	4-20mA	1.5~3.0							0~4	FOR REMOTE INDICATE, Unit: Mpa
PT8503-1	Control air inlet	1	4-20mA	0.65~0.75	0.55						0~1	FOR ALARM, Unit: Mpa
PT8001	fuel oil inlet	1	4-20mA	0.7~1.0	0.65						0~1.6	④, Unit: Mpa
PT8103-1	Lubricating oil inlet to turbo charger	1	4-20mA	0.14~0.20	0.12		0.1				0~0.4	⑤, Unit: Mpa
PS8103-1	Lubricating oil inlet to turbo charger	1	switch	0.14~0.20					0.04		0~0.4	⑤, Unit: Mpa, For 0311113/14/15/16, MET
PS8103-1	Lubricating oil inlet to turbo charger	1	switch	0.14~0.20					0.08		0~0.4	⑤, Unit: Mpa, For 0311117/18/19/20, ABB
PT8108	System lubricating oil inlet	1	4-20mA	0.19~0.25	0.17		0.15				0~0.4	①, Unit: Mpa
PS8109	Lub oil inlet to main bearing and thust bearing	1	switch	0.19~0.25					0.13		0~0.4	①, Unit: Mpa
PT8421-1	Cooling water inlet air cooler	1	4-20mA	0.2~0.45 c)	normal valve-0.3bar						0~0.4	Unit: Mpa
PT8601-1	Scavenge air receiver	1	4-20mA	INDICATION ONLY							0~0.6	Unit: Mpa
PT8108-1	Piston cooling oil inlet	1	4-20mA	0.14~0.20	0.12						0~0.4	①, Unit: Mpa
PT8503~A/B	Control air inlet (For ECS)	2	4-20mA	0.65~0.75							0~1	FOR ECS SYSTEM, Unit: Mpa
PT8501~A/B	Starting air inlet (For ECS)	2	4-20mA	1.5~3							0~4	FOR ECS SYSTEM, Unit: Mpa
TS8107	thrust bearing segment	1	Switch	55~70						90	20~150	Unit: °C
TE8106	thrust bearing segment	1	Pt100	55~70		75		80			0~200	Unit: °C
TE8005	fuel oil inlet (参照操作手册705章节)	1	Pt100	T	(T-5)	T+5					0~200	③, Unit: °C
TE8112	System lubricating oil inlet	1	Pt100	40~47		55		60			0~200	Unit: °C
TE8113	Piston cooling oil outlet/cyl	6	Pt100	50~65		70		75			0~200	Unit: °C
TE8117-1	Lubricating oil outlet T/C	1	Pt100	70~90		110		120			0~200	Unit: °C

ITEM	DESCRIPTION	QUATITY	类型	工作范围 (service)	报警值 (alarm)		降速 (slow down)		停车 (shut down)		量程/设定值范围	Remark
					low	high	low	high	low	high		
TE8422-1	Cooling water inlet air cooler	1	Pt100	10~36		40					0~200	Unit: °C
TE8423-1	Cooling water outlet air cooler	1	Pt100	10~63		80					0~200	Unit: °C
TE8609	Scavenge air receiver	1	Pt100	15*)		55 e)		65 e)			0~200	Unit: °C
TE8610	Scavenge air box fire~alarm/cyl	6	Pt100	-		80		120			0~200	Unit: °C
TE8701-1	Exhaustgas before T/C	1	Pt100	380~500		580		590		610	0~700	For 0311113/14/15/16 Unit: °C
TE8701-1	Exhaustgas before T/C	1	Pt100	380~500		520		530		550	0~700	For 0311117/18/19/20 Unit: °C
TE8702	Exhaustgas after exhaust valve/cyl	6	Pt100	320~440		470 (deviation:50° C)		480 (deviation:60° C)			0~700	Unit: °C
TE8707-1	Exhaust gas outlet T/C	1	Pt100	220~340		380					0~700	Unit: °C
TE8202	Cylinder lub. oil inlet	1	Pt100	40~60		70					0~200	Unit: °C
FS8114	Piston cooling oil outler no flow/cylinder	6	switch		no flow		no flow					
LS4112	Leakage from HCU	1	switch			high						
LS8006	leakage from high pressure pipe	1	switch			high						
LS1235	Leakage from HPS	2	switch			high						FOR ECS SYSTEM
LS8611-1	Drain from WMC	1	switch			high						
ZT8420	Engine overspeed	1								97 rpm		
XC8813	Oil mist in crankcase	1set	switch			high density/Failure		high density				
PS1204-1	1# start up pump lub. Oil inlet	1	switch	0.15-0.22Mpa	0.07Mpa						-0.02-1	Unit: Mpa 0.07Mpa only for control

ITEM	DESCRIPTION	QUANTITY	类型	工作范围 (service)	报警值 (alarm)		降速 (slow down)		停车 (shut down)		量程/设定值范围	Remark
					low	high	low	high	low	high		
PS1204-2	2# start up pump lub. Oil inlet	1	switch	0.15-0.22Mpa	0.07Mpa						-0.02-1	Unit: Mpa 0.07Mpa only for control
ST8801-1	T/C speed	1		0-14550		13968		14259		14550		For 0311113/14/15/16/21/22/23/24 Unit: rpm
ST8801-1	T/C speed	1		0-18060		17337		17698		18060		For 0311117/18/19/20 Unit: rpm
PT8401	Jacket cooling water inlet(at inlet manifold)	1	4-20mA	0.37~0.55a)	0.33		0.29				0~1.0	LDCL-Unit: Mpa
PS8402	Jacket c.w. inlet	1	switch	0.37~0.55a)					0.01 f)		0~0.4	LDCL-Unit: Mpa
PT8413	Jacket cooling water outlet common pipe	1	4-20mA	0.26-0.42							0~1.0	Unit: Mpa
PDT8404	Jacket cooling water across cylinder liners	1	4-20mA	0.025-0.08			0.01				0-0.18	Alarm to be stated at sea trial between normal and Slowdown values. LDCL-Unit: Mpa
PDT8405	Jacket cooling water across cylinder covers & exh. Valves	1	4-20mA	0.04-0.12			0.01				0-0.18	Alarm to be stated at sea trial between normal and Slowdown values. LDCL-Unit: Mpa
PS8464	Circulation pump inlet pressure,	1	switch		0.1Mpa							For protection against dry running(local control). Connected to pump starter.
TE8407	Jacket cooling water inlet	1	Pt100	70~85	62						0~200	LDCL-Unit: °C
TT8408	Cyl. Liner jacket cooling water outlet	6	4-20mA	80~85	deviatio n:10	normal value+10		normal value+15			0~300	LDCL is not working for high load. To be stated at sea trail LDCL-Unit: °C alarm delay 300sec. Slow down delay 600sec.
				75~124	deviatio n:10	normal value+5		normal value+10			0~300	LDCL is working for low load. To be stated at sea trail LDCL-Unit: °C alarm delay 300sec. Slow down delay 600sec.
TE8410	Cyl. cover c.w. outlet	6	Pt100	80~87		90		95			0~200	LDCL-Unit: °C AH/SLD delay 150sec.
PDT8606	A/C air pressure drop	1/A. C.	4-20mA								0~0.02	Mpa, For EMS, For 0311117/18/19/20

ITEM	DESCRIPTION	QUATITY	类型	工作范围 (service)	报警值 (alarm)		降速 (slow down)		停车 (shut down)		量程/设定值范围	Remark
					low	high	low	high	low	high		
TE8612	T/C air intake temperature	2/TC	Pt100	-10~45							0~200	℃, For EMS, For 0311117/18/19/20
PT8706	Exh. gas receiver pressure	1	4-20mA	0. 1~0. 34							0~0. 6	Mpa, For EMS, For 0311117/18/19/20
PT8708	Turbine back pressure	1/TC	4-20mA	0. 1~0. 003		0. 0045					0~0. 01	Mpa, For EMS, For 0311117/18/19/20
TT 8818	Engine room temperature	1	4-20mA								-40~60	℃, For EMS, For 0311117/18/19/20
PT 8802	Engine room pressure		4-20mA	0. 095~0. 105							0. 094~0. 11	Mpa (abs), For EMS, For 0311117/18/19/20
XT 8819	Engine room Relative humidity		4-20mA								0~100%	%RH, For EMS, For 0311117/18/19/20

①Measured 1800mm above the crankshaft center for main L.O. and piston cooling oil.

②Measured 1000mm above the middle grating.

③To be adjusted depending on the fuel oil viscosity.

④Fuel oil viscosity max.700cst/50℃ measured at HCU level

⑤Measured at the turbocharger rotor center for turbocharger L.O.

*) Above water inlet temp.air cooler

a)The expansion tank is located more than 15m above the engine the top of the exhaust gas valves.
If the static pressure is above 2.6bar. Alarm=static pressure+0.7bar. SLD=static pressure+0.3bar.

b)With stopped cooling water pumps,the set point is the static pressure plus the stated valve

c)To be stated at sea trail

d)Lower than normal service value

e)To be cut during stop,To remain cut out until 3~5 minutes after start

f)The static pressure must be added to the stated value. The set point must be set and verified at seatrial with stopped pumps.Only required by GL

g)To be stated at sea trial. Lower than normal service value.

g)The delay time of sensor: 6-8 sec.

Prefix	GVA	Postfix	Description	Unit	Type	No. Of Cyl.	Normal service low	Normal service high	Low Alarm	Deviation	High Alarm	Slowdown or Loaddown	Deviation SLD	Shutdown	Comments
Hydraulic power supply															
PS	1204	C	Lub. oil pressure at pump inlet after filter	bar	Binary N.C.		1		0,7						For protection against dry running (local control). Connected to pump starter. Alarm value is setting value
PT	1228	AL	Lub. oil pressure after LPS booster pump	bar	4-20mA		4,0	7,0							For Dual Fuel engines if LPS booster pump is applied. For Alarm level use alarm level for 8108+1bar.
PS	1229	C	Lub. oil pressure before LPS booster pump	bar	Binary N.C.				0,5						For Dual Fuel engines if LPS booster pump is applied. For protection against dry running (local control). Connected to pump starter. Alarm value is setting value
PDS	1231	AH	Lub. Oil difference pressure, across filter (Auto filter)	bar	Binary N.C.		0	0,6			0,8				
XC	1260	C	LPS booster pump start	-	Binary N.C.										For Dual Fuel engines if LPS booster pump is applied. To be started together with Main Lube Oil Pumps. Start=Closed contact
XC	1261	C	LPS booster pump Remote/Local/Fail	-	Binary N.C.		1				0				For Dual Fuel engines if LPS booster pump is applied.
XC	1262	C	LPS booster pump running	-	Binary N.C.										For Dual Fuel engines if LPS booster pump is applied. Running=Closed contact
TE	1270	AH	HPS bearing temperature	°C	PT100		55	60			70				Only for centre mounted HPS
Hydraulic control oil system (separate oil to HPS)															
PI	1301	I	Fine filter unit pressure indicator	bar											In plant/vessel piping
PI	1303	I	Lub oil pressure engine inlet	bar	4-20mA										In plant/vessel piping. Same normal range as PT8108
TE	1310	AH-Y	Lub. Oil temp. At engine inlet	°C	PT100		40	55			60	65			In plant/vessel piping
LS	1320	AL	Level alarm in tank	-	Binary N.C.		1		0						In plant/vessel tank
XS	1350	AH	WIO Water in hydraulic oil system	WA	Binary N.C.		0	0,45			0,5				WA: Water Activity (relative to saturation point) If analogue sensor 4-20mA=0-1 WA
XS	1351	AH	WIO Water in hydraulic oil system too high	WA	Binary N.C.		0	0,45			0,9				WA: Water Activity (relative to saturation point) If analogue sensor 4-20mA=0-1 WA
XS	1352	A	WIO sensor not ready	-	Binary N.C.		1				0				Optional (Maker dependent)
Top bracing															
Revision change															
Date		Des.	Chk.	A.C.	Revision change										
20170508		DFA	JYA	Z3	Updates according to chg.note.										
20141106		DFA	JYA												
Basic Standards:		Product Type:			G60ME-C9.5-TII/TIII										
Info. No.:		Item Name:			GUIDANCE VAL.-AUTOMATION										
341910					5657261-7										
Final User Info No.:		Final User Description:			Final User Ident. No.:										

Prefix	GVA	Postfix	Description	Unit	Type	No. Of Cyl.	Normal service low	Normal service high	Low Alarm	Deviation	High Alarm	Slowdown or Loaddown	Deviation SLD	Shutdown	Comments
PT	1501	AL	Top bracing accumulator pressure	bar	4-20mA		6	8	4						
EGR – Exhaust Gas Recirculation															
XC	1608	C	EGR common alarm	-	Binary N.C.		1				0				Only EGR engines
XC	1639	C	EGR cooler no flow (TC cut-out)	-			0								Only EGRTC engines, optional cooler cut-out in TII mode
XC	1648	C	EGR cooler reduced flow	-			0								Only EGRTC engines, optional flow reduction
ECS to/from safety system															
XC	2001	Z	Shut down to Engine Control Units/Emergency stop	-	Binary N.O.		0							1	Channels for: ECU-A & ECU-B
XC	2002	Z	Shut down to Cylinder Control Units/Emergency stop	-	Binary N.O.		0							1	Channels for all cylinders
XC	2005	C	Reset shut down	-	Binary N.O.		0				1				Channels for: ECU-A & ECU-B
XC	2010	Y	Slow down command from safety/slowdown system	-	Binary N.O.		0					1			Channel for EICU-A required, EICU-B optional
XC	2011	Z	Shut down to SF Plant Safety Unit	-	Binary N.C.		1							0	Only GI, GIE, LGIM and LGIP engines
XC	2020	Z	Shut down (Non-cancellable)	-	Binary N.O.		0							1	Channels for: EICU-A & EICU-B
XC	2021	Z	Shut down (cancellable)	-	Binary N.O.		0							1	Channels for: EICU-A & EICU-B
ECS to/from alarm system															
XC	2201	A	Power failure	-	Binary N.C.		1		0						Channels for: EICU-A, EICU-B, SCRCU (SCR) & EGRI1 (EGR)
XC	2202	A	ME common alarm	-	Binary N.C.		1		0						Channels for: EICU-A, EICU-B & SCRCU (SCR)
XC	2205	A	Slow down prewarning	-	Binary N.O.		0		1						Channel for EICU-A required, EICU-B optional
XC	2207	C	Slow down Request	-	Binary N.O.		0		1						Channel for EICU-A required, EICU-B optional
XC	2210	A	Engine stopped	-	Binary N.O.		0		1						Channel for EICU-A required, EICU-B optional
XC	2212	A	External Second Fuel shut down request	-	Binary N.O.										Only GI, GIE, LGIM & LGIP engines SF Shut Down=Closed contact
XC	2213	A	Double Pipe HC Alarm	-	Binary N.C.		1				0				Only GI, GIE, LGIM & LGIP engines
XC	2221	A	Second Fuel control Power Failure	-	Binary N.C.		1		0						Only GI, GIE, LGIM & LGIP engines. Channels for: SPCU & SPSU.
XC	2222	A	Second Fuel Common Alarm	-	Binary N.C.		1		0						Only GI, GIE, LGIM & LGIP engines. Channels for: SPCU & SPSU.
ECS outputs															
XC	2405	C	Engine Load	%	4-20mA		0	120							For cooling water control on LDCL engines
Power Supply Units to Alarm System															
XC	2909	AL	UPS mains supply fail	-	Binary N.C.		1		0						Channels for: UPS-A & UPS-B

Date		Des.	Chk.	A.C.	Revision change		Chg. Not.	Rev.
20170508		DFA	JYA	Z3	Updates according to chg.note.		124702	03
Basic Standards:		Product Type:			Size:		Page No.:	
Info. No.:		Item Name:			G60ME-C9.5-TII/TIII		A32 (8)	
341910		GUIDANCE VAL.-AUTOMATION			Item Id.:		5657261-7	
Final User Info No.:		Final User Description:			Final User Ident. No.:			

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Prefix	GVA	Postfix	Description	Unit	Type	No. Of Cyl.	Normal service low	Normal service high	Low Alarm	Deviation	High Alarm	Slowdown or Loaddown	Deviation SLD	Shutdown	Comments
XC	2910	AL	UPS battery discharging	-	Binary N.C.		1		0						Channels for: UPS-A & UPS-B
XC	2911	AL	UPS battery protective device tripped	-	Binary N.C.		1		0						Channels for: UPS-A & UPS-B
Tacho/crankshaft pos. system															
ZT	4020	Z	Tacho for safety	RPM										1,09	Factor to be multiplied with RPM at MCR
Engine cylinder components															
LS	4112	C-AH	Leakage from cylinder units/pipe	-	Binary N.C.		1				0				
PS	4112	C-AH	Leakage from cylinder units/pipe	bar	Binary N.O.		0				0,6				Connected to ME-ECS, setting value only
DF-ECS to other GI related systems															
XC	6360	C	ELWI enable	-			1				0				Only GI & GIE engines
XC	6361	I	Dual fuel mode for Bridge Indication	-			0				1				Only GI, GIE, LGIM & LGIP engines. Optional, alternative to information in serial RCS protocol
Dual Fuel Engine related Components															
XC	6428	C	SF ELFI enable	-			1				0				Only LGIM & LGIP engines
Fuel oil system															
PT	8001	I-AL	Fuel oil, inlet engine (after filter)	bar	4-20mA		7	10	6,5						
PDI	8003	I	Pressure drop of fuel across fuel oil filter	bar			0,2	0,5							In plant/vessel piping
VT	8004	I-AL-AH	Fuel oil, inlet engine (after filter)	cSt			10	15	7		20				In plant/vessel piping
TE	8005	I	Fuel oil, inlet engine (after filter)	°C	PT100										
LS	8006	AH	Leakage from high pressure pipes	-	Binary N.C.		1				0				
ZV	8020	C	Fuel oil cut off at engine inlet (Shut Down)	-	Binary N.O.		0				1				only for engines classified by GL.
Lubrication oil system															
PT	8103	I-AL	Lub. oil inlet to turbocharger / turbocharger	bar	4-20mA		1,4	2,0	1,2						TC type dependent
TIT	8106	I-AH-Y	Thrust bearing segment	°C	PT100		40	70			75	80			
TE	8107	Z	Thrust bearing segment	°C			40	70						90	
PT	8108	I-AL-Y	Lub. oil inlet to main bearings and thrust/guide bearing	bar	4-20mA		1,9	2,5	1,7			1,5			Measured on pressure gauge placed 1800 mm above crankshaft centreline
PT/PS	8109	Z	Lub. oil inlet to main bearings and thrust/guide bearing	bar			1,9	2,5						1,3	Measured on pressure gauge placed 1800 mm above crankshaft centreline
TE	8112	I-AL-AH	Lub. oil inlet, system oil	°C	PT100		40	47	35		55				
TE	8113	I-AH-Y	Piston cooling oil outlet pr. each cylinder	°C	PT100		50	65			70	75			
FS	8114	AL-Y	Piston cooling oil outlet pr. each cylinder	-	Binary N.O.		0		1			1			No-flow alarm, 6 sec. delay between Alarm and Slow Down/Load reduction
TE	8117	I-AH-Y	Lub. oil outlet from turbocharger pr. each turbocharger, MAN TC	°C	PT100		70	90			95	120			
Revision change															
Date				Des.		Chk.		A.C.		Revision change					
20170508				DFA		JYA		Z3		Updates according to chg.note.					
Basic Standards:				Product Type:		Size: A3									
Info. No.:				Item Name:		G60ME-C9.5-TII/TIII									
341910				Item Name:		GUIDANCE VAL.-AUTOMATION									
Final User Info No.:				Final User Description:		Page No.: 03									
Final User Info No.:				Final User Description:		Page No.: 3 (8)									
Final User Info No.:				Final User Description:		Page No.: 5657261-7									

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MAN

Prefix	GVA	Postfix	Description	Unit	Type	No. Of Cyl.	Normal service low	Normal service high	Low Alarm	Deviation	High Alarm	Slowdown or Loaddown	Deviation SLD	Shutdown	Comments
TE	8117	I-AH-Y	Lub. oil outlet from turbocharger pr. each turbocharger, ABB TC	°C	PT100		70	90			110	120			
TE	8117	I-AH-Y	Lub. oil outlet from turbocharger pr. each turbocharger, Mitsubishi TC	°C	PT100		70	80			85				Refer to makers documentation for Slow Down values
TE	8118	I-AH	Lub. oil outlet from engine (inlet to oil cooler)	°C	PT100		50	60			65				
TE	8123	I-AH-Y	Main bearing oil outlet temp	°C			50	60		5	65	70	7		Channels for all main bearings. Alarm to be stated at sea/site trial acc. To alarm system requirements
TE	8124	I-AH-Y	Crankpin bearing oil outlet temp	°C	PT100		50	60		5	65	70	7		Channels for all crank pins. Alarm cut-out until 3 minutes after start. Alarm to be stated at sea/site trial acc. To alarm system requirements
TE	8125	I-AH-Y	Crosshead bearing oil outlet temp	°C	PT100		50	60		5	65	70	7		Channels for all crossheads. Alarm cut-out until 3 minutes after start. Alarm to be stated at sea/site trial acc. To alarm system requirements
XS	8126	AH	Bearing Wear Alarm	-	Binary N.C.		1				0				
XS	8127	A	Bearing Wear System Failure	-	Binary N.C.		1				0				
XS	8129	Y	Bearing Wear Slowdown	-	Binary N.O.		0					1			
XS	8150	AH	Water in lubrication oil (WIO sensor)	WA	Binary N.C.		0	0,45			0,5				WA: Water Activity (relative to saturation point) If analogue sensor 4-20mA=0-1 WA Cut-out if lubrication oil temp. is below normal operating temp.
XS	8151	AH	Water in lubrication oil - level too high (WIO sensor)	WA	Binary N.C.		0	0,45			0,9				WA: Water Activity (relative to saturation point) If analogue sensor 4-20mA=0-1 WA Cut-out if lubrication oil temp. is below normal operating temp.
XS	8152	A	Water in lubrication oil / WIO sensor not ready	-	Binary N.C.		1				0				Optional (Maker dependent)
Cylinder lub. oil system															
TE	8202	I-AH	Cylinder lub. oil temperature	°C	PT100		40	60			70				
LS	8212	AL	Level Switch, Booster unit tank	-	Binary N.C.		1		0						
TS	8213	C	Cylinder lubricating heating	°C	Binary N.C.		1				40				Set point for switch adjustment
Cooling water system															

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Date	Des.	Chk.	A.C.	Revision change		Chg. Not.	Rev.
20170508	DFA	JYA	Z3	Updates according to chg.note.		124702	03
Basic Standards:		Product Type:		Size:		Page No.:	
				G60ME-C9.5-T11/T111		A3 4 (8)	
Info. No.:		Item Name:		Item Id.:			
341910		GUIDANCE VAL.-AUTOMATION		5657261-7			
Final User Info No.:		Final User Description:		Final User Ident. No.:			

Prefix	GVA	Postfix	Description	Unit	Type	No. Of Cyl.	Normal service low	Normal service high	Low Alarm	Deviation	High Alarm	Slowdown or Loaddown	Deviation SLD	Shutdown	Comments										
PT	8421	AL-AH	Cooling water inlet Scavenge air cooler	bar	4-20mA			2,5			3,5				Conventional sea water cooling system Low Alarm to be stated at sea trial (normal value-0.3bar)										
TE	8422	I-AH	Cooling water inlet Scavenge air cooler	°C	PT100		10	36			40				Central cooling water system. Set point 10°C or seawater temp+4°C (min. 10°C)										
TE	8422	I-AH	Cooling water inlet Scavenge air cooler	°C	PT100		10	32			40				Conventional sea water cooling system. Set point 10°C										
TE	8423	I-AH	Cooling water outlet/Scavenge air cooler	°C	PT100		10	63			80				Central cooling water system										
TE	8423	I-AH	Cooling water outlet/Scavenge air cooler	°C	PT100		10	50			80				Conventional sea water cooling system										
PDT	8424	I	Pressure drop of cooling water across Scavenge air cooler	bar	4-20mA		0,25	0,8																	
TE	8431	I	Cooling water inlet to lub. oil cooler(s)	°C	PT100		10	32							Conventional seawater cooling system										
PT	8440	I-AH-AL	Cooling water inlet air cooler (s) (WHR)	bar	4-20mA		3,5	4,5							Normal range and alarm level plant specific										
TE	8441	I-AH	Cooling water inlet air cooler (s) (WHR)	°C	PT100										Normal range and alarm level plant specific										
TE	8442	I-AH	Cooling water outlet / air cooler (WHR)	°C	PT100						80				Normal range level plant specific										
PDT	8443	I-AL	Scavenge air cooler (WHR/Stage 1)	bar	4-20mA										Normal range and alarm level plant specific										
TE	8456	I-AH	EGR Cooler Cooling water outlet	°C	PT100		10	63			80				Central cooling water system For engines with EGR										
PS	8478	C	Circulation pump inlet pressure, LDCL/LDHT	bar			1		1						For protection against dry running (local control). Connected to pump starter. Alarm value is setting value Replaces PS8464										
Scavenge air																									
TE	8605	R	Scavenge air before air cooler pr. each air cooler	°C	PT100		170	250							MCR value, engine load and ambient condition dependent										
PDT	8606	R	Pressure drop of air across air cooler pr. each air cooler	mbar	4-20mA										Normal service value according to shop trial results										
TE	8608	I-AH	Scavenge air after air cooler pr. each air cooler	°C	PT100						80				Normal service value = TE8422 + 12°C										
TE	8609	I-AH-Y	Scavenge air receiver	°C	PT100						55	65			Alarm to be cut during Stop. To remain cut out until 3-5 minutes after Start. Normal Service value = TE8422 + 15°C										
TE	8610	AH-Y	Scavenge air box - fire alarm pr. each cylinder	°C	PT100						80	120													
Date																Chg. Not.		Rev.							
20170508																A.C.		03							
20170508																JYA		Z3		Updates according to chg.note.		124702		03	
Basic Standards:																Product Type:		Size:		Page No.:					
																G60ME-C9.5-TII/TIII		A3		6 (8)					
Info. No.:																Item Name:		Item Id.:							
341910																GUIDANCE VAL.-AUTOMATION		5657261-7							
Final User Info No.:																Final User Description:		Final User Ident. No.:							

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Prefix	GVA	Postfix	Description	Unit	Type	No. Of Cyl.	Normal service low	Normal service high	Low Alarm	Deviation	High Alarm	Slowdown or Loaddown	Deviation SLD	Shutdown	Comments
LS	8611	AH	Water mist catcher - water level	-	Binary N.C.		1				0				
TE	8612	R	Compressor inlet temperature pr. each turbocharger	°C	PT100		-10	45							2 sensors pr. T/C
PT	8615	R	Compressor inlet pressure pr. each turbocharger	°C	PT100										
Exhaust gas system															
TIT	8701	I-AH-Y	Exh. gas before turbocharger pr. each turbocharger	°C	4-20mA		380	500							Measured in turbine inlet. Values at nominal MCR, dependent on layout, engine load and ambient conditions. TC make dependent values for alarm and slowdown. Higher values may apply for WHR tuned engines
TIT	8702	I-AH-Y	Exh. gas after exh. valves pr. each cylinder (average)	°C	4-20mA		320	440		50	470	480	60		Deviation alarm to be cut-out below 200°C The normal service values apply under the following conditions: Ambient temp. in engine room 25°C, Scavenge air temp. in receiver 35°C Values at nominal MCR, dependent on engine layout and load
PT	8706	R	Exhaust gas receiver	bar	4-20mA		1	3,4							The normal service values apply under the following conditions: Ambient temp. in engine room 25°C, Scavenge air temp. in receiver 35 °C Higher values may apply for WHR tuned engines
TIT	8707	I-AH	Exhaust gas outlet turbocharger pr. each turbocharger	°C	4-20mA		220	340			380				Normal service value at MCR
PT	8708	I-AH	Exhaust gas outlet turbocharger pr. each turbocharger	mbar	4-20mA		0	30			45				
Miscellaneous functions															
ZT	8801	I-AH-Y	Turbocharger speed pr. turbocharger	RPM	4-20mA						0,96	0,98			Factor to be multiplied with max RPM for continous operation. Slowdown applied in case of: Variable turbocharger, Exhaust gas by pass, Turbocharger Cut Out system, Power turbine and Hybrid TC. Reference to Doc. No. 1883352-9
PT	8802	I	Engine room pressure	bar(abs)	4-20mA		0,95	1,05							
PI	8803	I	Air inlet for dry cleaning of turbocharger	bar			4,5	10							
PI	8804	I	Cleaning water inlet to turbocharger	bar			0,5								Relative to exhaust gas pressure (higher than)
WT/WI	8812	I-AH-Y	Axial vibration monitor	mm		5	0,00	2,16			2,89	3,61			Alarm delay 20 sec. Slowdown prewarning 100 sec.

