	Vol. 1 - Operation Manual	Index

MAN Diesel

50-108ME/ME-C

VOLUME I
OPERATION

Edition 0003 – 2006

Warning!

It is important that all MAN Diesel engines are operated within the given specifications and performance tolerances specified in the engines' Technical Files and are maintained according to the MAN Diesel maintenance instructions, in order to comply with given emission regulations.

In accordance with Chapter I of the code of Federal Regulations, Part 94, Subpart C, §94.211, NOTICE is hereby given, that Chapter I of the Code of Federal Regulations, Part 94, Subpart K, §94.1004 requires that the emissions related maintenance of the diesel engine, shall be performed as specified in MAN Diesel instructions, including, but not limited to, the instructions to that effect included in the Technical File.

Instruction Book 'Operation'

for 50-108ME/ME-C Engines

General Edition 0001

In view of the continued development of our diesel engines, the present instruction book has been made to apply generally to our engines of the types:

50 – 108 ME/ME-C

The different systems are explained on the basis of standard systems, whereas each particular engine is built to the specification in the contract for the plant in question, i.e. the information in this book is <u>for guidance purposes only.</u>

All references to this instruction book should include title, edition No., and possibly page No.

Example: Instruction book OPERATION, Edition 0001, Section 701-02, Page 3(12).

For a specific engine, also the name of the vessel, the engine number and the engine builder should be specified.

Further details may be found in:

- Plant installation drawings
- Instruction book Vol. I Operation
- Instruction book Vol. II Maintenance
- Instruction book Vol. III Components, Descriptions
- Shop trial/report
- Sea trial/report

for the engine concerned.

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Contents

This instruction book is divided into **nine Chapters** and an **Index** – as listed below:

Each **Chapter** is subdivided into separate sections and sub-sections. For convenience, the main titles and topics are summarized on the first page(s) of each chapter.

The **Index** gives a comprehensive list of the subjects covered.

Service Letters

In order to ensure the most efficient, economic, and up-to-date operation of the MAN B&W engines, we, and our licensees, regularly send out ‘Service Letters’, containing first-hand information regarding accumulated service experience.

The Service Letters can either deal with specific engine types, or contain general instructions and recommendations for all engine types, and are used as a reference when we prepare up-dated instruction book 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 instruction book.*

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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 room staff.

Special Dangers

WARNING !

Keep clear of space below crane with load.

The opening of cocks may cause discharge of hot liquids or gases.

Carefully consider which way liquids, gases or flames will move, and keep clear.

The dismantling of parts may cause the release of springs.

The removal of fuel valves (or other valves in the cylinder cover) may cause oil to run down onto the piston crown. If the piston is hot, an explosion might blow out the valve.

When testing fuel valves, do not touch the spray holes as the jets may pierce the skin.

Do not stand near crankcase doors or relief valves – nor in corridors near doors to the engine room casing – when alarms for oil mist, high lube oil temperature, no piston cooling oil flow, or scavenge box fire is registered. See also Chapter 704.

WARNING !

In design and layout of the engines, MAN B&W Diesel A/S has the basic philosophy that the failure of one part should not result in the engine becoming inoperative.

As some mechanical and electronical parts are essential for the safe functioning of the engine, such parts are duplicated to achieve redundant capability.

Should such a redundant part become wholly or partly inoperative, the failing part must be changed or repaired immediately to re-establish redundancy of the part or – if an emergency situation requires operation of the engine – as soon as the vessel calls at the nearest port.

Hydraulic System

WARNING !

Before repair or maintenance work is started, the plant must be stopped and the current be switched off at the main switch. Open the drain valve to decrease the pressure to zero. During repairs, the drain valve must be open.

Always measure the pressure and check that the system is depressurized before disassembling the part concerned from the system.

Never service the hydraulic system when the pumps are running, unless absolutely necessary (bleeding the system).

Leak detection must always be carried out using a long piece of wood to secure proper distance to eventually outflowing oil.

Leaking seals cannot be repaired by tightening. Sealing is only possible by replacing the sealing elements with new parts.

Never carry out welding or soldering on any part of the hydraulic system.

Only use nitrogen as pre-charge gas on accumulators.

Cleanliness

The engine room should be kept clean both above and below the floor plates.

If there is a risk of grit or sand blowing into the engine room when the ship is in port, the ventilation should be stopped and ventilating ducts, skylights and engine room doors closed.

Welding, or other work which 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 covered.

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

Fire

WARNING !

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 in the event that 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 is cold, welding and the use of naked flames will involve 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 having a low flash point.