Date		Des.	Chk.	A.C.	Revision change		Chg. Not.	Rev.
20170508		DFA	JYA	Z3	Updates according to chg.note.		124702	03
Basic Standards:		Product Type:			Size:		Page No.:	
Info. No.:		Item Name:			A3		7 (8)	
341910		GUIDANCE VAL.-AUTOMATION			Item Id.:		5657261-7	
Final User Info No.:		Final User Description:			Final User Ident. No.:			

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1 Measuring Instruments, Identification

Remote Identification

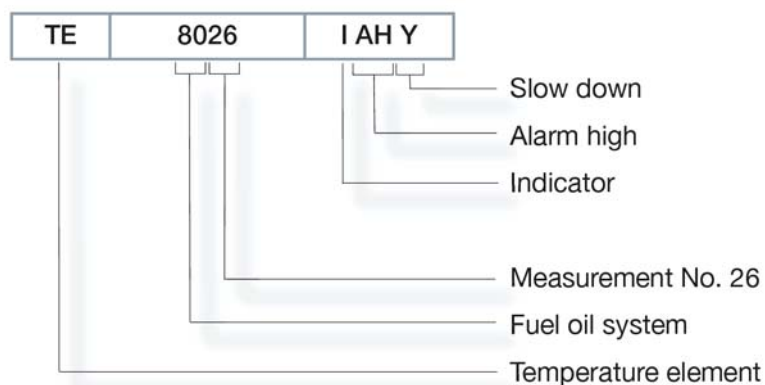
Codes for identification of instruments and signal-related functions.

PT	8108	AH
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First letter(s)		Identification number		Secondary letter(s)	
<i>Measured or indicating variable</i>		<i>The first two digits indicate the point of measurement, the next two are serial numbers.</i>		<i>Function</i>	
DS	Density switch	11	Manoeuvring system	A	Alarm
DT	Density transmitter	12	Hydraulic power supply	C	Control
GT	Gauging transmitter (load/index)	14	Combustion pressure supervision	H	High
FT	Flow transmitter	20	ECS to/from safety system	I	Indication (remote)
FS	Flow switch	21	ECS to/from remote control system	L	Low
LS	Level switch	22	ECS to/from alarm system	R	Recording
LI	Level indication (local)	30	ECS Miscellaneous input/output values	S	Switching
LT	Level transmitter	40	Tacho/crankshaft pos. system	Y	Slow-down
PDI	Pressure difference indication (local)	41	Engine cylinder components	X	Unclassified function
PDS	Pressure difference switch	50	VOC: supply system	Z	Shut-down
PDT	Pressure difference transmitter	51	VOC: sealing oil system		
PI	Pressure indication (local)	52	VOC: control oil system		
PS	Pressure switch	53	Other VOC related systems		
PT	Pressure transmitter	54	VOC engine related components		
ST	Speed transmitter	80	Fuel oil system		
TC	Thermo couple (NiCr-Ni)	81	Lubrication oil system		
TE	Temperature element (Pt-100)	82	Cylinder lub. oil system		
TI	Temperature indication (local)	83	Stuffing box drain system		
TS	Temperature switch	84	Cooling water system e.g. central cooling water e.g. sea cooling water e.g. jacket cooling water		
WS	Vibration switch				
WT	Vibration transmitter				
VS	Viscosity switch	85	Compressed air supply system e.g. control air e.g. starting air		
VT	Viscosity transmitter				
ZV	Position valve (solenoid valve)	86	Scavenge air		
ZS	Position switch (limit switch)	87	Exhaust gas system		
ZT	Position transmitter (e.g. proximity sensor)	88	Miscellaneous functions e.g. axial vibration		
XC	Unclassified control	90	Project specific		
XS	Unclassified switch				
XT	Unclassified transmitter	Note: ECS: Engine Control System VOC: Volatile Organic Compound			

The first link (first letter) indicates what is measured or the indicating variable. The second link is the Ident.No., in which the first two digits indicate the point of measurement or the indicating variable, followed by a serial number. The third link (secondary letter(s)) indicates the function of the measured value.

Example

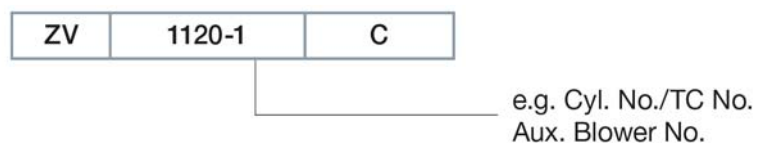


Repeated signals:

Signals which are repeated, such as per cylinder measurement or per turbo-charger measurement, etc. are provided with a suffix number. The suffix number is identical with the place of measurement, such as 1 for cylinder 1, etc. Where signals are redundant, suffix A or B may be used.

Examples

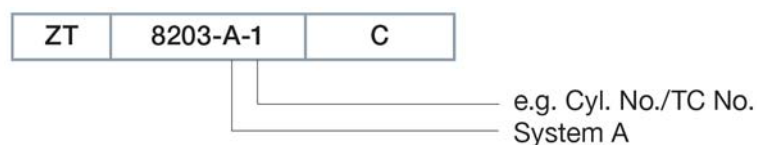
Cylinder or Turbocharger-Related Signals



Redundant Signals



Cylinder-Related Redundant Signals



Graphical presentation in PI-diagrams according to ISO 1219 I - II

2 List of Instruments

NOTICE

The list and illustrations on the following pages, are for guidance only.

Fuel Oil System

PI	8001	Fuel oil, inlet engine
PI	8001	Fuel oil, inlet engine (At local operator panel)
PT	8001	Fuel oil, inlet engine (After filter) (alarm low)
TI	8005	Fuel oil, inlet engine (After filter)
TE	8005	Fuel oil, inlet engine (After filter)
LS	8006	Leakage from high pressure pipes (alarm)
VZ	8020	Fuel oil cut out (shut down)

Lubrication Oil System

PT	8103	Lubricating oil inlet to Turbocharger/Turbocharger (alarm)
PI	8103	Lubricating oil inlet to Turbocharger/Turbocharger
TI	8106	Thrust bearing segment
TT	8106	Thrust bearing segment (alarm)
TE	8107	Thrust bearing segment (shut down)
PI	8108	System lubricating oil inlet 1800 above cl. of crankshaft
PI	8108	System lubricating oil inlet (At local operator panel)
PT	8108	Lubricating oil inlet to main bearing and thrust bearing (alarm + slow down)
PS	8109	Lubricating oil inlet to main bearing and thrust bearing (shut down)
TI	8112	System lubricating oil inlet
TE	8112	System lubricating oil inlet (alarm + slow down)
TI	8113	Piston cooling oil outlet/cylinder
TE	8113	Piston cooling oil outlet/cylinder (alarm + slow down)
FS	8114	Piston cooling oil outlet/cylinder (alarm + slow down/ no flow)
TI	8117	Lubricating oil outlet Turbocharger/Turbocharger
TE	8117	Lubricating oil outlet Turbocharger/Turbocharger (alarm)
XC	8126	Bearing wear monitoring system
XS	8150	Water in oil sensor, system lubricating oil inlet

Electronic Cylinder Lub. Oil System (Alpha cylinder lubricators)

TE	8202	Cylinder lubrication oil temperature
----	------	--------------------------------------

ZT	8203	Confirm cylinder lubricator piston movement, cyl/cyl
XC	8282	Confirm cylinder lubricator piston movement, cyl/cyl
ZT	8204	Activate cylinder lubricator, cyl/cyl
XC	8281	Activate cylinder lubricator, cyl/cyl
ZT	8208	Cylinder lube oil level
XC	8285	Cylinder lube oil level
TS	8213	Cylinder lubricator heating

Cooling Water System

PI	8401	Jacket cooling water inlet (At local operator panel)
PT	8401	Jacket cooling water inlet (alarm, slow down)
PS	8402	Jacket cooling water inlet (shut down)
PDI	8404	Jacket cooling water across cylinder liners
PDT	8404	Jacket cooling water across cylinder liners
PDI	8405	Jacket cooling water across cylinder covers & exh. valves
PDT	8405	Jacket cooling water across cylinder covers & exh. valves
TI	8407	Jacket cooling water inlet
TE	8407	Jacket cooling water inlet (alarm)
TT	8407	Jacket cooling water inlet
TI	8408	Jacket cooling water outlet/cylinder (alarm, slow down)
TT	8408	Jacket cooling water outlet/cylinder (alarm, slow down)
TI	8410	Cylinder cover cooling water outlet / cyl, (alarm, slow down)
TT	8410	Cylinder cover cooling water outlet / cyl, (alarm, slow down)
PT	8413	Jacket cooling water outlet common pipe
TT	8413	Jacket cooling water outlet common pipe
TT	8414	Cooling water outlet LDCL/LDHT
TI	8420	Cooling water outlet 3-way valve LDCL/LDHT
PI	8421	Cooling water inlet air cooler
PT	8421	Cooling water inlet air cooler (alarm)
TI	8422	Cooling water inlet air cooler
TE	8422	Cooling water inlet air cooler (alarm)
TI	8423	Cooling water outlet air cooler / air cooler
TE	8423	Cooling water outlet air cooler / air cooler (alarm)
PT	8440	Cooling water inlet air cooler(s) 1st. stage, (WHR)
TE	8441	Cooling water inlet air cooler(s) 1st. stage, (WHR)
TE	8442	Cooling water outlet 1st. stage / air cooler, (WHR)
PDT	8443	Pressure drop of cooling water across 1st. stage (WHR) / air cooler
PT	8444	Cooling water outlet air cooler(s), 1st. stage (WHR)

PT	8464	Circulation pump inlet pressure LDCL/LDHT
PS	8464	Circulation pump inlet pressure LDCL/LDHT
PT	8465	Circulation pump outlet pressure LDCL/LDHT
TI	8466	Circulation pump outlet pressure LDCL/LDHT
PI	8467	High temperature outlet pressure LDCL/LDHT
PI	8468	Outlet pressure after mixing valve LDCL/LDHT

Compressed Air Supply System (Control, starting air)

PI	8501	Starting air to main starting valve (At local operator panel)
PT	8501-A	Starting air inlet (alarm)
PT	8501-B	Starting air inlet (alarm)
PI	8503	Control air inlet (At local operator panel)
PT	8503-A	Control air inlet (alarm)
PT	8503-B	Control air inlet (alarm)
PS	8505	Air inlet to air cylinder for exhaust valve (alarm)

Scavenge Air

PI	8601	Scavenge air receiver (At local operator panel)
PI	8601	Scavenge air receiver
PT	8601-A	Scavenge air receiver
PT	8601-B	Scavenge air receiver
TI	8605	Scavenge air before air cooler / air cooler
TE	8605	Scavenge air before air cooler / air cooler
PDI	8606	Pressure drop across air cooler
TI	8608	Scavenge air after air cooler / air cooler
TE	8608	Scavenge air after air cooler / air cooler
TI	8609	Scavenge air receiver
TE	8609	Scavenge air receiver (alarm + slow down)
TE	8610	Scavenge air box-fire alarm / cylinder (alarm, slow down)
LS	8611	Water mist catcher – water level (alarm)

Exhaust Gas System

TI	8701	Exhaust gas before T/C (alarm, slow down)
TT	8701	Exhaust gas before T/C (alarm, slow down)
TI	8702	Exhaust gas after valve / cylinder (alarm, slow down)
TT	8702	Exhaust gas after valve / cylinder (alarm, slow down)
PI	8706	Exhaust gas receiver
TI	8707	Exhaust gas outlet T/C
TT	8707	Exhaust gas outlet T/C

Pneumatic System

ZS	1109-A	Turning gear dis-engaged
ZS	1109-B	Turning gear dis-engaged
ZS	1110-A	Turning gear engaged
ZS	1110-B	Turning gear engaged
ZS	1111-A	Main starting valve blocked
ZS	1111-B	Main starting valve blocked
ZS	1112-A	Main starting valve in service
ZS	1112-B	Main starting valve in service
ZV	1114	Slow turning valve
ZS	1116-A	Starting air distributor - open
ZS	1116-B	Starting air distributor - open
ZS	1117-A	Starting air distributor - closed
ZS	1117-B	Starting air distributor - closed
ZV	1120	Activate pilot pressure air to starting valve / cylinder
ZV	1121-A	Activate main starting valve – open
ZV	1121-B	Activate main starting valve – open

Hydraulic System

PT	1201-1	Pressure after non-return valve
PT	1201-2	Pressure after non-return valve
PT	1201-3	Pressure after non-return valve
ZV	1202-A	Pressure relief valve
ZV	1202-B	Pressure relief valve
PT	1204-1	Lub. oil pressure after filter
PT	1204-2	Lub. oil pressure after filter
PT	1204-3	Lub. oil pressure after filter
XC	1222	Swashplate for high pressure pump
XC	1231	Filter failure (Boll & Kirch)
LS	1235	Leakage from hydraulic system
LS	1236	Leakage from hydraulic system
XS	1238	Proportional valve for high pressure pump
TE	1270	HPS bearing temperature
XC	4101	Bosch-Rexroth Cylinder control unit
XC	4102	Bosch-Rexroth Cylinder control unit
ZT	4111	Exhaust valve position sensor
LS	4112	Leakage from HCU
ZT	4114	Fuel injection plunger position

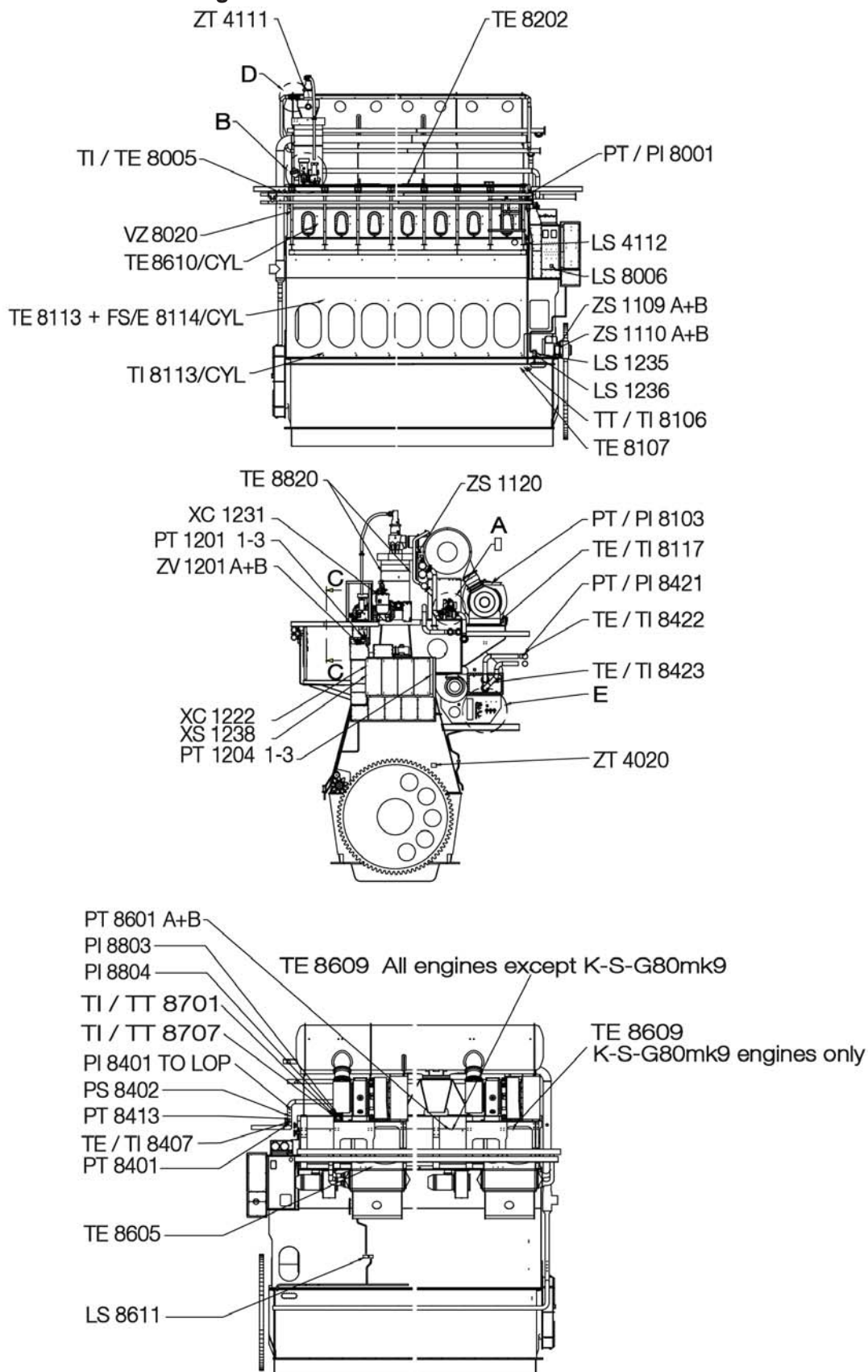
Miscellaneous

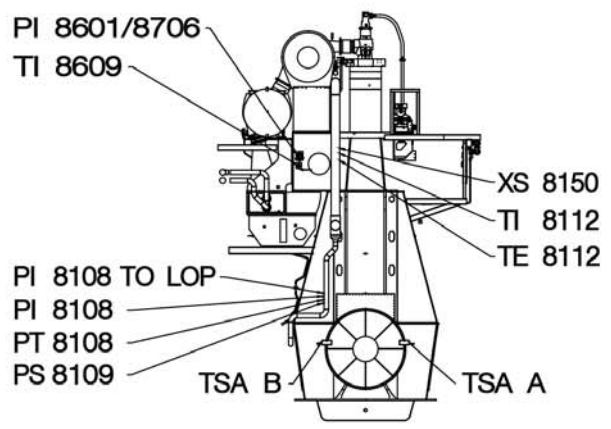
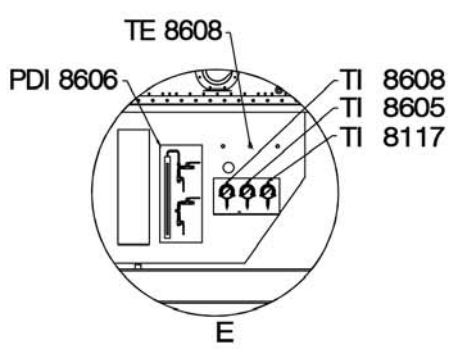
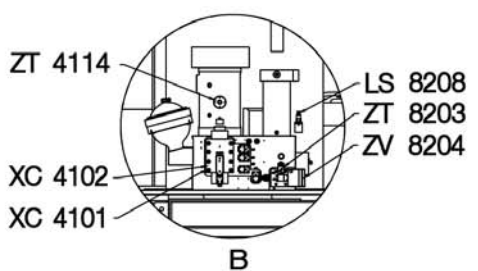
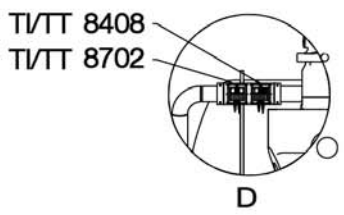
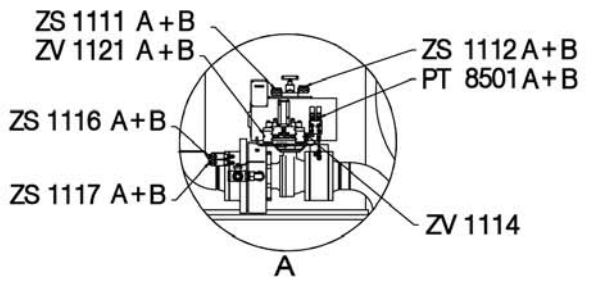
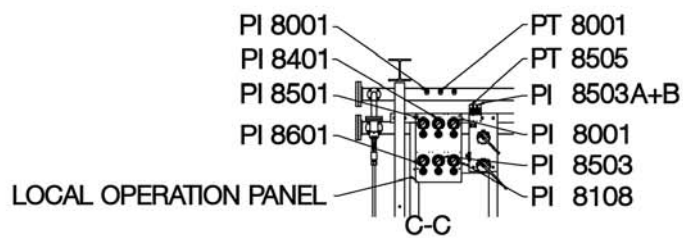
E	1180	Electric motor – Auxiliary blower
E	1181	Electric motor – Turning gear
E	1185	LOP, Local Operator Panel
ST	8801	Turbocharger speed monitoring (MAN T/C)
ST	8801	Turbocharger speed monitoring (ABB + Mitsubishi T/C)
PI	8803	Air inlet for dry cleaning of turbocharger
PI	8804	Water inlet for wet cleaning of turbocharger
WT	8812	Axial vibration monitor
XS	8813	Oil mist detector in crankcase (alarm + slow down)
XS	8814	Oil mist detector failure (alarm)
XT	8817	Turbocharger overspeed in case of VTA/VTG, WHR, EGB, TCO
TE	8820	Cylinder liner monitoring (alarm)

TACHO/Crankshaft Positioning System

ZT	4020	Tacho for safety
TSA-A		Tacho box A, Tacho system for ME engine with encoder
TSA-B		Tacho box B, Tacho system for ME engine with encoder

3 Instrumentation on Engine





Function of the individual valves in the pneumatic/electric manoeuvring system

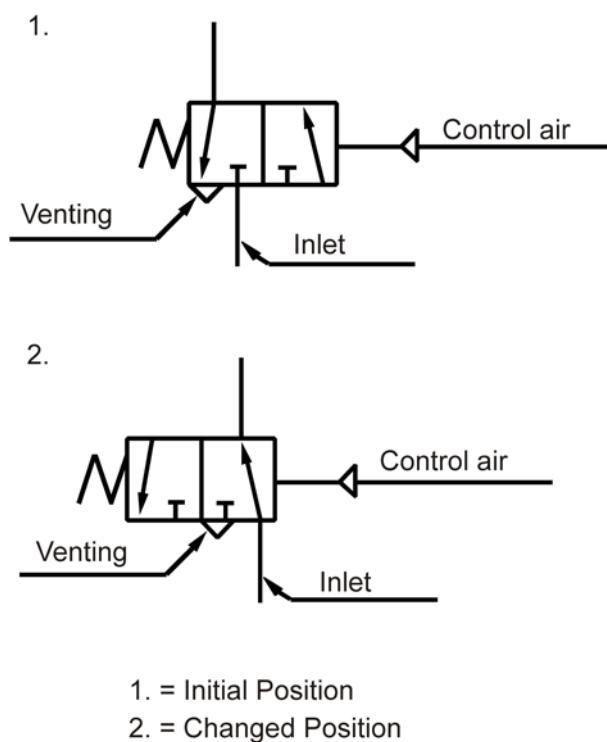
See drawing 7055-0155

Symbol description

The symbols consist of one or more square fields. The number of fields corresponds to the number of valve positions. The connecting lines are connected to the field which represents the valve position at a given moment of the process.

The change of position is conceived to take place by the fields being displaced at right angles to the connecting lines, which are assumed to have a stationary position on the paper. A short crossline on a broken line indicates a closed path.

Example of pressure controlled 2-position valve with spring return:

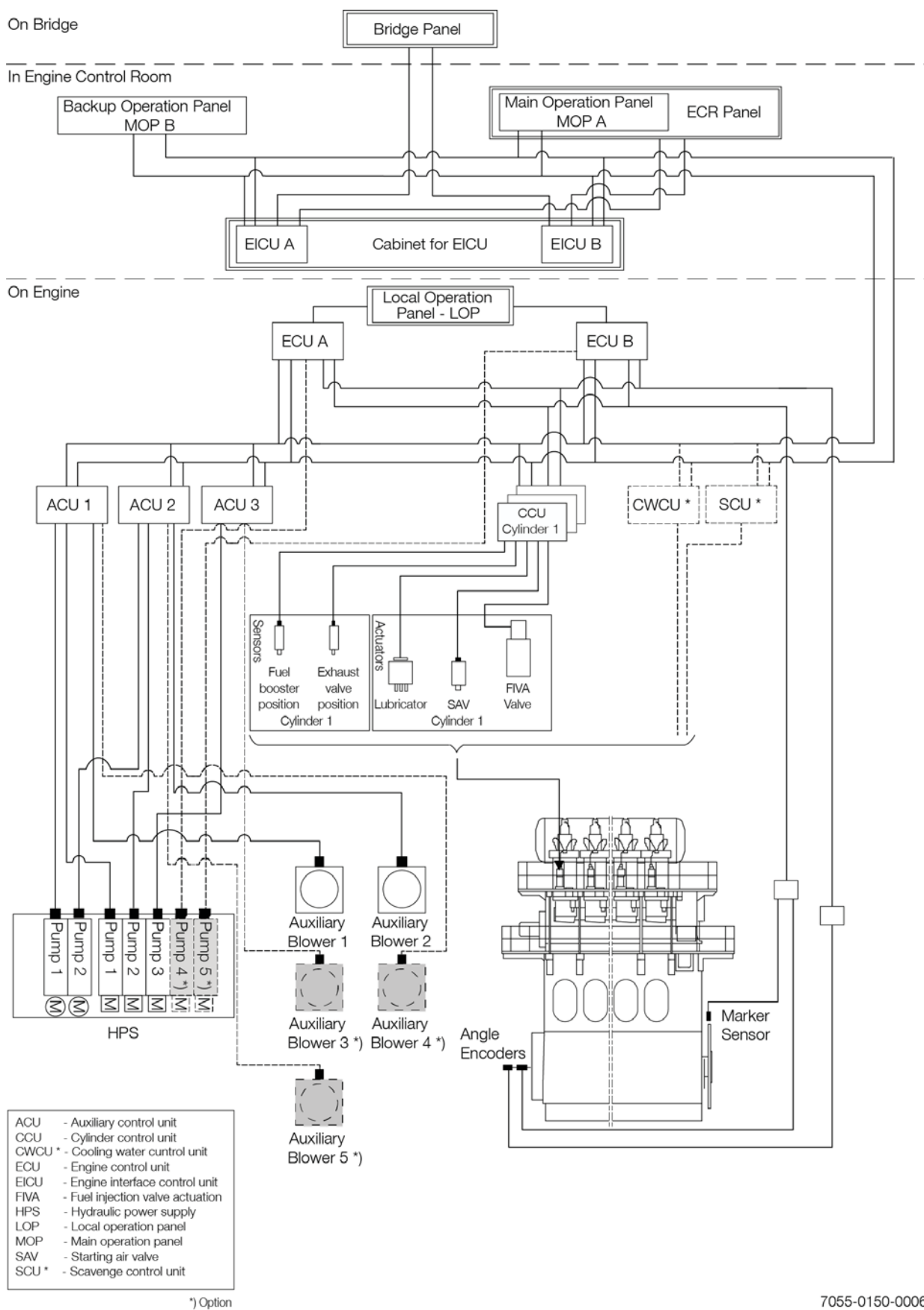


List of components in the manoeuvring system:

- 1: **Ball valve**
For manual cutting-off of control air supply.
- 2: **Pressure transmitter**
For alarm if control air supply pressure is too low. Alarm point 5.5 bar.
For alarm if control air pressure is not vented during FINISHED WITH ENGINE.
Alarm point 0.5 bar.
- 3: **Ball valve**
For manual cutting-off of air to exhaust valve air cylinder.

- 6: **Pressure gauge**
Indicates control air supply pressure.
- 12: **Two-position, five-way valve**
Controls the main starting valve. (Open or closed).
- 21: **Ball valve**
For draining off water from the manoeuvring system.
- 23: **Double non-return valve (Change over valve (OR))**
- 26: **Two-position, three-way valve**
Allows air to enter during start.
Prevents air inlet to starting air distributor system in the event of leaking main starting valve.
- 68: **Two-position, five-way valve**
Controls the slow turning valve. (Open or closed).
- 74: **Air receiver**
Reduces time lags in the manoeuvring system.
- 92: **Two-position, three-way solenoid valve**
Controls pilot signal to two-position, five-way valve 68. Slow-turning.
- 93: **Two-position, three-way solenoid valve**
Controls pilot signal to two-position, five-way valve 12. Main starting valve.
- 94: **Two-position, three-way solenoid valve**
Controls pilot signal to two-position, five-way valve 12. Main starting valve.
- 113: **Switch**
Gives signal to ECS/MOP when shut-off valve 118 is in SERVICE position.
- 115: **Two-position, three-way valve**
Blocks the START possibility when the turning gear is engaged.
- 116: **Switch**
Gives indication on the MOP and on Bridge if turning gear is engaged or disengaged.
- 118: **Shut-off valve**
For manual cutting-off of control air to the starting air distributor system.
- 119: **Switch**
Gives indication on Bridge when starting air distributor system is BLOCKED.
- 121: **Switch**
Gives signal to ECS/MOP and telegraph system/communication system when main starting valve is BLOCKED.
- 122: **Pressure transmitter for starting air pressure**
Blocks start possibility from Bridge if starting air pressure is too low. Switch point 15 bar.
- 123: **Switch**
Gives signal to ECS/MOP when main starting valve is in SERVICE position.
- 137: **Non-return valve**
Prevents back-flow of air from exhaust valve air cylinder.

- 140: **Pressure transmitter**
For alarm if control air supply pressure is too low. Alarm point 5.5 bar.
For alarm if control air pressure is not vented during FINISHED WITH ENGINE.
Alarm point 0.5 bar.
- 150: **Air pressure reduction unit**
Reduces starting air pressure to 7 bar.
- 154: **Two-position, three-way solenoid valve**
Allows the air to pass to the actuator 155 during Fuel Cut Off. Only if GL.
- 155: **Ball valve w. actuator**
Blocks for the fuel oil flow to engine during Fuel Cut Off. Only if GL.
- 160: **Ball valve**
For manual cutting-off control air supply to the LDCL system. Only with LDCL.
- 161: **Ball valve**
For manual cutting-off control air supply to the LDCL system. Only with LDCL option.
- 162: **Filter regulator**
Reduces control air pressure to 4 bar. Only with LDCL.
- 163: **Filter regulator**
Reduces control air pressure to 4 bar. Only with LDCL option.
- 164: **I/P Converter**
Controls pilot pressure to 3-way control valve 166. Only with LDCL.
- 165: **I/P Converter**
Controls pilot pressure to 2-way control valve 167. Only with LDCL option.
- 166: **3-way control valve**
Controls the cooling water temperature with variable set point, depending on engine load. Only with LDCL.
- 167: **2-way split range control valve**
Controls the cooling water temperature with variable set point, depending on engine load. Only with LDCL option.
- 168: **Two-position, three-way solenoid valve**
Leads pilot air to the Ball Valve W.Actuator 169. Only ME-GI engines.
- 169: **Ball valve w. actuator**
When activated (by pilot air through pos.168) it will switch to "Low-BN" 0 cylinder oil. When de-activated (no pilot air through pos.168) it will switch to "High-BN" cylinder oil. Only ME-GI engines.





Safety**Precautions**

For detailed sketch
see 0545-0100

○	Stop the Engine
○	Shut off starting air supply - At starting air receiver
○	Block the main starting valve
○	Shut off starting air distributor/distributing system supply
○	Shut off control air supply
○	Engage turning gear
○	Stop lubricating oil supply

Data

Ref.	Description	Value	Unit
T70-01	Angle encoder cover	20	kg
T70-02	Angle encoder bracket	35	kg
T70-10	Shaft alignment, maximum deviation	0.3	mm
T70-11	Shaft, tightening torque	170	Nm
T70-12	Bracket alignment, maximum deviation	0.3	mm

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

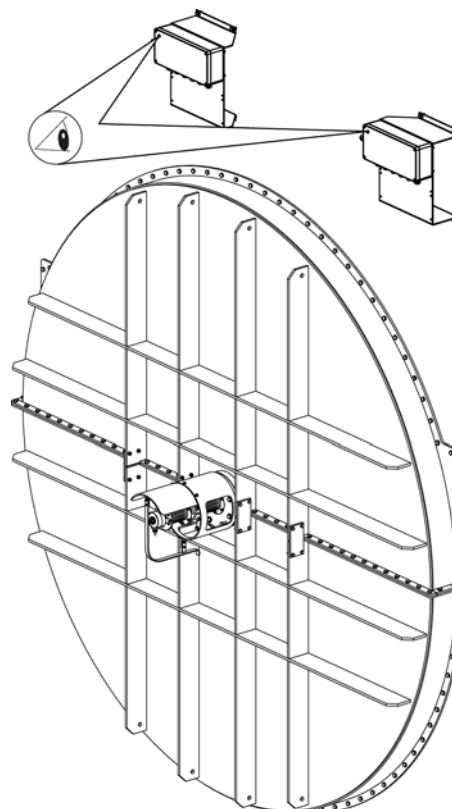
Plate	Item No.	Description
7670-0200	-	Torque spanners
7670-0300	-	Lifting tools, etc
7670-0410	078	Dial gauge and stand tool
2570-0010	398	Extractor tool

1. TSA-A

Check that power is supplied to the Tacho Signal Amplifier box.

Turn the crank throw for cylinder 1 towards TDC. Check that the LED indicator on TSA-A lights up when TDC is reached.

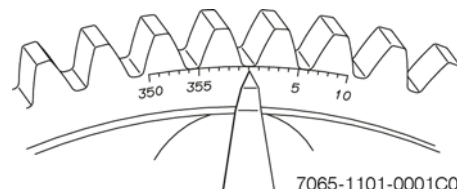
If the LED indicator on the TSA-A does not light up when TDC is reached, adjust the inner angle encoder.
See overhaul procedure



7065-1101-0003C01

2. TDC

Check the TDC of cylinder 1 against the mark on the turning wheel.



7065-1101-0001C02

3. TSA-B

Turn the engine a further 45° in the engines rotational direction. The LED on TSA-B should now light up.

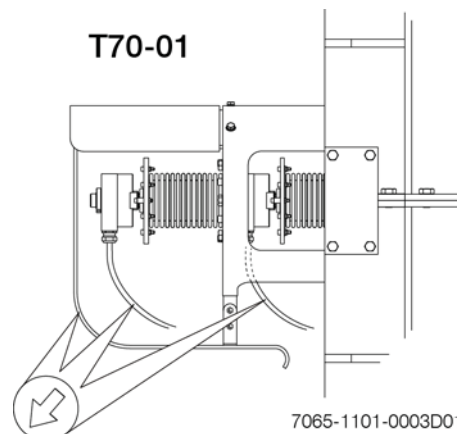
If the LED indicator on the TSA-B does not light up when TDC +45° is reached, adjust the outer angle encoder.
See overhaul procedure

1. Preparation

Tag the electrical plugs "Inner encoder" and "Outer encoder" before disconnecting them.

Remove the bracket (if mounted).

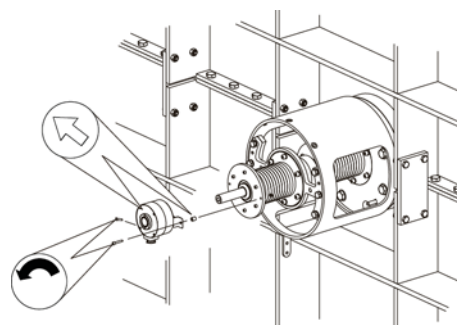
T70-01



7065-1101-0003D01

2. Remove the encoder

Loosen the screws as shown and pull the outer encoder off.



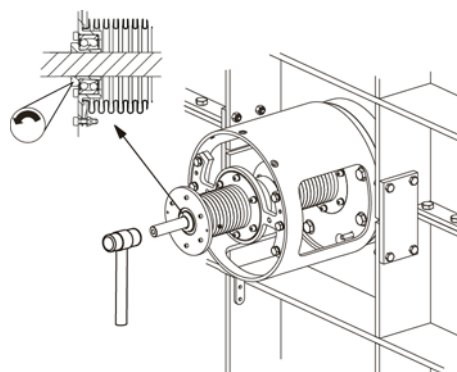
7065-1101-0003D02

3. Locking nut and washer

Loosen the locking washer and use a hook wrench to unscrew the locking nut on the bearing adapter sleeve. The locking nut should be unscrewed so far that the nut covers the thread on the end of the sleeve.

Slide the extractor tool onto the shaft. Tap the end of the extractor tool with a mallet to loosen the bearing adapter sleeve.

Unscrew the locking nut and remove the locking washer.



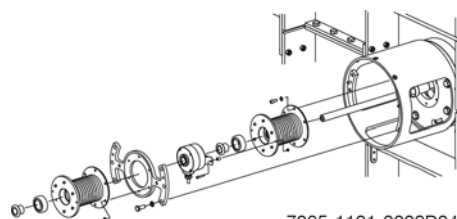
7065-1101-0003D03

4. Compensator & encoder

Unscrew the outer screws on the flange and remove the compensator.

Dismount the outer compensator and flange.

The inner encoder and compensator is dismantled in the same way as the outer encoder and compensator.



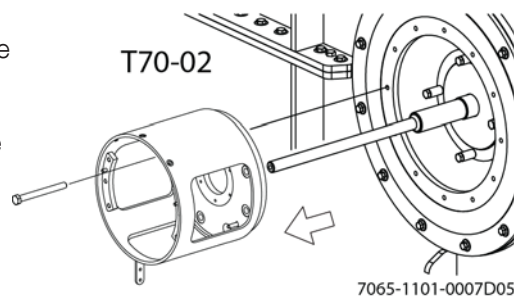
7065-1101-0003D04

5. Bracket

If it is necessary the mounting bracket can be dismantled.

Use a tackle and lifting strap to secure the bracket.

Unscrew the screws in the base plate and remove the bracket.

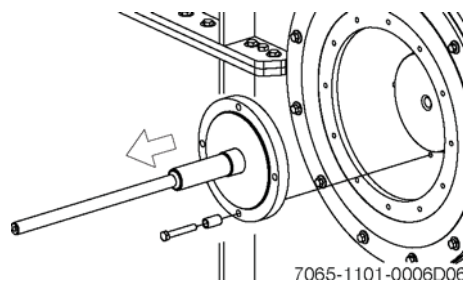


6. Shaft

If necessary, unscrew and remove the shaft.

NOTICE

Due to the need for realignment the shaft and the mounting bracket should only be dismantled when it is absolutely necessary.



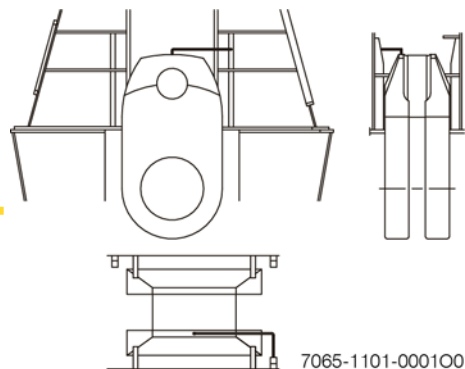
1. TDC

Turn the crank throw for cylinder 1 to TDC.

Check the TDC position with the pin gauge on the crank throw.

NOTICE

Before using the pin gauge, check the measurement from tip to tip with the value stamped on the pin gauge, and/ or the check-marks stamped on the fore end of the cylinder frame.



2. Adjustment

Loosen the clamping ring on the inner encoder (TSA-A).

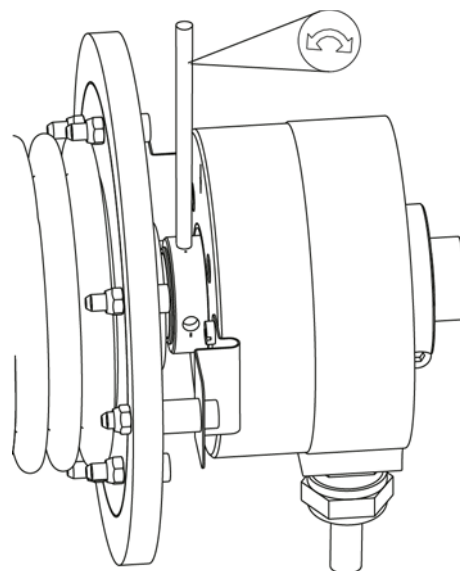
Use a mandrel or a drill to turn the encoder hollow shaft in the ahead direction until the indicator light turns on.

If the indicator light already is on, turn in the ahead direction until it goes off and then until it turns on again. Tighten the clamping ring.

Turn the engine 45° in the engines rotational direction and repeat the adjustment procedure on the outer angle encoder (TSA-B).

NOTICE

When adjusting the outer angle encoder a **CLOCKWISE** turning engine must be turned 45° in the **CLOCKWISE** direction and an **ANTICLOCKWISE** turning engine must be turned 45° in the **ANTICLOCKWISE** direction.



This concludes the mechanical adjustment of the angle encoders.

If the software settings need to be adjusted please contact MAN Diesel & Turbo.

After the adjustment, re-check the angle encoder.

See checking procedure.

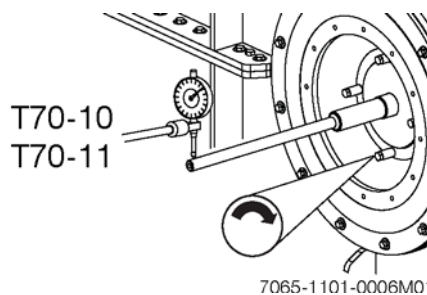
1. Shaft

Mount and tighten the shaft.

Check the shaft alignment using a dial gauge as shown.

Turn the engine one rotation. *See data.*

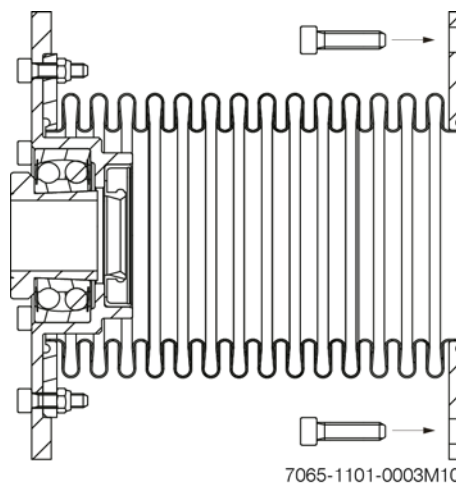
If the shaft alignment is not within specifications, apply some light force and bend the shaft lightly. Check the shaft alignment again.



2. Compensator

Loosely assemble the bearing sleeve, locking nut and compensator. Slide the assembly onto the shaft and mount the screws.

When positioning sleeve ensure contact between the sealing lip and sleeve.

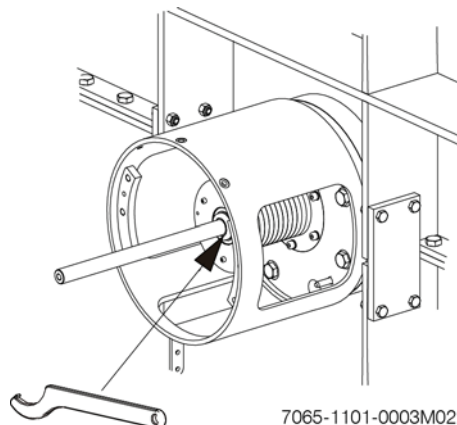


3. Secure

Tighten the locking nut to surface contact, then tighten a further 60° using a hook wrench.

Then unscrew the nut, place the locking washer in position and tighten the nut firmly again.

Lock the nut by bending one of the locking washer tabs into one of the nut slots.



4. Bearing

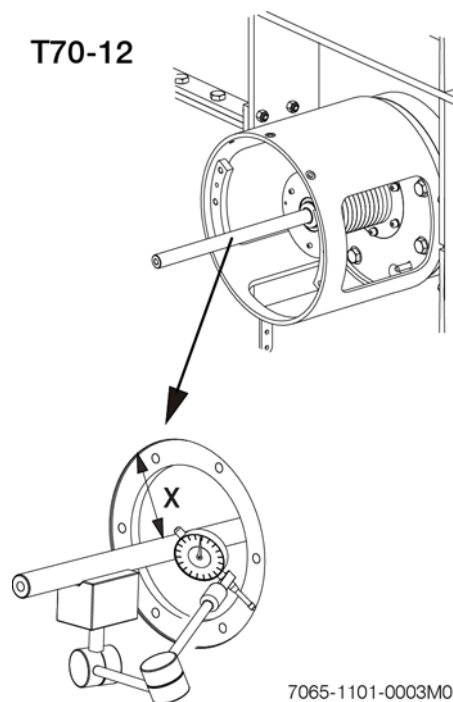
Mount the bracket.

Ensure that the pins are in place.

Mount the mounting bracket. Use a dial gauge caliper to ensure a maximum deviation from X of the value stated in *data T70-12* around the center shaft.

X is the distance between the center shaft and the rim of the compensator mounting recess on the flange.

T70-12

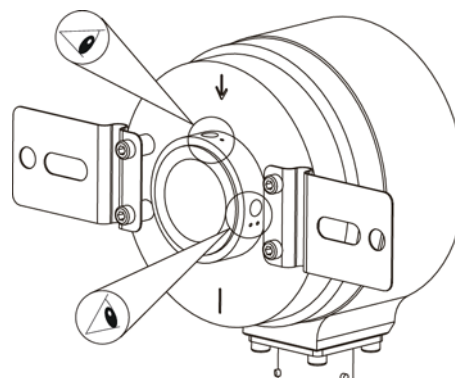


7065-1101-0003M01

5. Basic adjustment

Perform a basic adjustment of the angle encoder by turning the hollow shaft to a position where the dot; in case of a clockwise turning engine or the two dots in case of a counter clockwise turning engine, are in line with the arrow. Mount the inner encoder on the shaft.

When positioning sleeve ensure contact between the sealing lip and sleeve.



7065-1101-0001M03

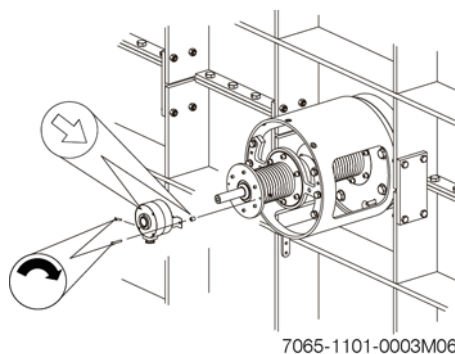
6. Inner encoder

Mount the encoder.

Adjust the encoder.
See overhaul procedure.

7. Outer encoder

Mount the outer encoder with bearing in the same way as shown for the inner encoder.



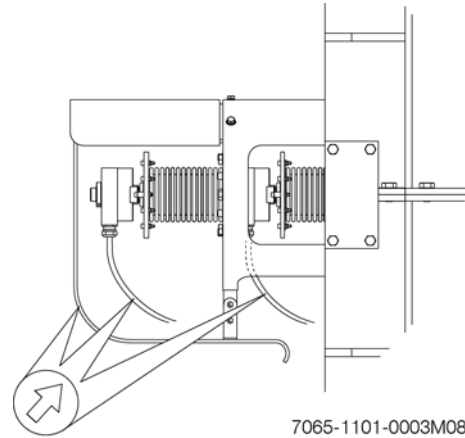
7065-1101-0003M06

8. Basic adjustment Perform a basic adjustment on the outer encoder as shown earlier and mount the encoder on the shaft.

Adjust the encoder.
See overhaul procedure.