Porous insulating material, soaked with oil from leakages, is easily inflammable and should be renewed. *See also Sections 704-01, 02 and 'Sealing Materials' in this Section.*

Order/Tidiness

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

No major objects must be left unfastened, and the floor and passages should be kept clear.

Spares

Large spare parts should, as far as possible, be placed near the area of application, 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, and portable working light should be obtainable everywhere. Special lamps should be available for insertion through the scavenge ports.

Low Temperatures – freezing

If there is a risk of freezing, then all engines, pumps, coolers, and pipe systems should be emptied of cooling water, or the cooling water treated to avoid freezing.

Check and Maintain

Measuring equipment, filter elements, and lubricating oil condition.

Entering the Crankcase or Cylinder

WARNING !

Always ensure that the turning gear is engaged; even at the quay, the wake from other ships may turn the propeller and thus the engine.

Check beforehand that the starting air supply to the engine and the starting air distributor, is shut off.

In case of oil mist alarm, precautions must be taken before opening to crankcase *(see Section 704-02).*

Turning Gear

Before engaging the turning gear, check that the starting air supply is shut off, and that the indicator cocks are open.

When the turning gear is engaged, check that the indicator lamp “Turning gear in” has switched on. Check turning gear starting blocking once every year.

Slow-turning

If the engine has been stopped for more than 30 minutes, slow-turning should always be effected, just before starting in order to safeguard free rotation of the engine, *see Chapter 703.*

Feeling over

Whenever repairs or alterations have been made to moving parts, bearings, etc., apply the “Feel-over sequence” *(see Section 703-03)* until satisfied that there is no undue heating (friction, oil-mist formation, blow-by, failure of cooling water or lubricating oil systems, etc.).

Feel over after 10-15 minutes’ running, again after 1 hour’s running, and finally shortly after the engine has reached full load. *See Section 703-03.*

Sealing Materials

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

These materials may have a **caustic effect** when being touched directly.

The gloves should be made of neoprene or PVC.
Used gloves must be discarded.

Safety Cap in Starting Air Line

If the 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.

! *Mount a new bursting disc and return the cover to the open position at the first opportunity.*

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 crew members are familiar with and well trained in the use and importance of the alarm system.

General Basis for Guidance Values

The values stated in the list on the following pages refer to layout point L1. (Nominal max. continuous rating).

The values must only be used as a guidance 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 Section 701-03, furtheron.

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.

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.

! *Attention must be paid to the temperature levels stated under Nos. 8123 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.

Guidance Alarm Limits and Measuring Values

(at max. continuous rating with engine running steadily). *The list applies to ME/ME-C Engines. For items marked with an *, further details are given in a footnote.*

Fuel Oil System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
PT 8001	I – AL	Fuel oil Inlet (after filter) *	7 – 8	6.5	Bar		
PT 8002	AL	Fuel oil before filter *		6.5	Bar		
PDI 8003		Fuel oil filter * Pressure drop across filter	0.2 – 0.5		Bar		
VT 8004	I-AH AL	Fuel oil viscosity *	10 – 15	20 7	cST cST		
TE 8005	I	Fuel oil inlet (after filter) *	T		°C		
LS 8006	AH	Leakage from high pressure pipes		Level high			

PT 8001	Fuel viscosity max. 700 cST at 50 °C measured at fuel pump level.
PT 8002	Yard supply. Fuel viscosity max. 700 cST at 50 °C.
PDT 8003	Yard supply.
VT 8004	Yard supply. Viscosity to be monitored and alarm given off by sensor built into the Viscorator
TE 8005	T = See chapter 705 Vol.1 Operation book.