9. Finally Mount the electrical connections.

Mount the bracket (if available).



Safety**Precautions**

*for detailed sketch
see 0545-0100*

☐	Stop the Engine
☐	Shut off starting air supply - At starting air receiver
☐	Block the main starting valve
☐	Shut off starting air distributor/distributing system supply
☐	Shut off safety air supply - Not ME Engines
☐	Shut off control air supply
☐	Engage turning gear
☐	Stop lubricating oil supply
☐	Shut down hydraulic power supply

Data

Ref.	Description	Value	Unit
T70-05	Check distance, pick-up arrangement	2.0-3.0	mm

The task-specific tools used in this procedure are shown on the plates at the end of this chapter or in the chapters indicated by the first two digits in the plate number, e.g. **2570-0010** refers to chapter 25, Bearings.

Tools

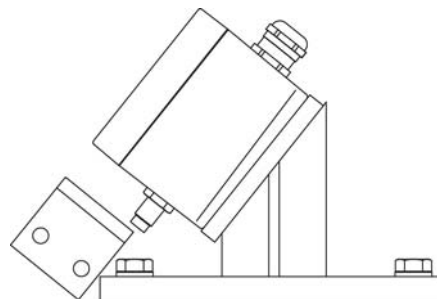
Plate	Item No.	Description
7670-0410	066	Slide caliper

The pick-up arrangement may vary from engine to engine to match the configuration of the control system installed on the specific engines.

The pick-up arrangement usually consists of one or more of the following pick-up systems:

1. **TDC pick-up system** The TDC pick-up arrangement normally consists of one or two sensors mounted on a bracket between the engine frame and the turning wheel. The sensors are normally triggered by a bracket (profile iron) bolted onto the turning wheel.

The purpose of the TDC pick-up system is for the engine control system to monitor when the crank throw for cylinder No. 1 reaches TDC.

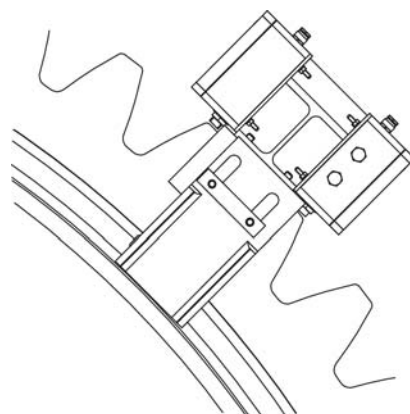


7065-1201-0003C01

2. **Control pick-up system**

The control pick-up arrangement normally consists of one or more brackets bolted onto the engine frame, each mounted with two sensors. The sensors are triggered by the teeth of the turning wheel or by a trigger ring.

The purpose of the control pick-up system is for the engine control system to continually monitor the position of the crankshaft and the direction of rotation.

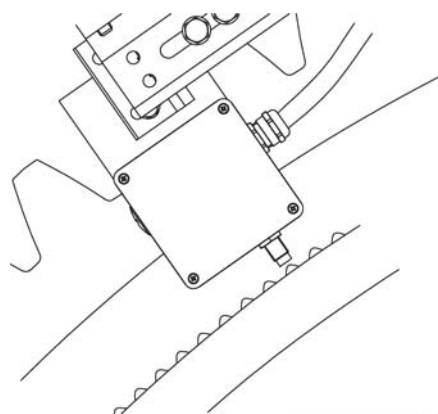


7065-1201-0003C02

3. **Safety pick-up system**

The safety pick-up arrangement normally consists of two pick-ups mounted on a bracket. The sensors are triggered by the teeth of the turning wheel or by a trigger ring.

The purpose of the safety pick-up system is for the engine safety system to continually monitor the rpm of the engine.



7065-1201-0003C03

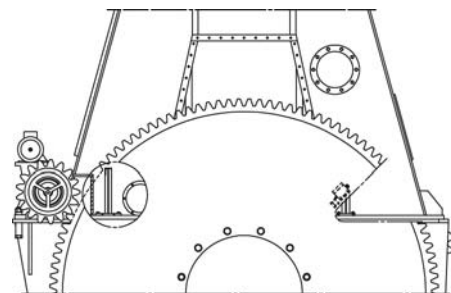
4. Manual checking

The sensors in the pick-up arrangement are continuously checked by the system itself and will activate an alarm on the main operating panel if a failure occurs.

Manual checking is to be carried out as described.

NOTICE

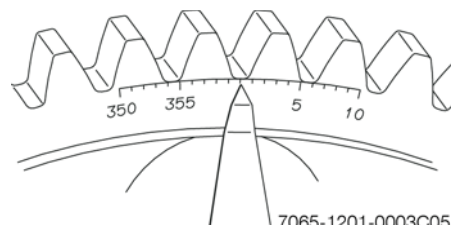
The drawings in this procedure are for guidance only and may vary from the actual engine configuration



7065-1201-0003C04

5. Adjustment of the TDC pick-up system

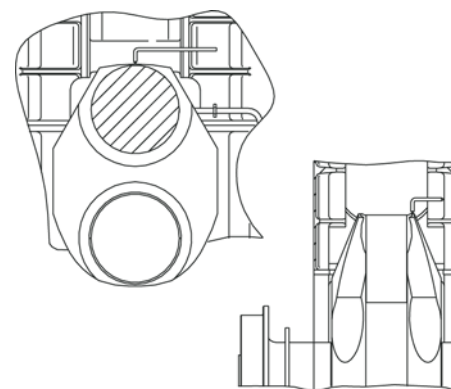
Turn the crank throw for cylinder No. 1 to TDC. Check the TDC of cylinder No. 1 against the 0° mark on the turning wheel.



7065-1201-0003C05

6. Check the position

Check the TDC position with the pin gauge on the crank throw.

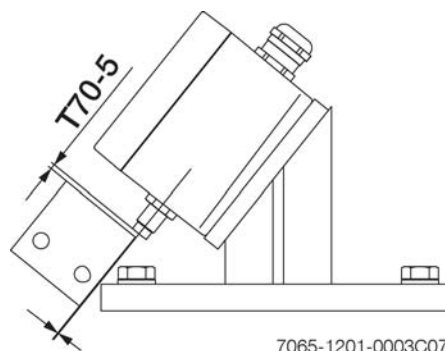


7065-1201-0003C06

7. Adjust the distance Check the clearance between the sensor tip and the bracket, and compare with the values stated *in data*. Make sure the centerline of the sensor is aligned with the edge of the bracket.

NOTICE

The values in the datasheet are standard values.



7065-1201-0003C07

If necessary, adjust the position of the sensor.

If correct signal does not occur, adjust the clearance in steps of 0.2 mm, until correct signal is obtained.

NOTICE

Make sure that the sensor tip does not touch the bracket while turning.

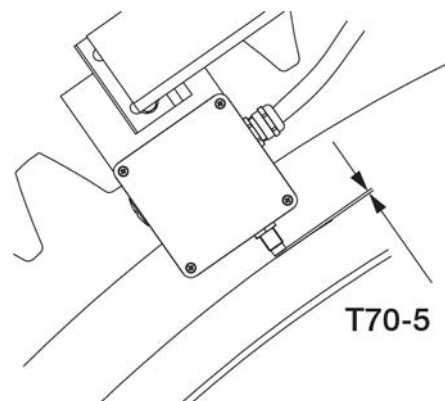
For further details and data regarding adjustment of the TDC pick-up system, see manufacturer's instructions.

8. Adjustment of the Control / Safety pickup system Turn the engine to center the highest point of the turning wheel/trigger ring below the sensor.

Check the clearance between the sensor tip and the turning wheel/trigger ring and compare with the values *in data*.

NOTICE

The values in the datasheet are standard values.



7065-1201-0003C08

If necessary adjust the position of the sensors.

If correct signal does not occur, adjust the clearance in steps of 0.2 mm, until correct signal is obtained.

NOTICE

Make sure that the sensor tip does not touch the turning wheel/trigger ring while turning.

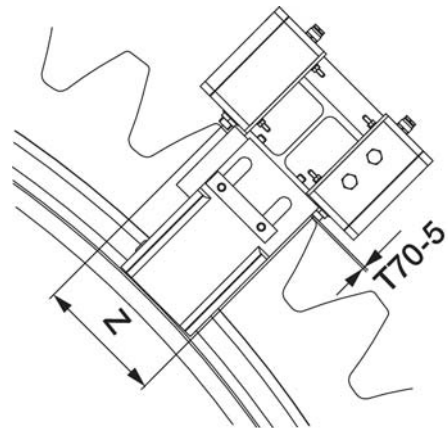
For further details and data regarding adjustment of the control/safety pickup system, see manufacturer's instructions.

9. In case of multiple sensors

Pick-up configurations with more than one sensor installed may require adjustment of the distance **Z** between the sensors.

Check and, if necessary, adjust the distance between the sensors according to manufacturer's instructions.

For further details and data regarding adjustment of the control/safety pickup system, see manufacturer's instructions.



7065-1201-0003C09

10. Replacement of sensors

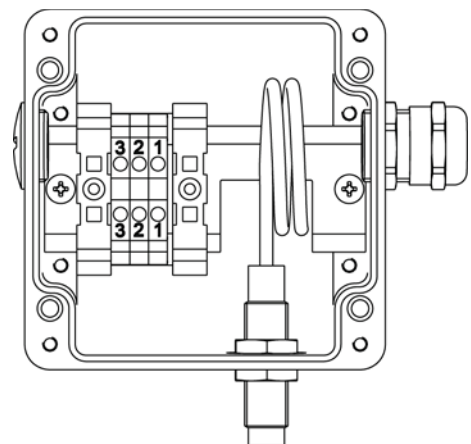
Prepare the sensor cable with sleeves and markings (BN to be marked 1, BU to be marked 2 and BK to be marked 3).

BN = +24v. , BU = 0v. and BK = OUT

Turn the engine to the point where the highest top of the turning wheel or on the axial cam is in front of the sensor which is to be replaced.

Open the sensor box, check cable colours and markings. Remove the old sensor. The sensor box must not be dismantled or moved.

Mount the new sensor into the sensor box. It should be installed with the correct clearance. *See data.* Secure the sensor with Loctite ® metal glue.



7065-1201-0001C04

11. Check the
functionality

After tightening, check position and
clearance.

Install the sensor cable in accordance
with the drawing. BN to terminal 1, BU
to terminal 2 and BK to terminal 3.

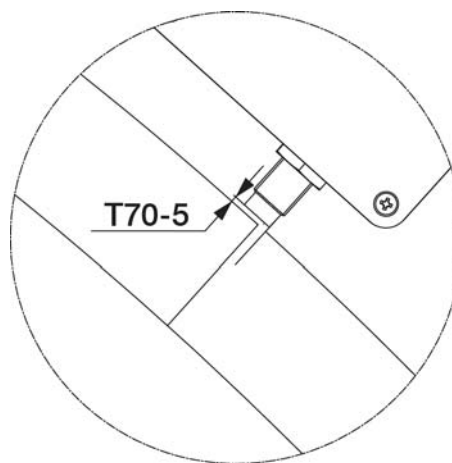
NOTICE

For sensors not mounted inside a
box, the cable connection box is
located on the aft of the engine
frame box.

Turn the engine to see if the sensor light
diode flashes, if not, stop turning.

Move a piece of steel near the sensor
head and check that the diode light
changes.

Test the signal in the service terminal in
the same way.



7065-1201-0003C10

Preface Chapter

Description

Work Card

Tool Plate

Tools	7640-0100-0002
Hydraulic Tools	7645-0100-0001
Hydraulic Tools	7665-0101-0006
Standard Tightening Torque	7665-0201-0003
Torque Spanner	7665-0301-0001
Tightening Gauge	7665-0401-0001
Screws and Nuts	7665-0501-0001
Working Platforms	7665-0601-0001
Lubricating Procedures	7665-0901-0001
Hydraulic Tools	7670-0100-0004
Torque Spanners	7670-0200-0004
Open-Ended Spanners	7670-0210-0007
Open-Ended Slugging Spanners	7670-0220-0004
Combination Spanners	7670-0230-0001
Ring Slugging Spanners	7670-0240-0006
Miscellaneous Spanners	7670-0250-0007
Open-Ended Spanners	7670-0260-0001
Lifting Tools	7670-0300-0020
Travelling Trolley	7670-0310-0001
Pliers	7670-0400-0004
Instruments	7670-0410-0001
Working Platforms	7670-0600-0011
Roundslings	7670-0320-0003
Pressure Gauge	7670-0450-0001

General

This chapter of the instruction book is intended to provide the user with information regarding all the special tools and standard tools necessary for correct maintenance of the engine.

Information includes operation and maintenance of hydraulic tools, tightening and locking of screws and nuts as well as tool plates to be used when ordering spare tools.

In addition tool plates relevant only to specific parts of the engine may be found in the back of each chapter of the instruction book.

⚠ DANGER**In case of malfunctioning hydraulic jacks or hoses**

- Always keep clear of area above the pressurised hydraulic jack during use.
Broken studs or malfunctioning jack can eject !
- Bursting hydraulic hose can eject oil into the skin!
Always inspect the hose assembly before use.
Defective or damaged hose assemblies **must** be replaced and discarded !

**⚠ WARNING****Keep the work area clear**

- Whipping hose ends poses a risk !
Verify correct engagement of couplings before applying hydraulic pressure
- Leaking hydraulic oil can pose a risk in case of skin contact.
Always use goggles and oil resistant gloves when working with hydraulic oil.

**⚠ CAUTION****First Aid**

If a fluid injection occurs, it must always be treated as a medical emergency!

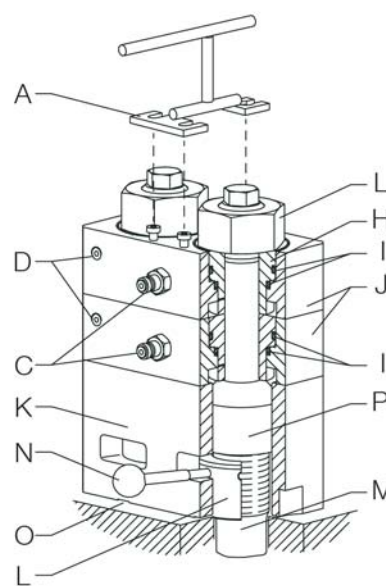
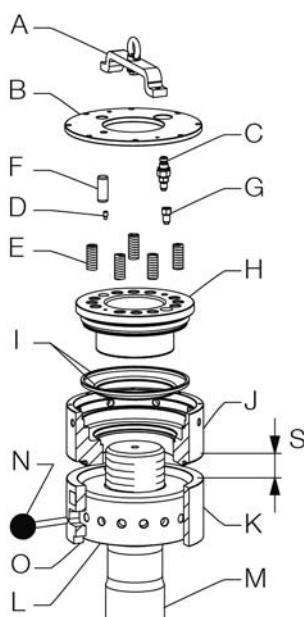
For operation of hydraulic tools,
see description 7645-0100 and work card 7665-0101.

1 General

A hydraulic jack consists of:

- | | |
|--------------------------|----------------------------------|
| A Lifting bracket * | J Cylinder |
| B Cover | K Support |
| C Snap-on coupling | L Nut |
| D Bleed screw | M Stud |
| E Piston Return Spring * | N Tommy bar |
| F Guide pin* | O Milled recess for feeler gauge |
| G Overstroke valve * | P Extension stud |
| H Piston | S Clearance |
| I Sealing rings | |

* Not present on all type of jacks.



7645-0100-0001DE04

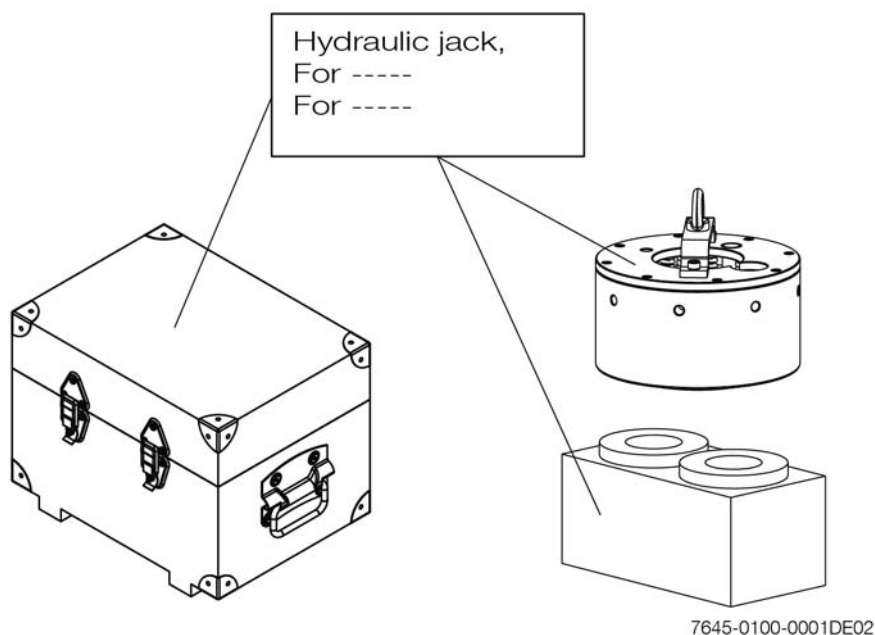
NOTICE

Hydraulic tool variants

The illustrations in this description is intended as examples and is not necessary an expression of the specific tool design.

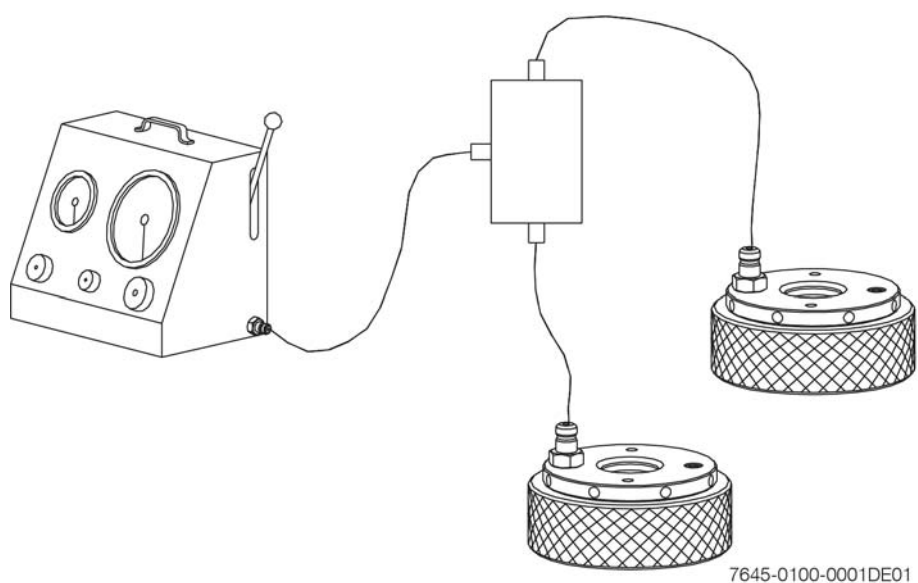
2 Purpose

The hydraulic jacks are designed for specific purposes. Thereby, the appearance or design may vary, some are circular, others are rectangular, but the basic function of all hydraulic jacks are similar. All hydraulic jacks are marked with a description text for its designated purpose which normally also is stated on the storage box.



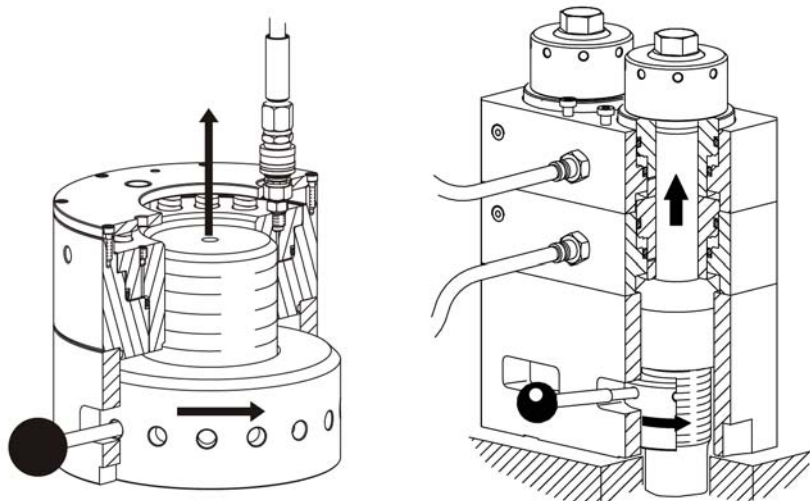
3 Connection

The jack(s) is/are connected, via a distributor block, to a high-pressure pump, which is able to deliver hydraulic oil at the pressure indicated on the jack and on the data sheet in the relevant section of this instruction book.



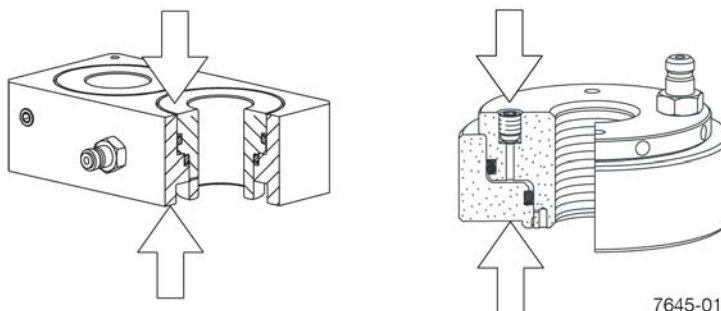
4 Function

The function of the jack in operation is that it lengthens the stud or bolt concerned, relative to the oil pressure applied and the piston area inside the jack. When the stud or bolt lengthens, the nut can be loosened or tightened, as required, with the aid of a tommy bar. The jack must not be exposed to blows or impacts.



7645-0100-0001DE03

If the hydraulic jack is without piston return springs it should be compressed firmly by hand before use to avoid the possibility to exceed maximum lift.
See max. lift, later in this description.



7645-0100-0001DE06

NOTE: When compressing the jacks it is recommended to connect the jack to the high-pressure pump and thereby leading the excessive oil from the jacks back to the pump.

4.1 Oil

The oil used must be pure hydraulic oil or turbine oil (with a viscosity of about SAE 20). Oils such as, for instance, lubricating oil (system oil) or cylinder lubricating oil must not be used, as these oils are normally alkaline and can thus damage the back-up rings.

When the jack is not in use it should be cleaned and kept in the boxes supplied.

5 Max. Lift

The jack is marked with a "Max. lift". If the jack is not compressed correctly before it is mounted on the stud there is a risk that the maximum lift is exceeded before the stated hydraulic pressure is reached. If the maximum lift is exceeded the jack will:

- **A** - If overstroke valve **is not** present

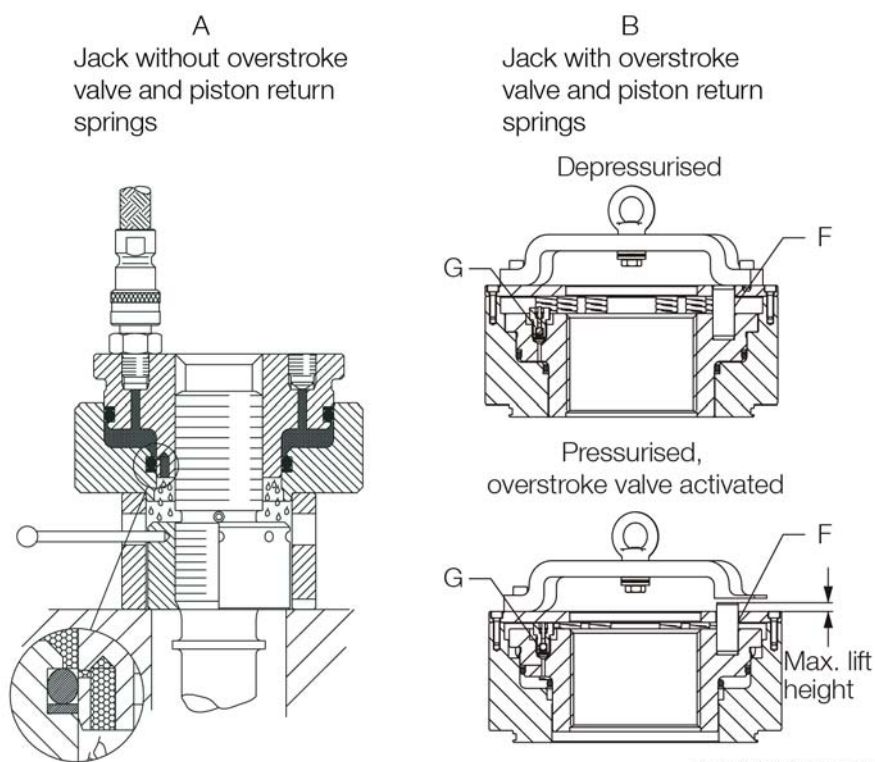
The oil pressure from the pressure chamber is relieved through a relief bore in the piston into the space between the stud and the support ring. When the pressure is relieved in this way, the lowermost sealing ring will most likely be damaged. Therefore inspect and, if necessary, replace this sealing ring.

- **B** - If overstroke valve **is** present

The overstroke valve releases the oil pressure into the space beneath the cover. The oil can then be seen seeping out of the openings in the jack.
NOTE: If the overstroke valve has been activated, it may be necessary to over-haul the valve.

In both cases, *see work card 7665-0101 'Overhaul'*.

If a guide pin is present the lift can be measured on the protruding guide pin on top of the jack (F).



7645-0100-0001DE05



Eye protection and gloves must be used when working with hydraulic tools.

Studs or bolts provided with threads for attaching hydraulic tools and with circular nuts must only be loosened and tightened up by means of the hydraulic tools supplied.

The jack(s) is/are connected, via a distributor block, to a high-pressure pump, which is able to deliver hydraulic oil at the pressure indicated on the jack and on the data sheet in the relevant section of this instruction book. The stud or bolt concerned is thereby lengthened relative to the oil pressure applied and the piston area, and the nut can be loosened or tightened, as required, with the aid of a tommy bar.

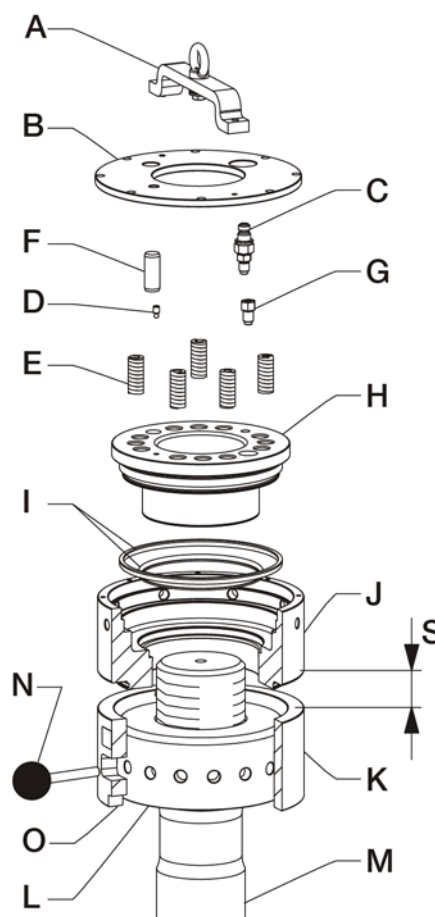
The jacks must not be exposed to blows or impacts.

The jacks are marked with a "Max. lift". This value must not be exceeded.

The hydraulic jacks are fitted with piston return springs to ensure the correct retraction of the piston when pressure is released.

1. The hydraulic tools The hydraulic tools consist of a set of jacks with an internal thread to suit the tool attachment thread on the stud or bolt, and a support rings.

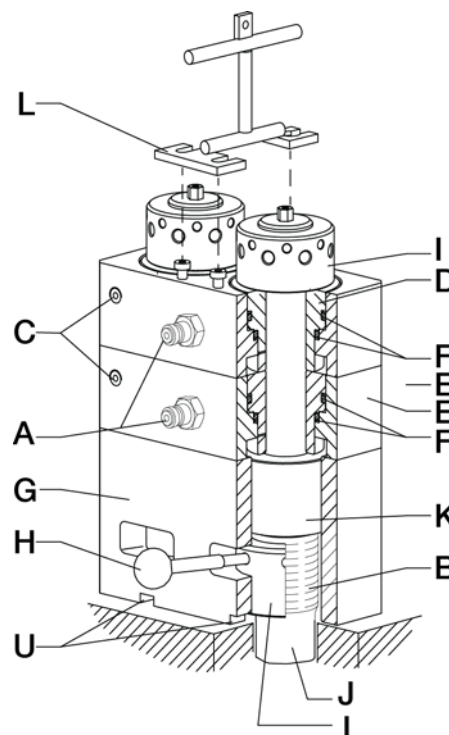
- A Lifting bracket
- B Cover
- C Snap-on coupling
- D Bleed screw
- E Piston Return Spring
- F Guide pin
- G Overstroke valve
- H Piston
- I Sealing rings
- J Cylinder
- K Support ring
- L Nut
- M Stud
- N Tommy bar
- O Milled recess for feeler gauge
- P Extension stud
- Q Support
- S Clearance



7665-0101-0002C01

2. For main bearings

For the main bearings, the hydraulic tool consist of a double jack with two extension studs. This jack is designed for the simultaneous dismantling of both nuts on one side of the main bearing.



7665-0101-0006C02

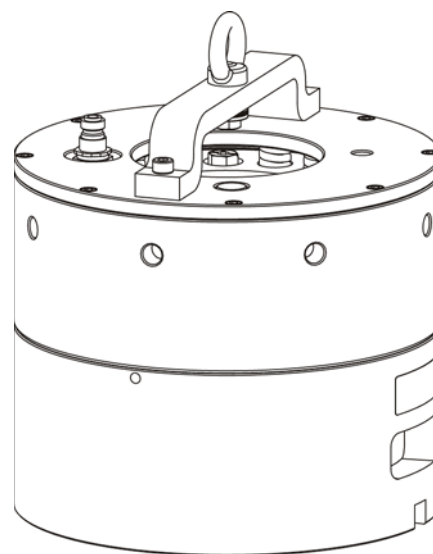
3. For cylinder cover

For the cylinder cover, the hydraulic tool consists of eight individual jacks suspended from a common lifting tool. The support rings are mounted below each jack using spring pins.

NOTICE

It is not necessary to dismantle the support rings when overhauling the cylinder cover jacks.

Operation of the cylinder cover jacks is identical to the operation of the single hydraulic jacks.



7665-0101-0002C03

4. Overstroke

The hydraulic jacks are designed so that, in the event that the "Max. lift" limit is exceeded, the pressure is relieved by an overstroke valve mounted in the piston. The overstroke valve releases the oil pressure into the cavity beneath the cover. The oil can then be seen seeping out of the openings in the jack.

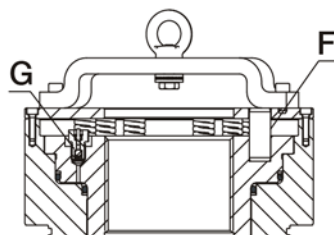
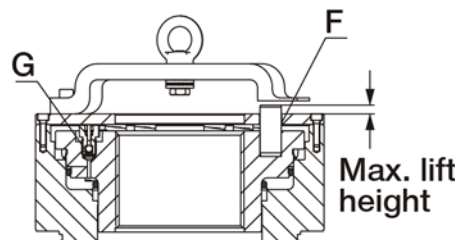
NOTICE

If the overstroke valve has been activated, it may be necessary to overhaul the valve.

See overhaul procedure.

The oil used must be pure hydraulic oil or turbine oil (with a viscosity of about SAE 20). Oils such as, for instance, lubricating oil (system oil) or cylinder lubricating oil must not be used, as these oils are normally alkaline and can thus damage the backup rings.

The following instructions must be closely followed to prevent accidents or damage, and after use the jacks should be cleaned and kept in the wooden boxes supplied.

Depressurized**Overstroke valve activated**

7665-0101-0002C04



Eye protection and gloves **must** be used when working with hydraulic tools.

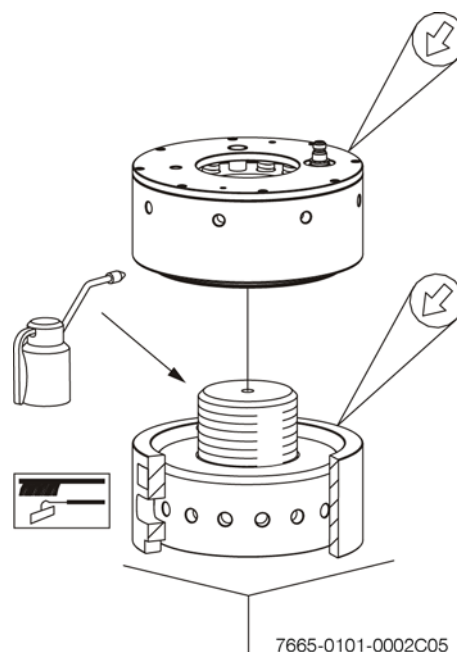
Dismount a nut using a single hydraulic jack

1. Clean the tool/nut

Carefully clean the thread, the nut and the surrounding parts.

Lubricate the thread of the bolt/stud with molybdenum disulphide grease or with graphite and oil or similar.

Place the support ring around the nut in such a position that the tommy bar can be applied through the slot when the nut is to be dismantled.



2. Mounting

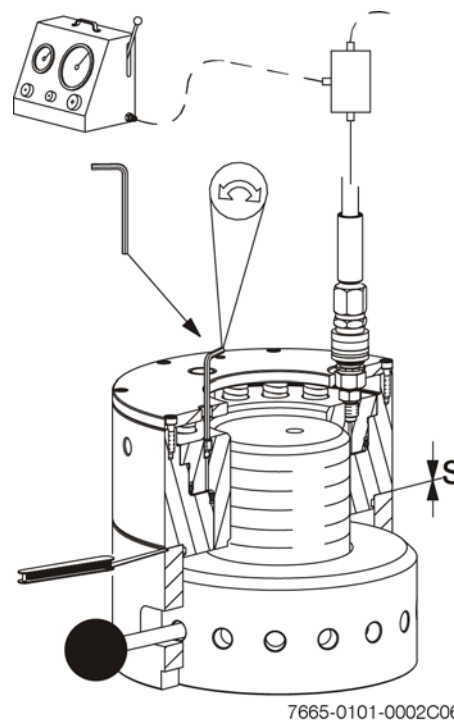
Screw the jack on to the tool attachment thread of the bolt/stud, until the cylinder of the jack bears firmly against the support ring..

Connect the hydraulic jack, the distributor block and the high pressure pump by means of high pressure hoses.

Unscrew the jack $\frac{3}{4}$ of a turn to create a clearance between the jack and support ring. When loosening nuts on staybolts it is necessary to unscrew the jack 2,5 turns.

Loosen the bleed screw in the jack and start the pump. Fill the system with oil until oil without air bubbles flows from the bleed hole and tighten the bleed screw.

The clearance between the jack and support ring ensures that the jack can be removed after the nut is loosened.



After adjustment, check that the parts are guided correctly together and that there is no clearance between the piston and cylinder of the jack.

3. Pressurisation

Gradually increase the oil pressure to the stated value. Use the tommy bar during the pressurisation to determine when the nut is loose.



WARNING

Keep clear above the jack

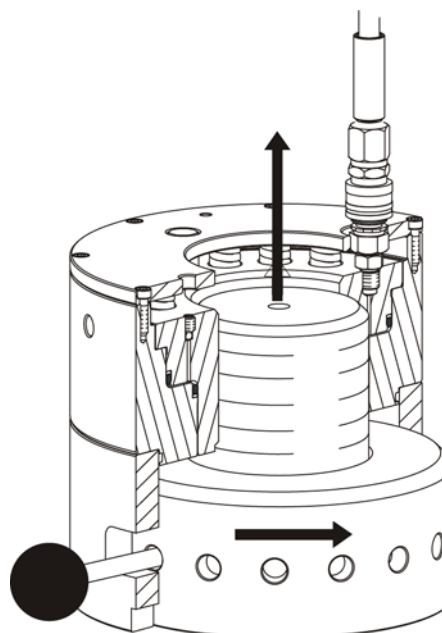
Do not hold any parts of your body over the hydraulic jack during pressurisation.

- If there is a weakness in the stud/bolt you can be hit if it breaks. The stud/bolt will react like a spring.

If the nut does not come loose, the pressure may be increased by up to 10% of the working pressure stated on the jack.

NOTICE

Make sure not to exceed the max. lifting height stamped on the jack.



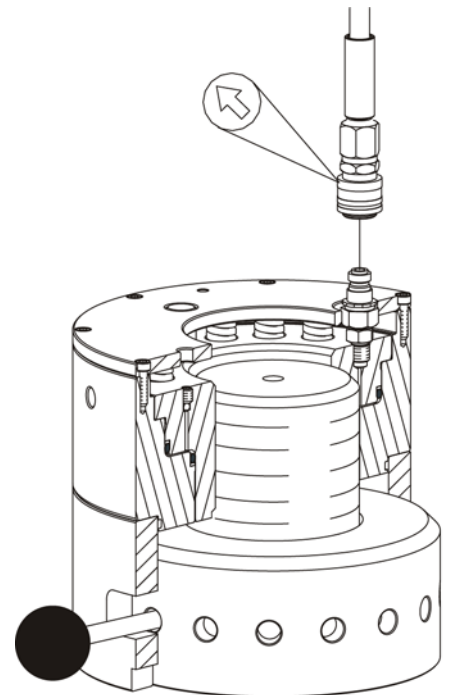
7665-0101-0002C07

4. Unscrew the nut

Unscrew the nut with the tommy bar, make sure that the nut is not screwed up against the jack.

Relieve the system of pressure and disconnect the high-pressure pump.

Remove the hydraulic tool and the nut.



7665-0101-0002C08

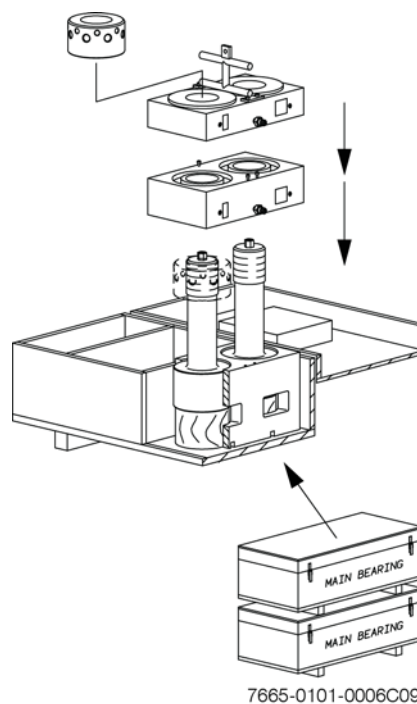


Eye protection and gloves **must** be used when working with hydraulic tools.

Dismount nuts using a double hydraulic jack

1. Assembling

Assemble the main bearing tightening tools, using the wooden box as a guide for correct assembling.

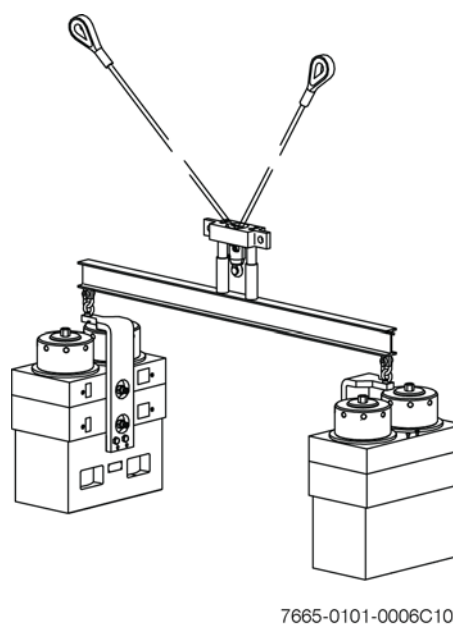


2. Positioning the jacks

Using the lifting tool, lift the two main bearing jacks into the crankcase. *See work card 2565-0401.*

Carefully clean the main bearing studs, the nuts and the surrounding parts.

Lower the jacks on to the nuts of the main bearing, and screw the extension studs on to the main bearing studs.



3. Adjustment

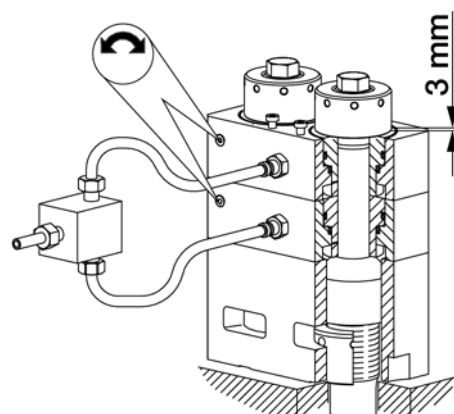
The clearance between the pistons and the cylinder of the top jack is adjusted by unscrewing the upper nuts 1 turn $\approx$ 3mm.

The clearance between the jack and spacer ring ensures dismantling of the jack after loosening the nut.

Connect the hydraulic jacks, the distributor block and the high-pressure pump by means of high-pressure hoses.

Loosen the bleed screws in both jacks, and fill up the system with oil until oil, without bubbles, flows out of the bleed holes.

Re-tighten the bleed screws.



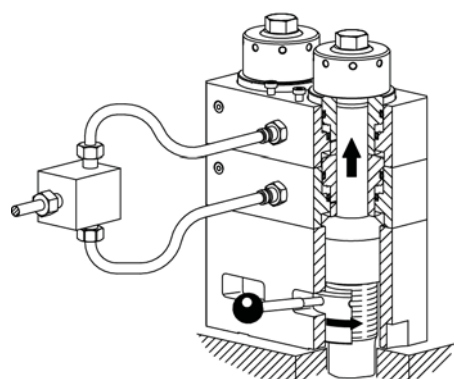
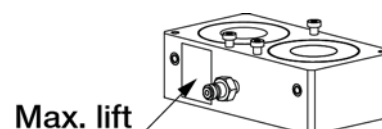
7665-0101-0006C11

4. Unscrew the nut

Increase the oil pressure to the prescribed value. Use the tommy bar during the pressure increase to determine when the nut is loose. If the nut does not come loose, the pressure may be increased by 10% of the working pressure marked on the jack.

NOTICE

Make sure not to exceed the max. lifting height stamped on the jack.



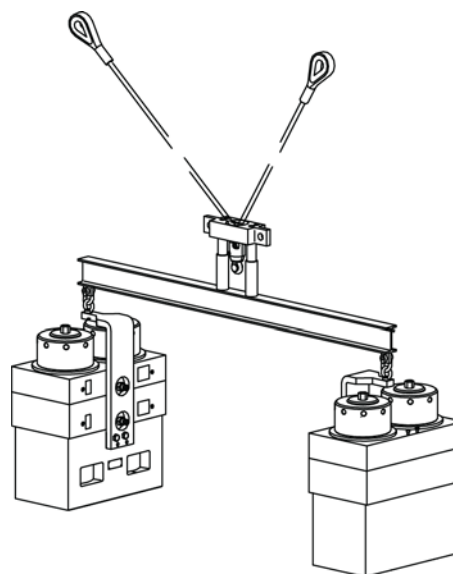
7665-0101-0006C12

Unscrew the lower nuts 1½ turns with the tommy bar, making sure that the nuts are not screwed up against the extension stud.

5. Remove the jacks

Relieve the system of pressure, disconnect the high-pressure pump, and unscrew the extension studs from the main bearing studs.

Using the lifting tool, remove the hydraulic jacks from the crankcase.



7665-0101-0006C10

Mount a nut using a single hydraulic jack**1. Clean the tool and nut**

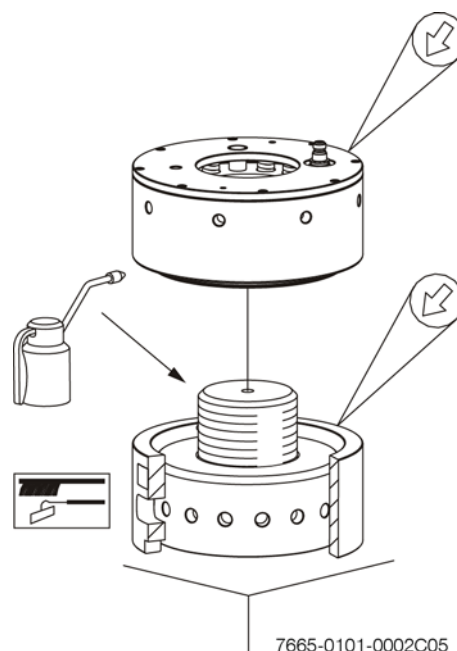
Thoroughly clean the nut, the thread, the jack, the contact faces, and the surrounding parts.

Lubricate the thread of the stud/bolt with molybdenum disulphide grease or with graphite and oil or similar.

Mount the nut on the thread and tighten it with the tommy bar.

Check with a feeler gauge that the contact face of the nut bears on the entire circumference.

Place the support ring around the nut in such a position that the tommy bar can be applied through the slot for the purpose of tightening the nut.



7665-0101-0002C05

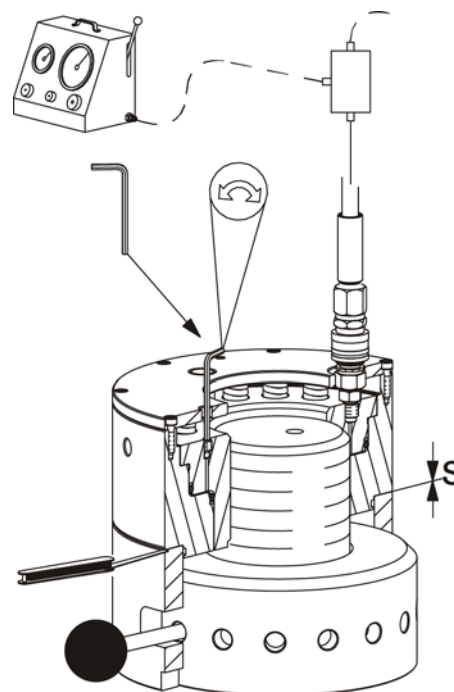
2. Mount the jack

Screw the hydraulic jack on to the stud. Make sure that the jack bears firmly against the support ring and that the parts are guided correctly together.

Connect the hydraulic jack, the distributor block and the high-pressure pump by means of high-pressure hoses.

Loosen the bleed screw in the jack and fill up the system with oil, until oil without bubbles flows out of the bleed hole.

Re-tighten the bleed screw.



7665-0101-0002C06

3. Pressurisation

Gradually increase the oil pressure to the stated value. Tighten the nut by means of the tommy bar applied through the slot of the support ring.

NOTICE

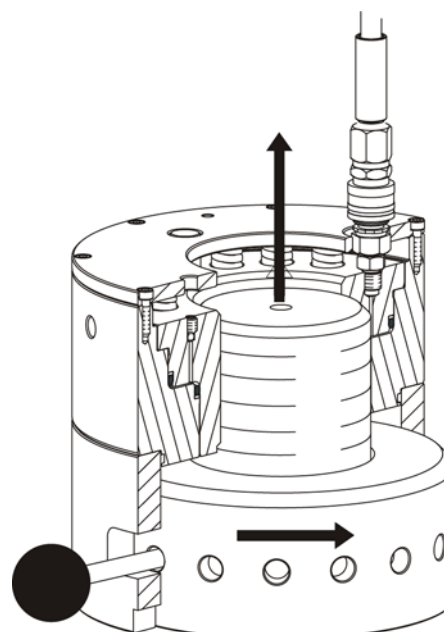
Make sure not to exceed the max. lifting height stamped on the jack.

Depressurize and pump up to the prescribed pressure again.

WARNING**Keep clear above the jack**

Do not hold any parts of your body over the hydraulic jack during pressurisation.

- If there is a weakness in the stud/bolt you can be hit if it breaks. The stud/bolt will react like a spring.



7665-0101-0002C07

4. Check with a feeler gauge

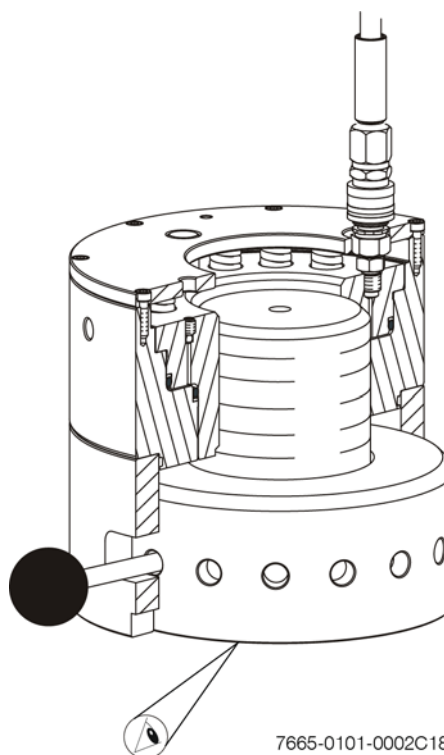
While maintaining the pressure, check with a feeler gauge, inserted through the recess at the bottom of the support ring, that the nut bears against the contact face.

Relieve the system of pressure and disconnect the high-pressure pump.

Remove the hydraulic tool.

NOTICE**New studs, bolts or nuts**

When new studs, bolts or nuts are tightened for the first time, do not remove the jack, but pressurise the jack again and re-tighten the nut. Repeat this step 2 times.



7665-0101-0002C18

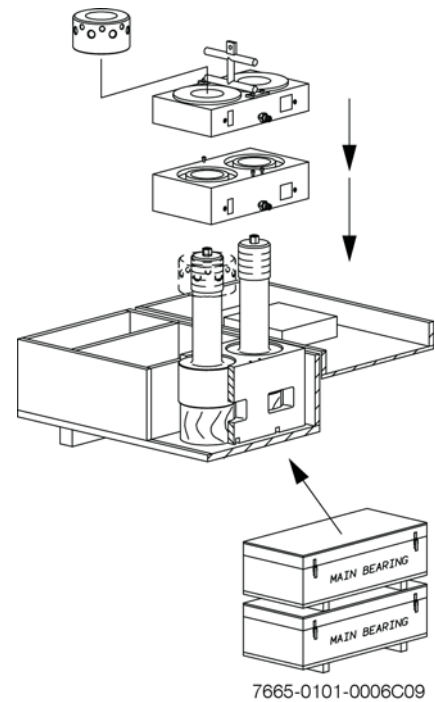


Eye protection and gloves **must** be used when working with hydraulic tools.

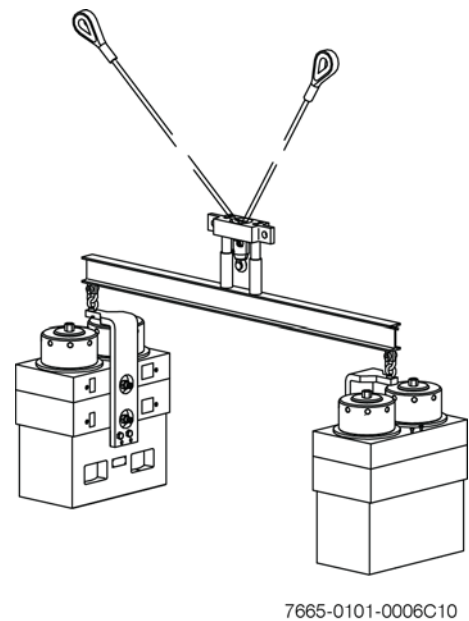
Tightening nuts using a double hydraulic jack

1. Assembling

Assemble the main bearing tightening tools, using the wooden box as a guide for correct assembling.



2. Positioning the jacks Using the lifting tool, lift the two main bearing jacks into the crankcase.
See work card 2565-0401.



3. Adjustment

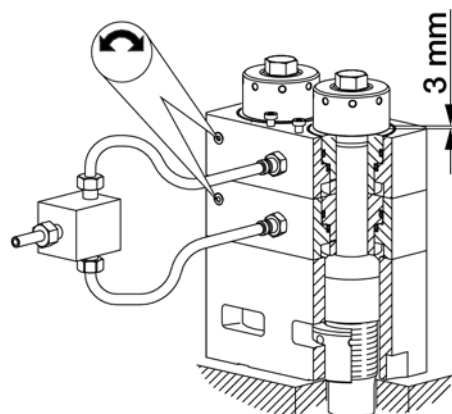
Carefully clean the main bearing studs, the nuts and the surrounding parts.

Lower the jacks on to the nuts of the main bearing, and screw the extension studs on to the main bearing studs.

Connect the hydraulic jacks, the distributor block and the high-pressure pump by means of high-pressure hoses.

Loosen the bleed screws in both jacks, and fill up the system with oil until oil, without bubbles, flows out of the bleed holes.

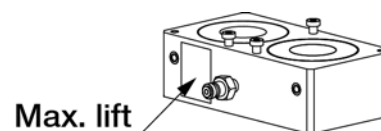
Re-tighten the bleed screws.



7665-0101-0006C11

4. Unscrew the nut

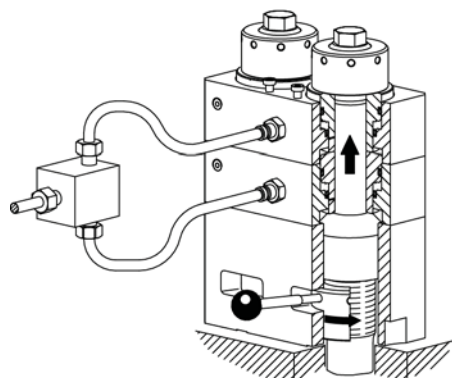
Increase the oil pressure to the prescribed value, and tighten the nuts by means of the tommy bar applied through the slots of the spacer ring.

**NOTICE**

Make sure not to exceed the max. lifting height stamped on the jack.

NOTICE**Equal tension**

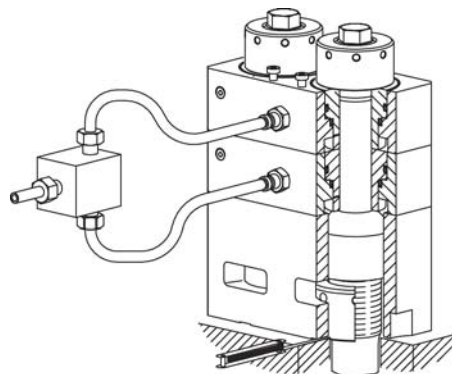
Check that the nuts are tightened equally by counting the number of times/holes that the tommy bar is moved during tightening.



7665-0101-0006C12

5. Checking recesses

While maintaining the pressure, check with a feeler gauge introduced through the recesses at the bottom of the spacer ring that the nuts bear against the contact face.



7665-0101-0006C13

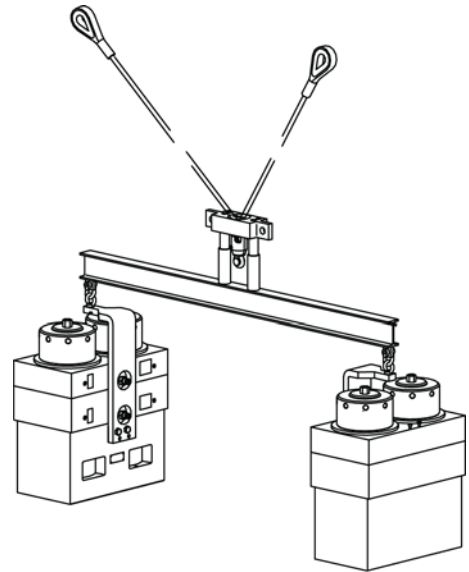
6. Relieving the pressure

Relieve the system of pressure, disconnect the pump, and unscrew the extension studs from the main bearing studs.

NOTICE**New studs, bolts or nuts**

When new studs, bolts or nuts are tightened for the first time, do not remove the jack, but pressurise the jack again and re-tighten the nut. Repeat this step 2 times.

Using the lifting tool, remove the hydraulic jacks from the crankcase



7665-0101-0006C10

The maintenance of a hydraulic jack is based on observation; it is typically initiated by a hydraulic oil leakage. The oil leakage likely originates from leaking sealing rings or a leaking overstroke valve.

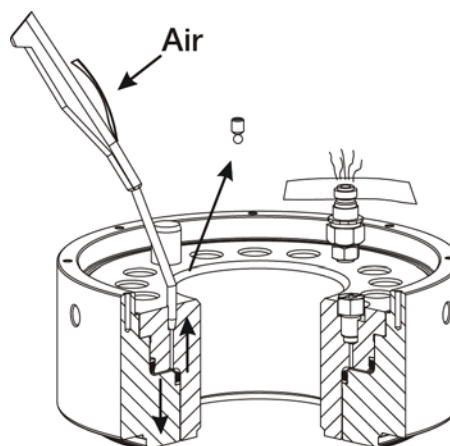
1. Separate the jack

The hydraulic jacks require no maintenance except cleaning of overstroke valve and replacement of defective sealing rings, each of which consists of an O-ring and a back-up ring mounted in ring grooves in the piston and cylinder.

The piston and cylinder are easily separated by taking off the cover and piston return spring, and pressing the parts apart with the help of compressed air.

Make sure that there are no marks or scratches on the sliding surfaces of the parts. The presence of metal particles will damage the sealing rings.

Keep the sliding surfaces and O-rings coated with molybdenum disulphide grease.



7665-0101-0002C27



Compressed air

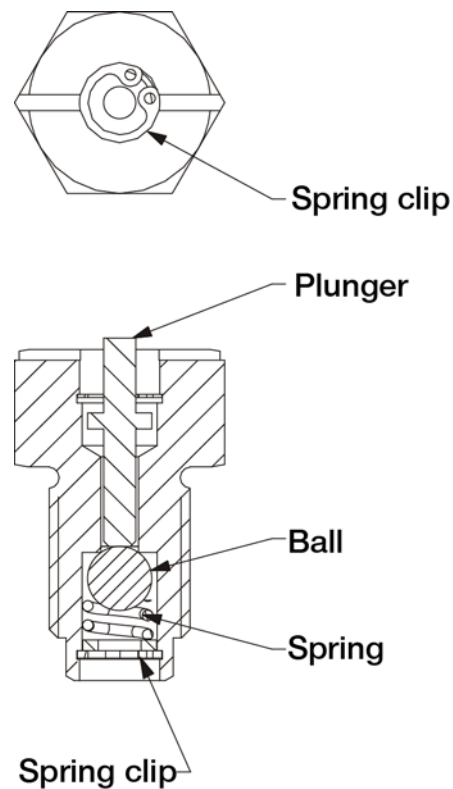
Always use protective gloves and eye protection when working with compressed air.

2. Inspect the sliding surfaces

If the overstroke valve leaks oil without being activated the hydraulic jack has to be dismantled and disassembled.

Disassembly is done by removing the two spring clips. Take care not to loose the ball and spring.

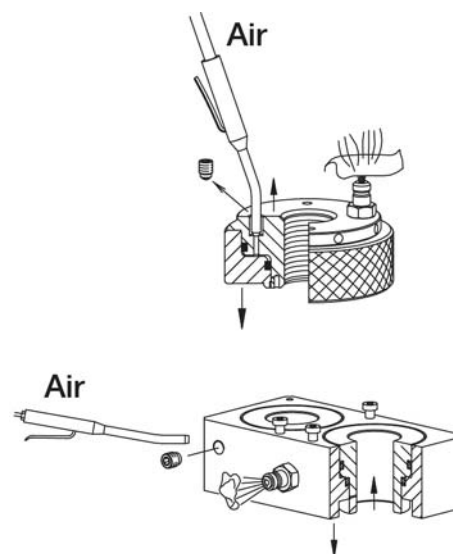
Clean the overstroke valve with compressed air. If this does not remedy the fault the overstroke valve has to be replaced. The pistons and cylinders of the double jacks are separated in the same easy way as described for the single jack.



7665-0101-0002C28

3. Disassembly

The piston and cylinder of the cylinder cover jacks are separated in the same way as described for the single jack.

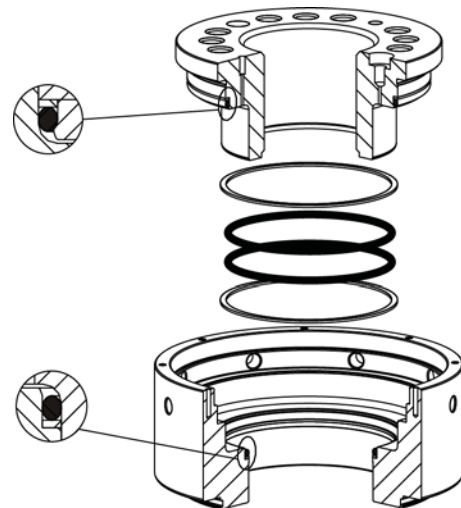


7665-0101-0006C29

4. Sealing rings

When changing the sealing rings, first mount the back-up ring and then the O-ring.

See the sketch for the correct mounting of both the upper and the lower sealing rings. The same principle applies to all the jacks.



7665-0101-0002C30

5. Assembly

After mounting the sealing rings, coat the piston and cylinder with molybdenum disulphide grease or spray lubricant and press the piston and cylinder together.

See that the rings do not get stuck between the piston and cylinder.

When tightening screws, studs or nuts for which no torque is specified in the instruction procedure or the related data sheet, the standard torques specified in this procedure are to be applied.

1. Standard

Standard screws and nuts lubricated with a Molybdenum Disulphide (MoS₂) based lubricant.

Thread	Tightening torque	Thread	Tightening torque
M8	15 Nm	M22	400 Nm
M10	35 Nm	M24	460 Nm
M12	50 Nm	M27	610 Nm
M14	80 Nm	M30	950 Nm
M16	135 Nm	M33	1200 Nm
M18	190 Nm	M36	1650 Nm
M20	260 Nm	M39	2100 Nm

7665-0201-0003C01

2. Self-locking

Self-locking nuts.

Thread	Tightening torque	Thread	Tightening torque
M8	20 Nm	M22	430 Nm
M10	40 Nm	M24	490 Nm
M12	60 Nm	M27	650 Nm
M14	90 Nm	M30	1000 Nm
M16	150 Nm	M33	1250 Nm
M18	210 Nm	M36	1700 Nm
M20	290 Nm	M39	2200 Nm

7665-0201-0001C02

3. With glue/Loctite

Screws and nuts locked with glue/Loctite.

Thread	Tightening torque	Thread	Tightening torque
M8	25 Nm	M22	580 Nm
M10	50 Nm	M24	660 Nm
M12	70 Nm	M27	900 Nm
M14	115 Nm	M30	1350 Nm
M16	190 Nm	M33	1700 Nm
M18	270 Nm	M36	2350 Nm
M20	380 Nm	M39	3000 Nm

7665-0201-0003C03

4. Cam lock washers

Screws and nuts locked with cam lock washers.

For correct mounting of washers, see word card 7665-0501.

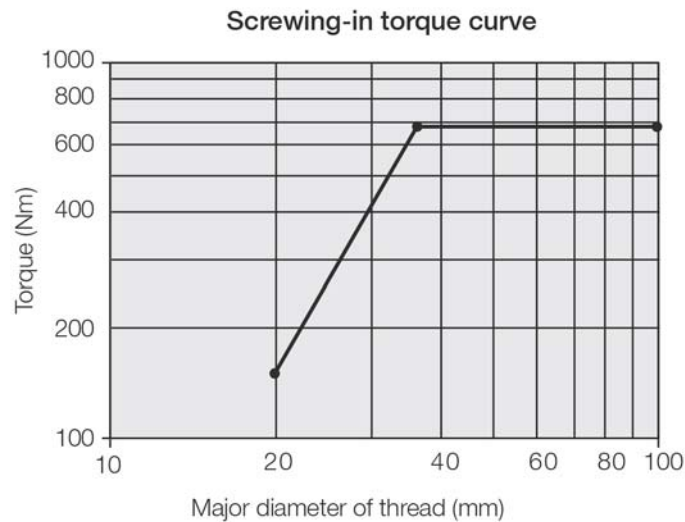
Thread	Tightening torque	Thread	Tightening torque
M8	30 Nm	M22	550 Nm
M10	50 Nm	M24	700 Nm
M12	85 Nm	M27	1000 Nm
M14	135 Nm	M30	1400 Nm
M16	200 Nm	M33	1900 Nm
M18	290 Nm	M36	2400 Nm
M20	400 Nm	M39	3100 Nm

7665-0201-0003C04

5. **Screwing-in of studs** The intention of this procedure is to ensure that the studs are screwed right to the bottom of the threaded holes.

Carefully clean off any burrs and loose particles from the thread and contact faces, and coat the thread with a lubricant having a particle size of approx. $0.5\ \mu\text{m}$, for instance molybdenum disulphide (MoS_2) or a non-synthetic graphite mixed with oil.

The studs are to be screwed-in applying the torque specified in the instruction procedure in use. If nothing is mentioned in the instruction procedure, the figure below indicates the torque. For thread sizes $> \text{M}36$ the curve indicates a screwing-in torque of 680 Nm



7665-0201-0001C05

Preparations

Before screwing on the nuts, the threads and the contact faces should be greased with a mixture of graphite and oil or molybdenum disulphide with a friction coefficient $\mu = 0.1-0.12$ (e.g. MOLYKOTE paste type G).

The nuts should fit easily on the thread, and it should be checked that they bear on the entire contact face.

In the case of new nuts and studs, the nuts are to be tightened and loosened two or three times so that the thread may assume its definite shape - thus obviating the risk of loose nuts.

Nuts secured with a split pin are to be tightened to the stated torque and then to the next split-pin hole.

The torque spanner must not be used for torques higher than those stamped on it, and it must not be damaged by hammering on it or the likewise.

1. Rahsol Torque Spanner

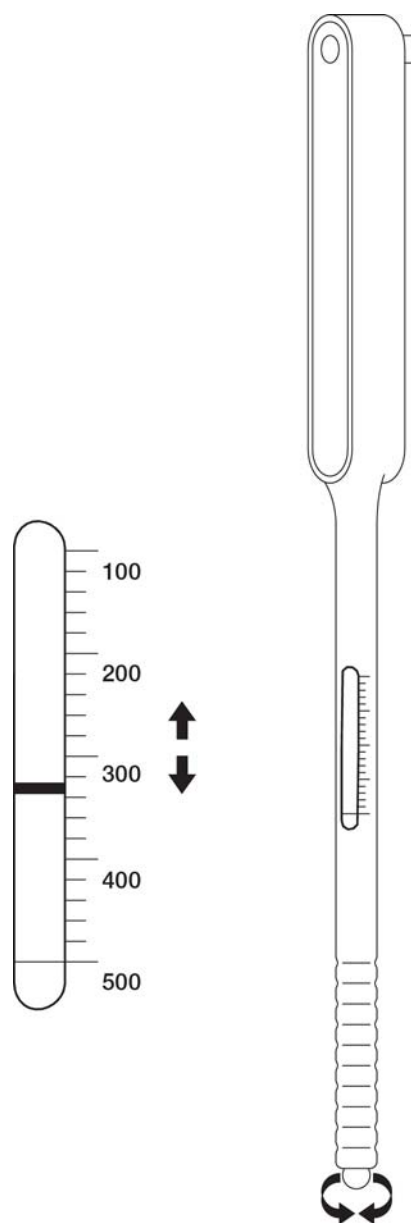
The handle of the torque spanner is provided with a scale indicating the torques at which the spanner can be set.

For setting the spanner at the required torque, there is a ball on a small arm at the end of the handle.

When the ball is pulled, a small crank handle appears. A spring-loaded slide in the handle is provided with a mark which, when the crank handle is turned, can be set at the required torque on the scale. The torque spanner works as follows:

The above-mentioned spring acts on a pawl system in the handle. When the pre-set torque has been reached, the pawl system is released, at which moment a small jerk is felt in the spanner, and a small click is heard.

When the torque spanner is not in use, the spring inside should be released by adjusting to minimum torque.



7665-0301-0001C01

Before screwing on the nuts, grease the threads and the contact faces with a mixture of graphite and oil or molybdenum disulphide with a friction coefficient

$\mu = 0.1-0.12$ (e.g. MOLYKOTE paste type G)

The nuts should fit easily on the thread, and it should be checked that they bear on the entire contact face.

1. **Pre-tightening with a torque spanner** Before tightening the nuts according to a tightening gauge or tightening angle, they must be pre-tightened with a torque spanner.
See work card 7665-0301.

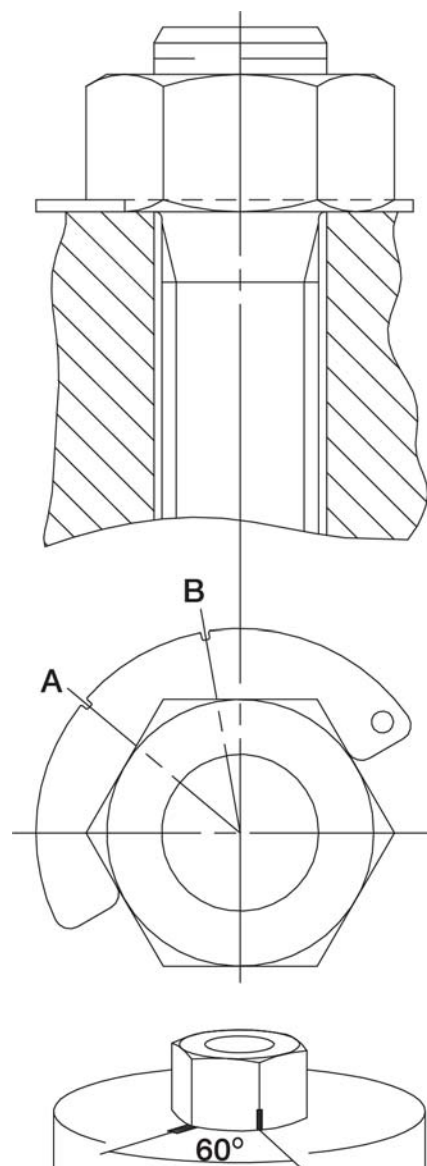
Apply a pre-tightening torque of:

- thread M8 - M20 = 50 Nm
- thread M22 - M27 = 100 Nm
- thread M30 - M39 = 150 Nm
- thread M42 - M48 = 200 Nm

This is in order to ensure a uniform basis for the subsequent tightening with gauge or tightening angle.

2. Tightening with a tightening gauge

After pre-tightening, place the tightening gauge round the nut, and mark off with chalk on the nut at slot **A** on the tightening gauge, and make another chalk mark on the contact face at slot **B**. Then tighten the nut until the two chalk marks coincide.



7665-0401-0001C01

3. Tightening without a tightening gauge

For tightening angles of e.g. 30°-45° and 60°, we usually do not deliver a tightening gauge. Therefore, after pre-tightening, mark the angle on a corner of the nut and on the contact face, respectively. Then tighten the nut until the two marks coincide.

When tightening new studs or bolts for the first time, loosen again and repeat the procedure - including pre-tightening with a torque spanner, to allow the parts to settle.

Locking Devices

Some screwed and bolted connections on the engine, as well as some movable joints, are secured against untimely loosening by means of different types of locking devices.

When assembling the engine after overhauls, it is vital that all such screws and nuts are again locked correctly.

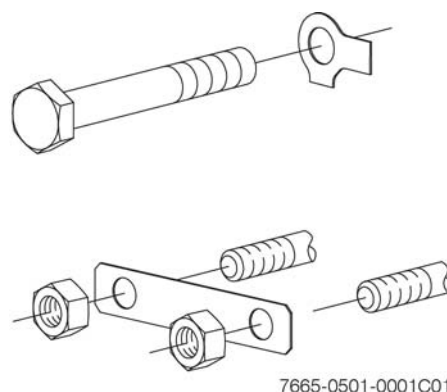
NOTICE

Make sure only to mount locking devices on nuts and screws which have been mounted with locking devices by the engine manufacturer.

1. Lock washers

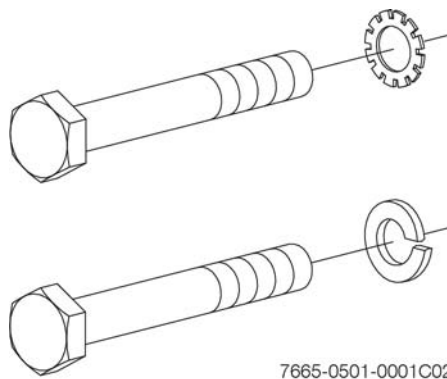
Lock washers, tab washers, locking plates, etc., must always be replaced.

The tab-like projections, etc., on the washers are to be bent back over one of the flats of the screw or nut concerned.



2. Spring washers

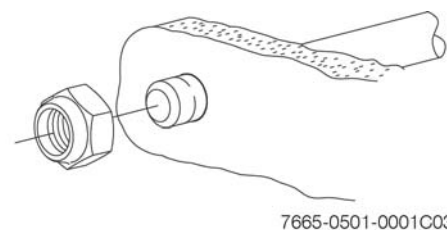
Used spring washers must be replaced.



3. Self-locking nuts

Self-locking nuts may only be used five times. Therefore, give the nut a centre punch mark each time it is loosened.

To tighten a self-locking nut to a specific torque, first measure the torque required to turn the nut itself, and then add this torque to the torque value stated on the data sheet of a procedure.



4. Locking wire

Locking wire should be mounted after the screws or nuts have been tightened to the correct torque. Do not overtighten or loosen the units to get a correct alignment of the wire holes. Always mount new wire after tightening-up the units.

Any tendency of the screws or nuts to loosen will be counteracted by a tightening of the locking wire. Do not secure more than four units in a series, unless otherwise specified.

5. Mounting procedure

Fig. 1

Insert wire, grasp the upper end of the wire and bend it around the head of the screw, then under the other end of the wire, be sure that the wire is tight around the head.

Fig. 2

Twist the wire clockwise until it is just short of the hole in the second screw. Keeping the wire under tension, twist it until tight. When the wire is tight, the wire shall have approximately 7-10 twists per 25 mm. One twist is a twist of the wires through an arc of 180°, equal to half of a complete turn.

Fig. 3

Insert the uppermost wire in the second screw, and pull it tight.

Fig. 4

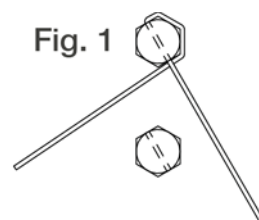
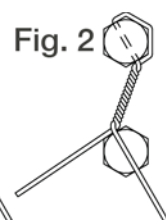
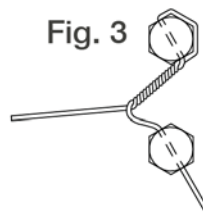
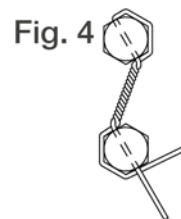
Bend the lower wire around the screw, and under the end protruding from the screw.

Fig. 5

Keeping the wire under tension, twist it min. 3 twists, counterclockwise until tight.

Fig. 6

During the final twisting motion, bend the wire along the screw head. Cut off excess wire.

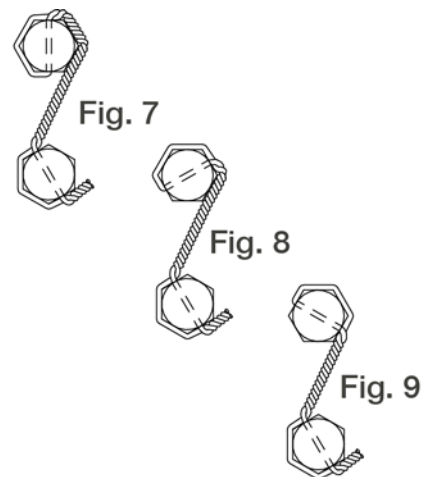
Fig. 1**Fig. 2****Fig. 3****Fig. 4****Fig. 5****Fig. 6**

7665-0501-0001C04

6. Preferred mounting

Fig. 7-9

Show the preferred ways of mounting the locking wire on screws with wire holes oriented in different angles.



7665-0501-0001C05

Screws and Nuts • Checking

7. Routing

Fig. 10

Shows how to route the locking wire on screws in different planes.

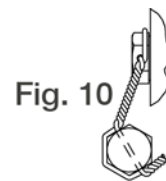


Fig. 11

Wire that passes over the top of a nut is an acceptable alternative only if it routes around the protruding screw thread.



Fig. 12

Wire that passes over the top of a nut is also an acceptable alternative if the hole is located as shown in the figure.



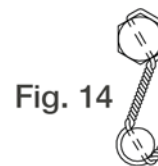
Fig. 13

Where drilling of locking wire holes has caused a thin wall section, route the wire as shown in the figure, to prevent damage to the nut.



Fig. 14

Locking wire can be mounted to any other part of the assembly if nothing else is possible.



7665-0501-0001C06

Work Card
7665-0501-0001

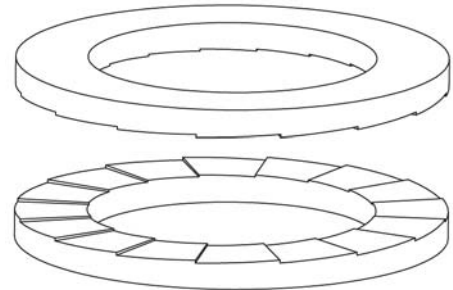
8. Cam Lock Washers Cam lock washers with rising cams on one side and radial teeth on the other.

9. Description

Fig. 15

The washers are installed in pairs, cam face to cam face. When the bolt and/or nut is tightened the teeth grip and seat the mating surfaces. The cam lock washer is locked in place, allowing movement only across the face of the cams. Any attempt from the bolt/nut to rotate loose is blocked by the wedge effect on the cams.

Fig. 15



7665-0501-0001C07

10. Using cam lock washers

Fig. 16

Different uses of the cam lock washers.

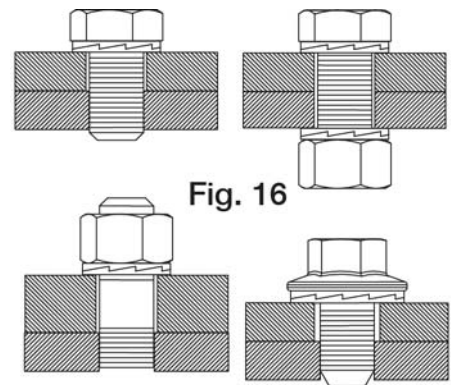


Fig. 16

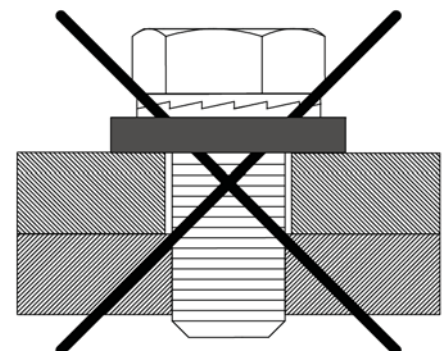
7665-0501-0001C08

11. Wrong use of cam lock washers

Fig. 17

Do not use the cam lock washers in conjunction with other loose washers.

Fig. 17



7665-0501-0001C09

NOTICE

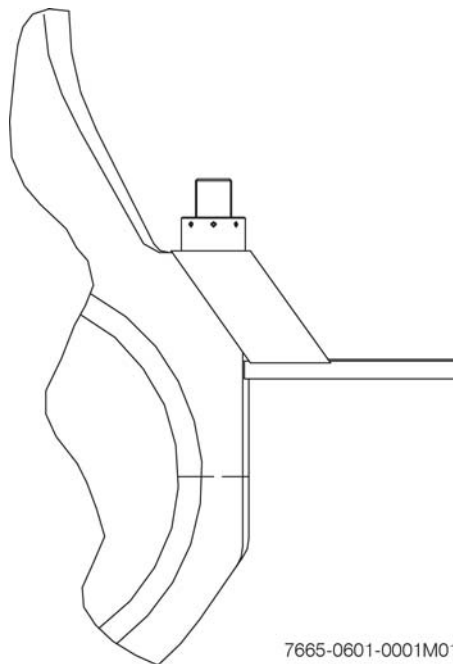
Cam lock washers must be installed in pairs and are not to be substituted by other types of washers.

Before carrying out the checking and overhaul procedures underlined below in Items 1, 2 and 4, platform boards should be mounted inside the engine crankcase.

During mounting of the platforms, always use the harness, lanyard and fall arrester. It is always recommended to clean and wipe off oil from steps, crank throw, doorways and assembling surfaces.

The platform boards are placed inside the engine as shown in the following instruction.

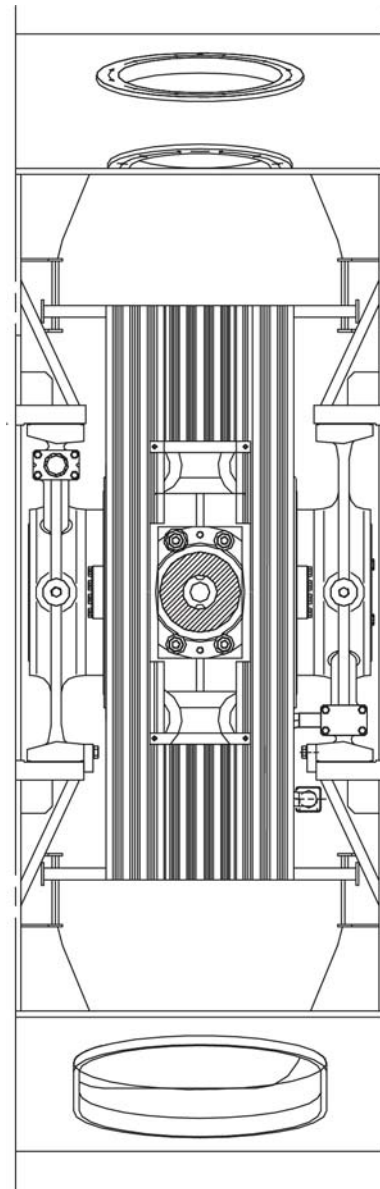
1. Checking the crankshaft alignment, using an Autolog Turn the engine into a position where it is possible to place the ladder on the crankpin bearing stud nuts.



7665-0601-0001M01

2. Piston rod stuffing box and telescopic pipe

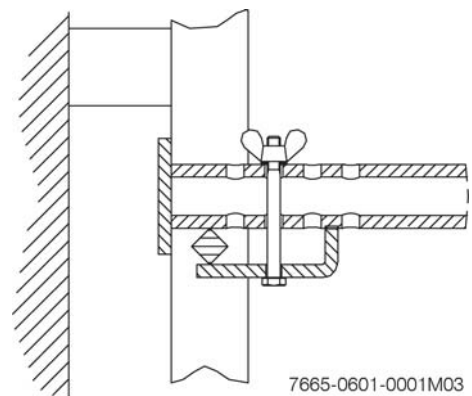
Put in the standard platform board as a floor as shown on the sketch. Turn the engine to BDC. Mount the platform board from the exhaust side of the engine as shown.



7665-0601-0001M02

3. Mounting of the working platform support

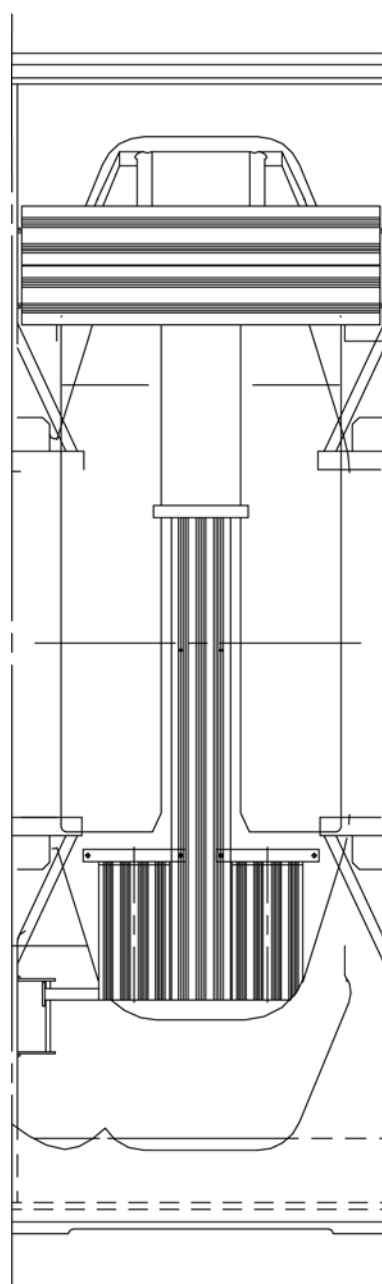
The working platform support is mounted as shown in the sketch.



7665-0601-0001M03

4. Main bearing
dismantling

Turn the engine to 80° after TDC. Mount
the platform support in a longitudinal
direction on the steps in the bedplate.



7665-0601-0001M04

Working Platforms • Mounting

Work Card
7665-0601-0001

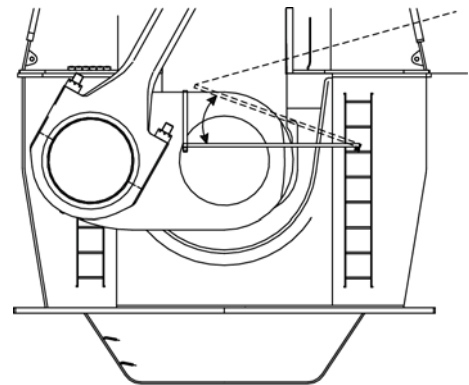
5. Mount the longest platform board

Mount the longest platform board, with the ladder attached, on the support and, by means of a rope, lower the platform support ladder into place on the crank throw.

The double platform board can now be placed on the support and the long platform board.

NOTICE

Always remember to remove the platform boards on completion of each working procedure or before turning the engine.

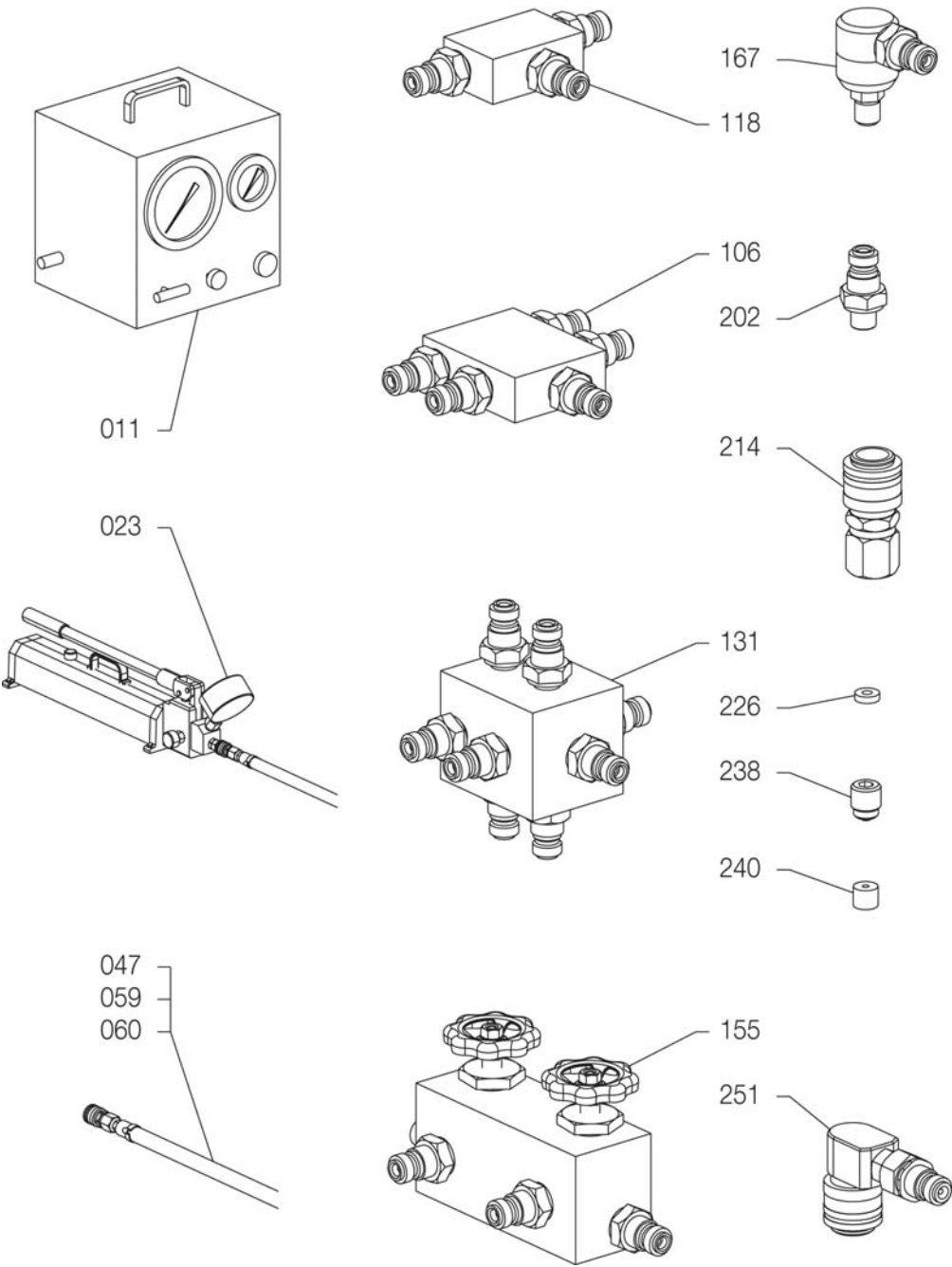


7665-0601-0001M05

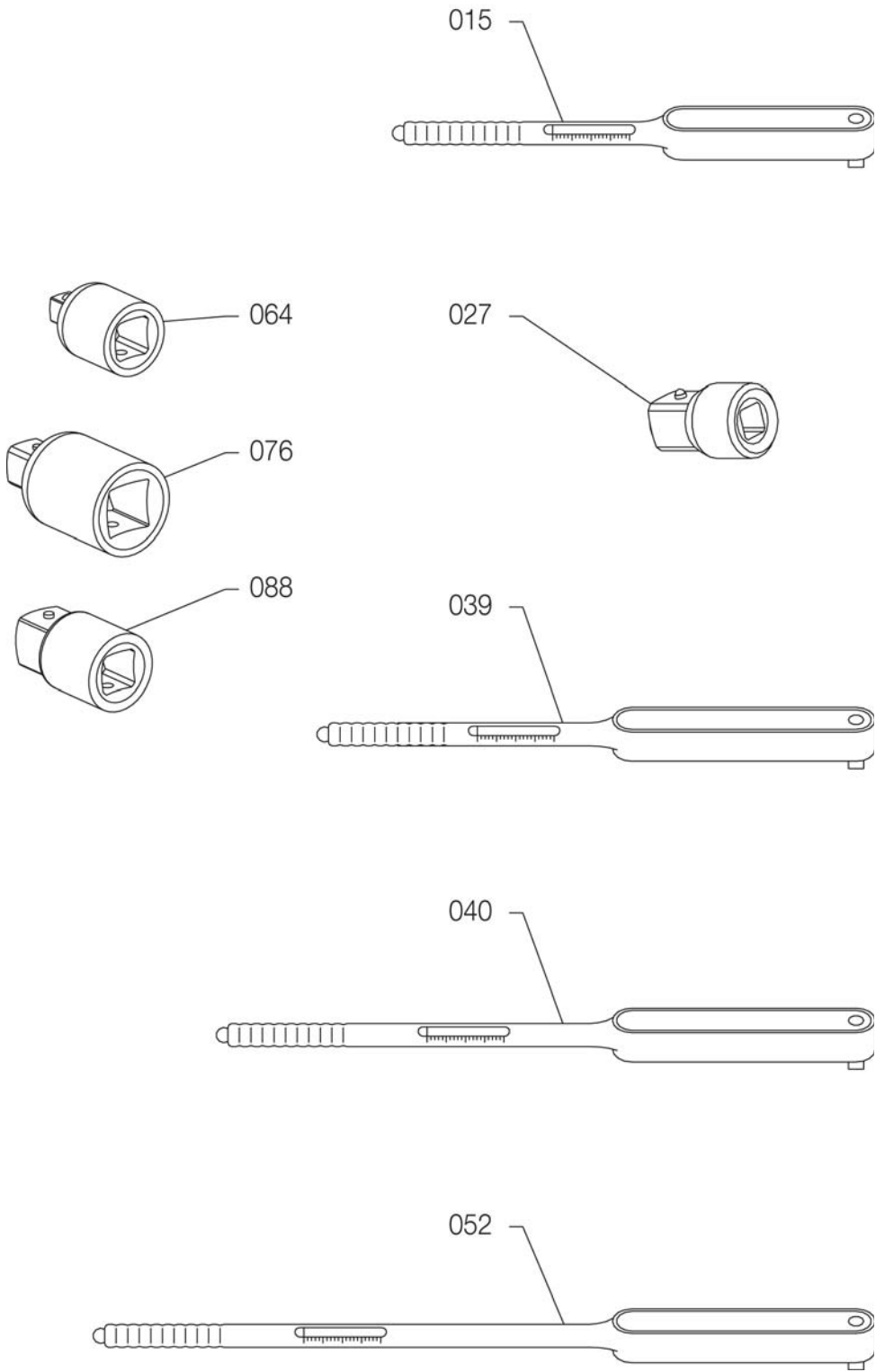
1. Molybdenum Disulphide

The following procedure is to be followed prior to the mounting of metal surfaced parts which are to function as seals.

- Clean the surface with a cleaning fluid and ensure that the entire surface is completely free of grease.
- Allow 5 minutes for the cleaning fluid to evaporate.
- With a clean leather cloth, and using circular movements, rub a mixture of fine grained particles of Molybdenum Disulphide (MoS_2) and mineral oil (e.g. Moly-cote G-n Plus, or likewise) hard onto the metal surface.
- Remove any excessive paste and ensure that the metal surface is only coated with a thin, uniform, layer of the above mentioned mixture.
- Protect the wet paste and cloth from dust or other foreign particles.



2013-01-16 - en

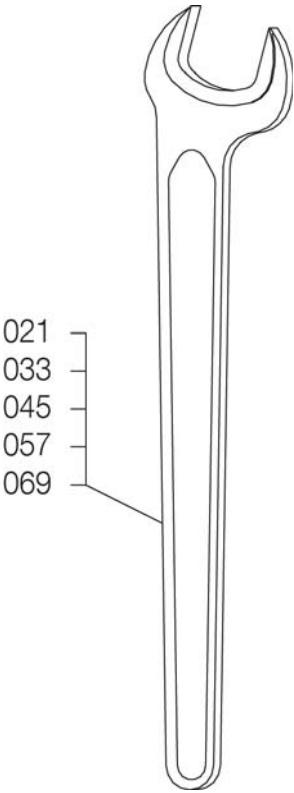


Torque Spanners

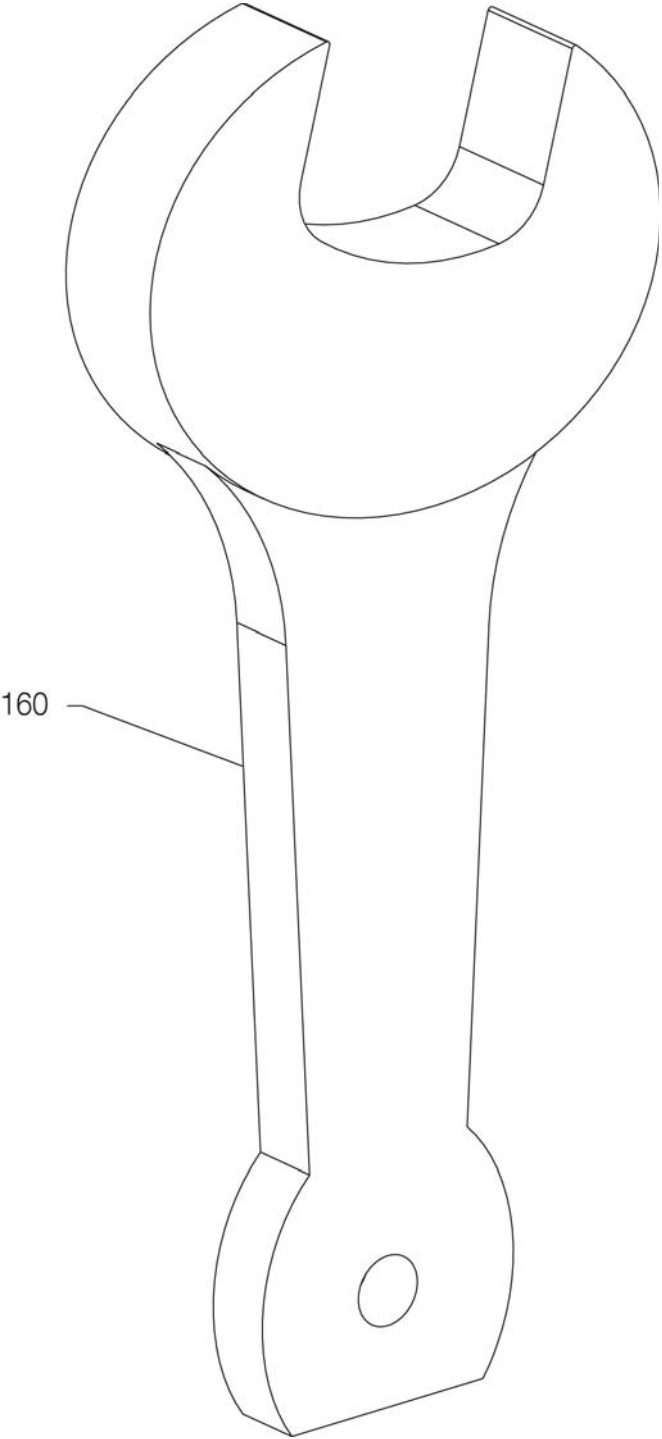
Plate

7670-0200-0004

[illegible]

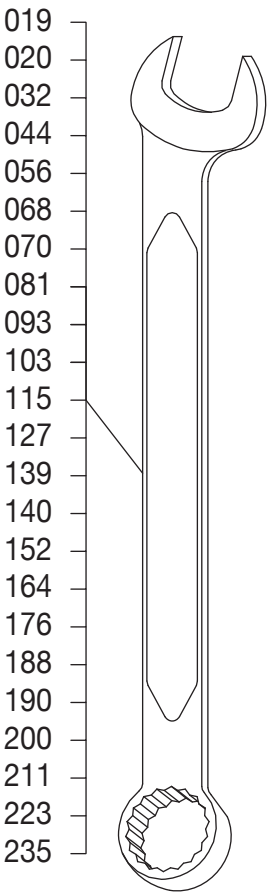


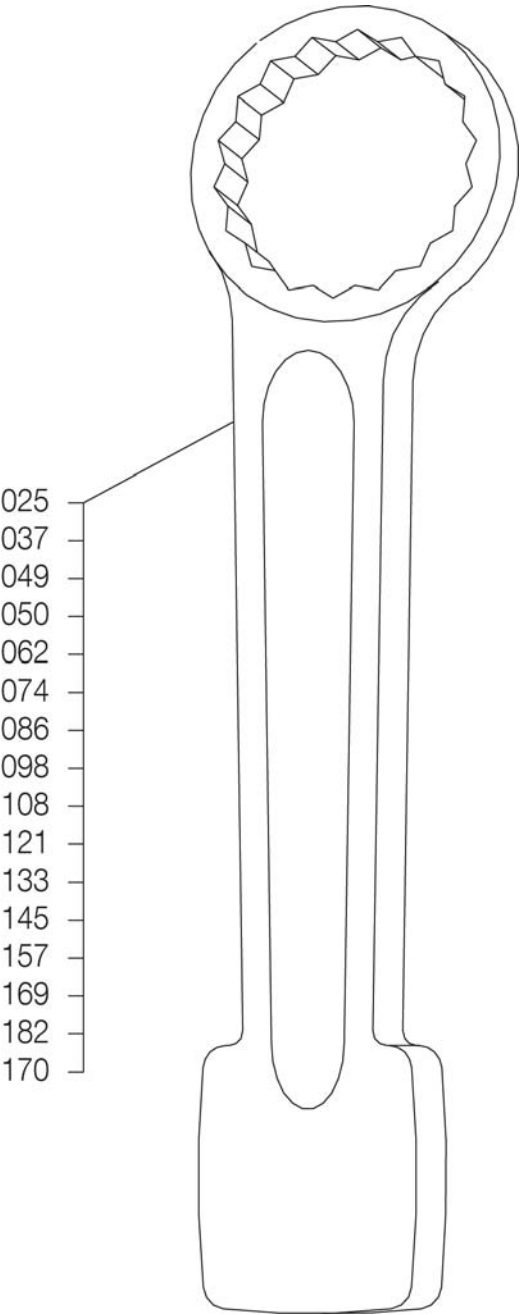
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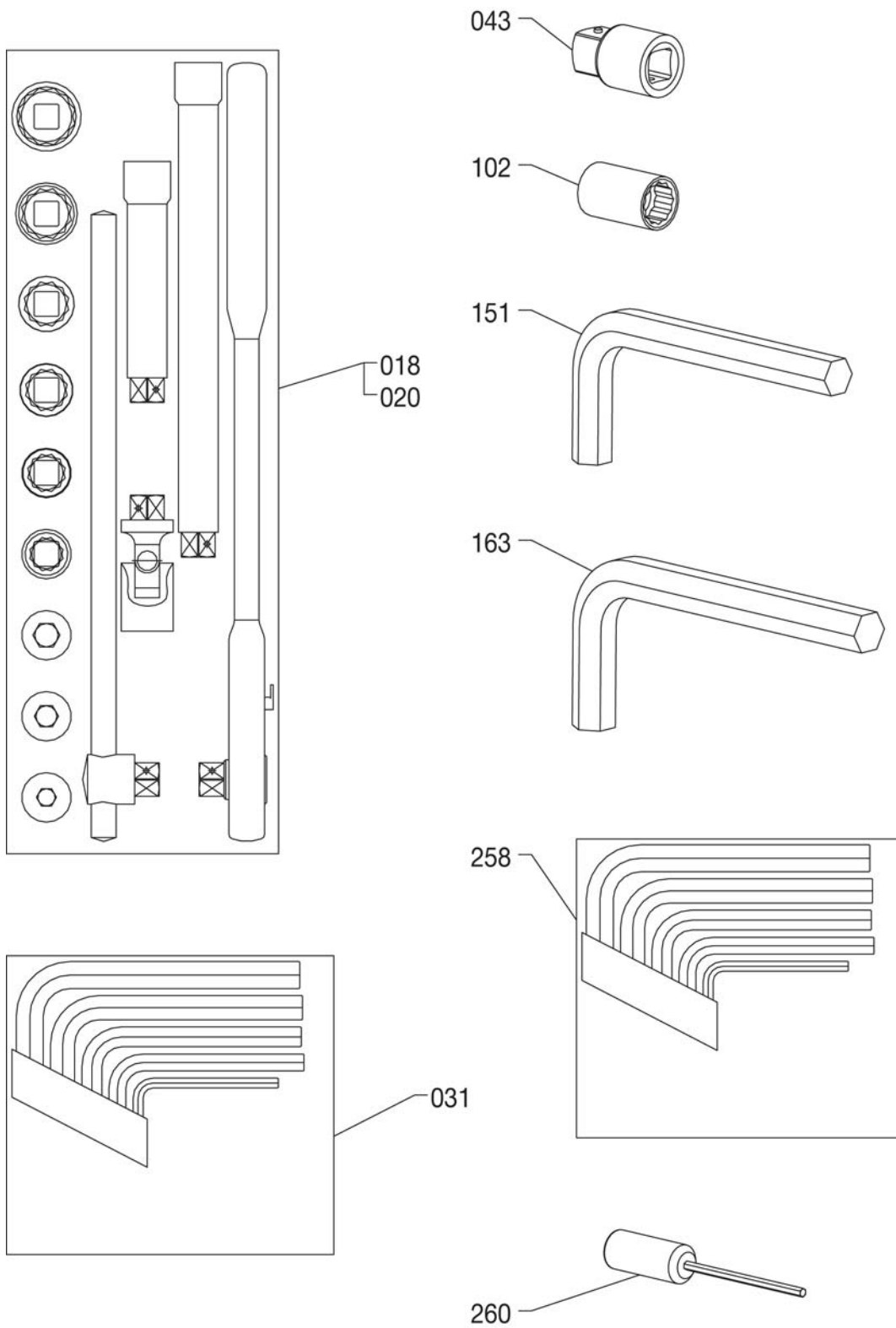
Open Ended Slugging Spanners

Plate
7670-0220-0004





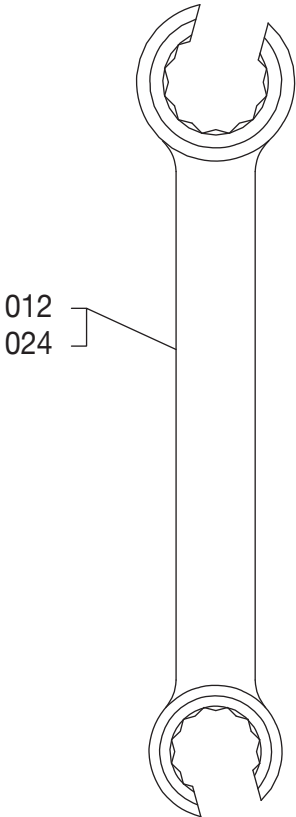
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Miscellaneous Spanners

Plate
7670-0250-0007

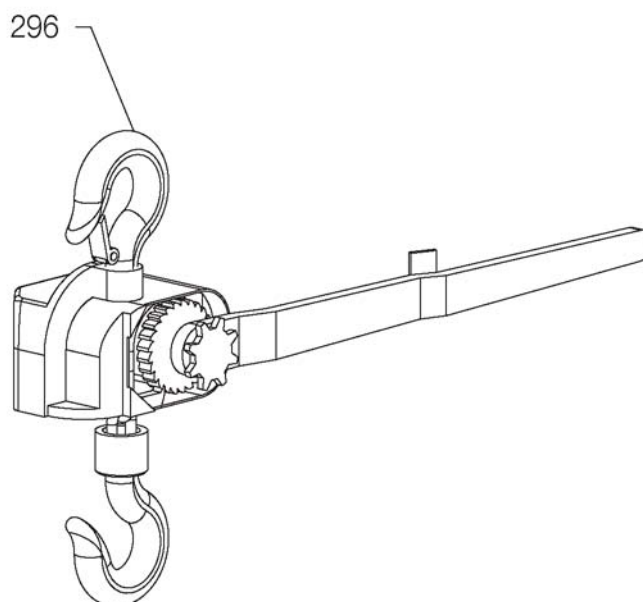
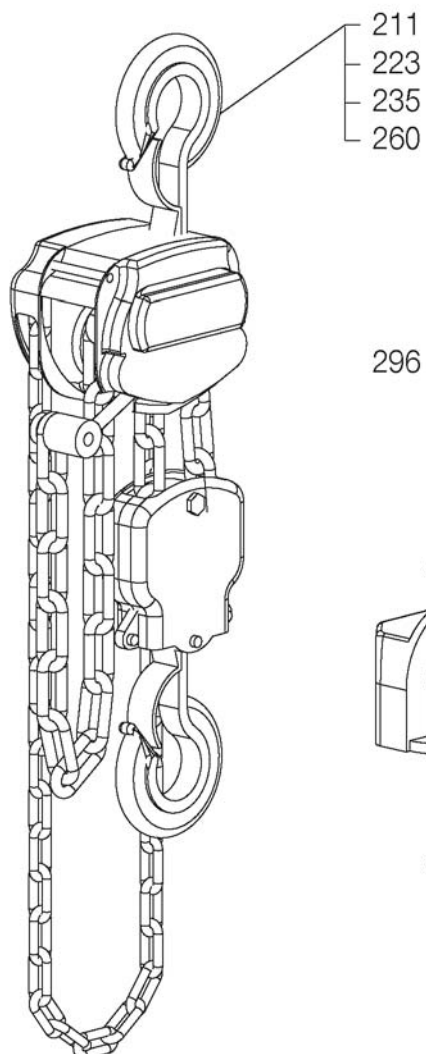
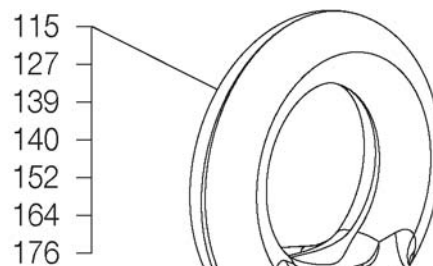
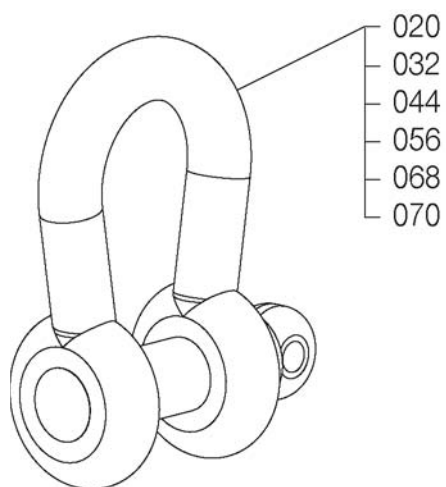
Item No.	Qty	Item Designation
018	-	Tool set, complete, size 10-22mm
020	-	Tool set, complete, size 24-46mm
031	-	Box and key set, complete
043	-	Adapter for socket wrench, 20/12.5mm
102	-	Socket spanner, size 46mm
151	-	Hex key, size 22mm
163	-	Hex key, size 24mm
258	-	Hexalobular external key set
260	-	Bit hexagon socket screw



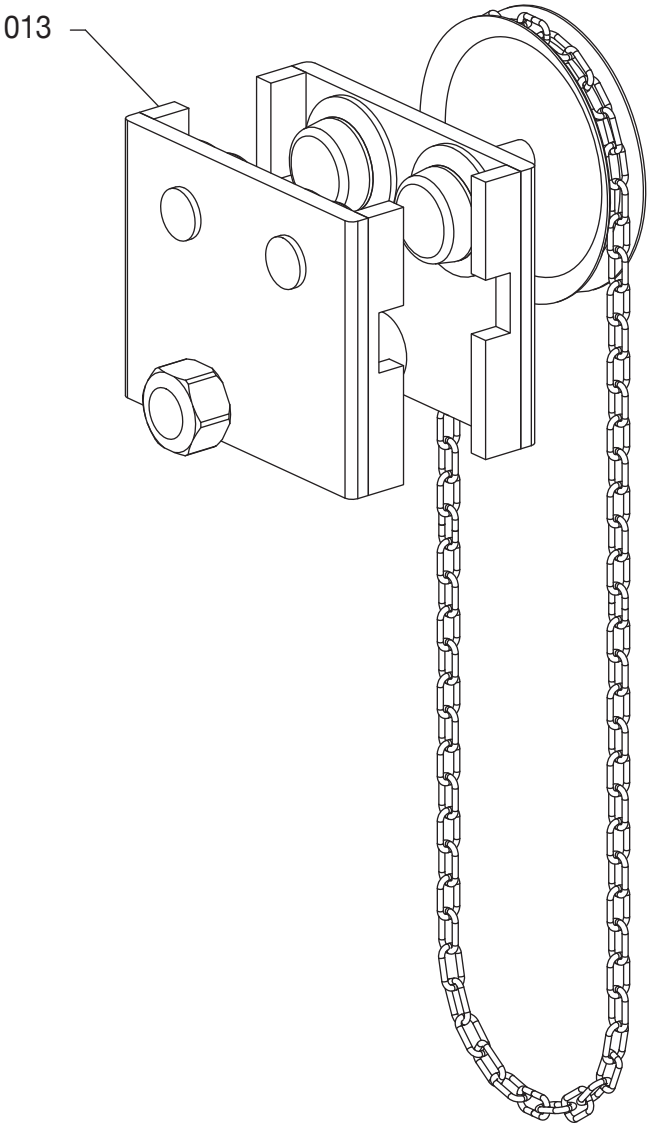
Plate

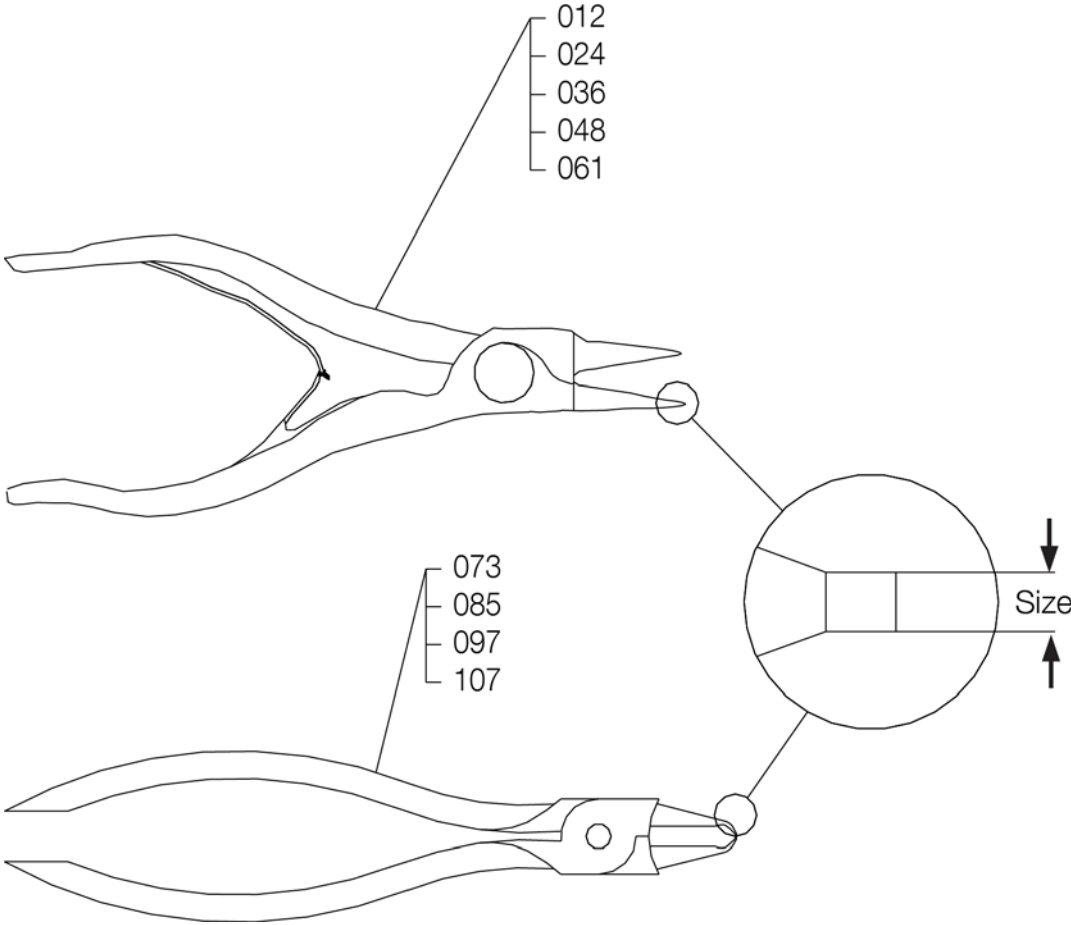
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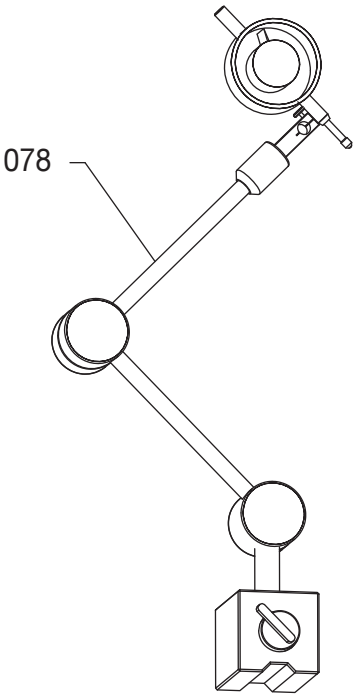
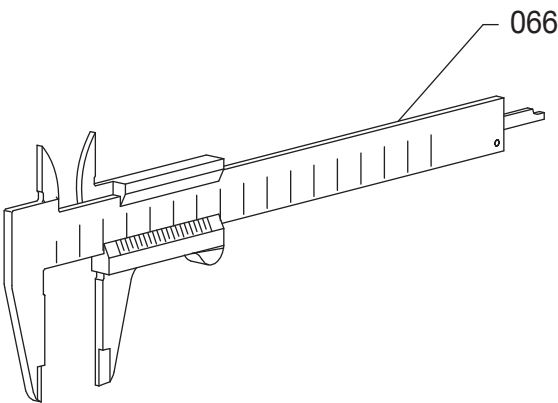
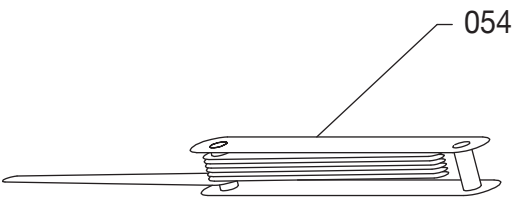
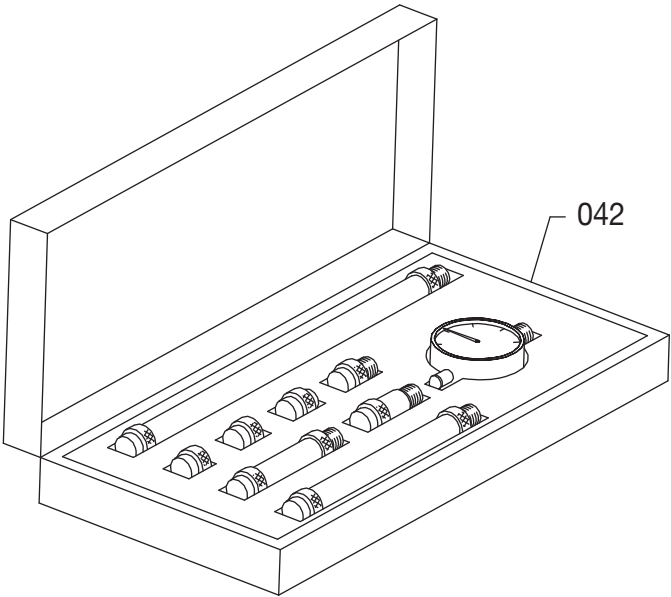
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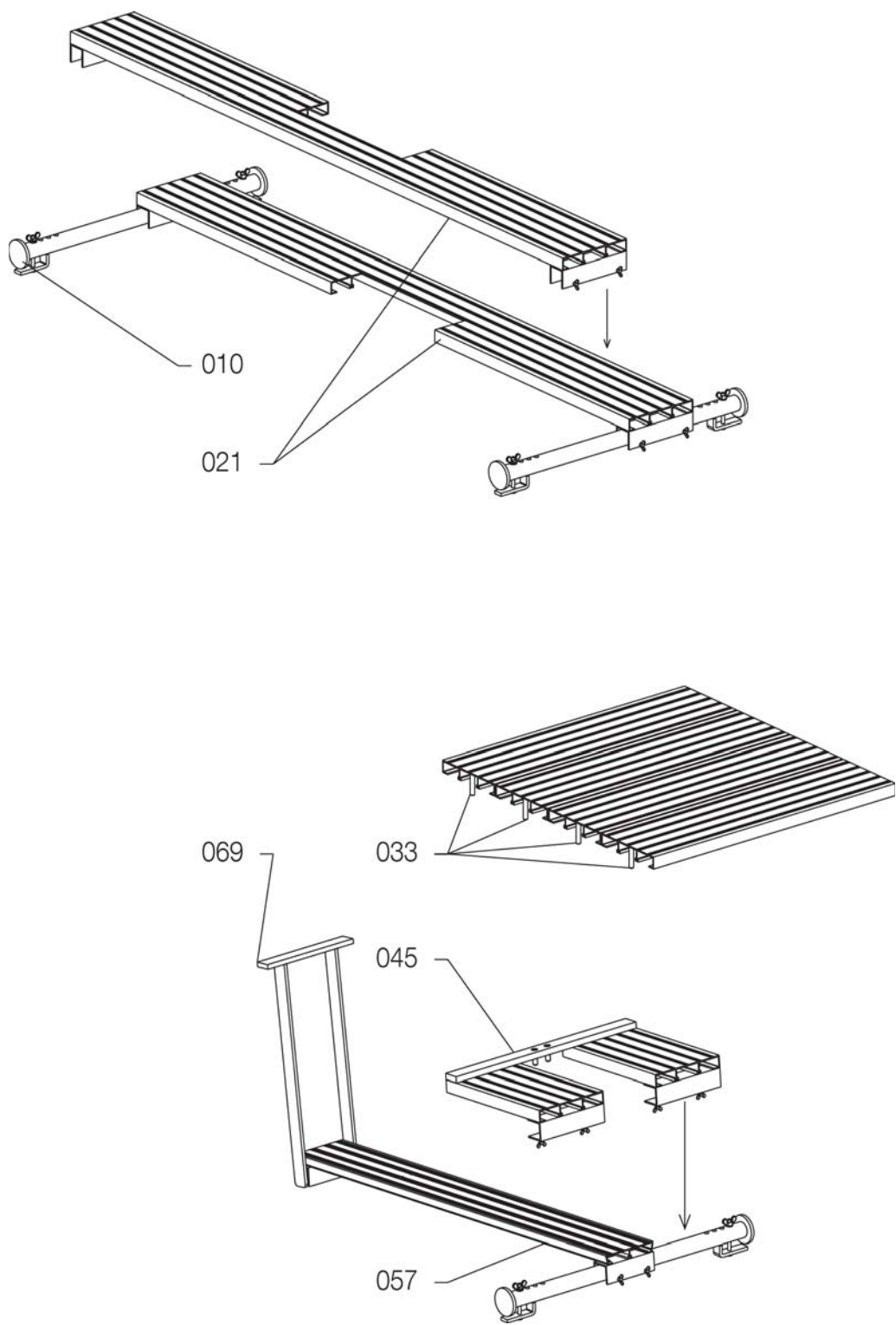
Item No.	Qty	Item Designation
020	-	Anchor shackles with screw pin, 8mm
032	-	Anchor shackles with screw pin, 9mm
044	-	Anchor shackles with screw pin, 12mm
056	-	Anchor shackles with screw pin, 15mm
068	-	Anchor shackles with screw pin, 18mm
070	-	Anchor shackles with screw pin, 21mm
115	-	Eye bolt, 10mm
127	-	Eye bolt, 12mm
139	-	Eye bolt, 16mm
140	-	Eye bolt, 20mm
152	-	Eye bolt, 24mm
164	-	Eye bolt, 30mm
176	-	Eye bolt, 8mm
211	-	Chain tackle, 0.5 ton
223	-	Chain tackle, 1 ton
235	-	Chain tackle, 2 ton
260	-	Chain tackle, 5 ton
296	-	Pull lift, 3 ton

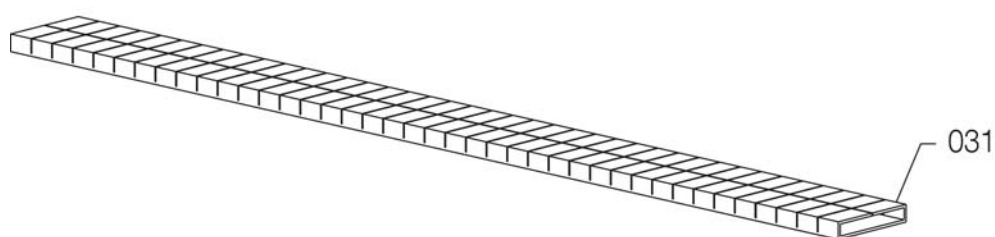






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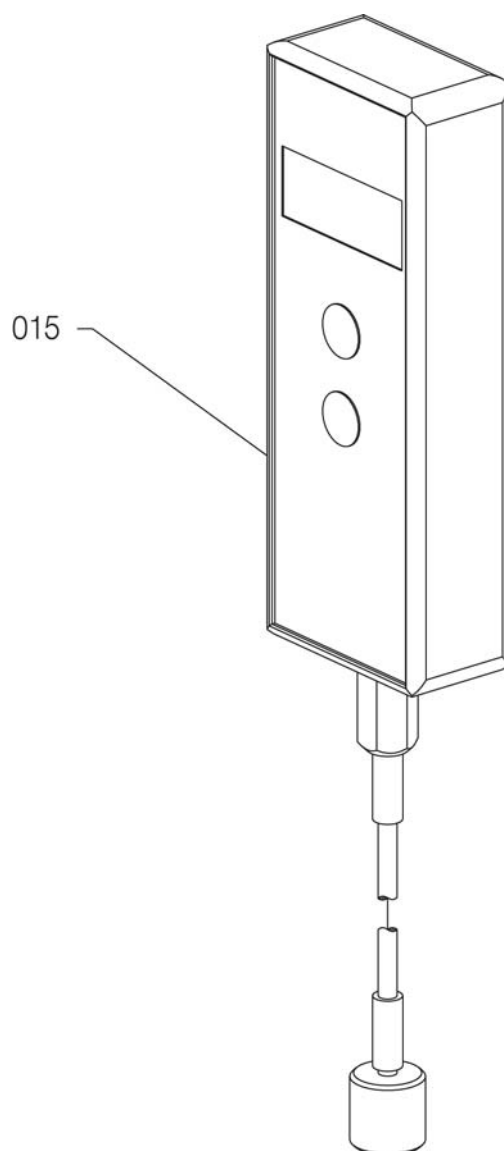


Roundslings

Plate
7670-0320-0003

Item No.	Qty	Item Designation
018	-	Roundslings, 5000 kg
020	-	Roundslings, 1500 kg
031	-	Chafing device for roundslings





Pressure Gauge

Plate

7670-0450-0001

Pressure Gauge

Plate

7670-0450-0001

Item No.	Qty	Item Designation
015	-	Pressure gauge for minimess