Lubricating Oil System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
PT 8103	I – AL	Lub. oil inlet to turbocharger	1.5 – 2.2	1.2	Bar		
TE 8106	I - AH	Thrust bearing segment	55 – 70	75	°C		
	Y			80		H	
TE 8107	Z	Thrust bearing segment	55 – 70	90	°C		H
PT 8108	I – AL	Lubrication oil inlet *			Bar		
		S50ME-C	2.0 - 2.3	1.6			
		S60ME-C, L60ME-C, S60ME,	2.1 - 2.4	1.7			
		S65ME-C, L70ME-C, K80ME-C	2.2 - 2.5	1.8			
		S70ME-C, S80ME-C, K90ME-C,	2.3 - 2.6	1.9			
		K98ME-C, K98ME	2.4 - 2.7	2.0			
		K90ME					
		S90ME-C					
	Y	S50ME-C		1.4		L	
		S60ME-C, L60ME-C, S60ME,		1.5			
		S65ME-C, L70ME-C, K80ME-C					
		S70ME-C, S80ME-C, K90ME-C,		1.6			
		K98ME-C, K98ME,					
		K90ME		1.7			
		S90ME-C		1.8			
PT 8109	Z	Lubrication oil inlet *			Bar		L
		S50ME-C		1.2			
		S60ME-C, L60ME-C, S60ME,		1.3			
		S65ME-C, L70ME-C, K80ME-C					
		S70ME-C, S80ME-C, K90ME-C,		1.4			
		K98ME-C, K98ME					
		K90ME		1.5			
		S90ME-C		1.6			
TE 8112	I – AH	Lubrication oil inlet	40 – 47	55	°C		
	AL			35			
	Y			60		H	
TE 8113	I - AH	Piston cooling oil outlet/cylinder	50 – 65	70	°C		
	Y			75		H	
FS 8114	Y	Piston cooling oil outlet/cylinder		No flow		L	
TE 8117	I – AH	Lub. oil outlet from turbocharger/TC					
		MAN/TCA COM	70 – 90	95	°C		
		MHI/MET COM	70 – 90	85	°C		
		ABB/TPL COM/ABB/VTR COM	70 – 90	110	°C		
	Y			120	°C	H	
TE 8118	I – AH	Lub. oil outlet from engine	50 – 60	65	°C		
TE 8120	I – AH	Main bearing metal temperature *	50 – 70	75	°C		
	Y					80	

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
TE 8121	I – AH Y	Crankpin bearing metal temperature *	50 – 70	75	°C	 80	
TE 8122	I – AH Y	Crosshead bearing metal temperature *	50 – 70	75	°C	 80	
TE 8123	I - AH Y AH Y	Main bearing oil outlet* Deviation from average	50 - 60	65 70 +/- 5 +/- 7	°C	 H H	
TE 8124	I - AH Y AH Y	Crankpin bearing* Deviation from average	50 - 60	65 70 +/- 5 +/- 7	°C	 H H	
TE 8125	I - AH Y AH Y	Crosshead bearing oil outlet, fore* Deviation from average	50 - 60	65 70 +/- 5 +/- 7	°C	 H H	
LS 8130	AL – Y	Lub. oil level in tank *		Low level			
PDS 8140	AH	Lub. oil difference pressure-across filter (Boll & kirsch)	0 - 0.6	>0.8			
XS 8152	A	WIO sensor not ready		fail			

PT 8108, PT 8109. Measured by pressure gauge placed 1.8 m above crankshaft centreline. For Lub. oil pumps of centrifugal type, the pressure at stopped engine will be about 0.2 bar lower. (The difference in pressure at stopped and running engine is mainly caused by influence of oscillation forces, especially in piston cooling space.).

TE 8117 Inlet reference, see sensor TE 8112.

TE 8120 – TE 8125 * Please note that the “Normal service value” is to be stated at sea trial, but, in between the range stated. With regard to the “Alarm”, “Slow down” and “Shut down” levels they should be 5°C, 10°C and 20°C above the sea trial finding respectively, however, maximum the value stated.

TE 8124 and TE 8125 Cut off at stopped engine. Cut off to remain until 3 minutes after start.

LS 8130 For separate lubricating system of the turbochargers.

Cylinder Lubrication Oil System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
TE 8202	AH	Cylinder Lub. oil temperature	40 – 60	70	°C		

Cooling Water System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
PT 8401	I – AL Y	Jacket cooling water inlet *	3.5 – 4.5	2.0 1.5	Bar Bar	 L	
PS 8402	Z	Jacket cooling water inlet *	3.5 – 4.5	X	Bar		L
PDT 8403	I – AL Y	Jacket cooling water pressure loss across engine *	0.8 – 1.4	X X 0.2	Bar Bar	 X 0.4	
TE 8407	I – AL	Jacket cooling water inlet	65 – 70	57	°C		
TE 8408	I – AH	Jacket cooling water outlet/cyl. S50ME-C S60ME-C, L60ME-C, S60ME, S65ME-C, L70ME-C, S70ME-C, K80ME-C, S80ME-C, K90ME-C, K90ME, S90ME-C, K98ME-C, K98ME, K108ME-C	 75 – 80 80 – 85	 85 90	°C		
	Y	S50ME-C S60ME-C, L60ME-C, S60ME, S65ME-C, L70ME-C, S70ME-C, K80ME-C, S80ME-C, K90ME-C, K90ME, S90ME-C, K98ME-C, K98ME, K108ME-C		90 95	°C	H	
TE 8409	I – AH	Jacket cooling water outlet temp, at turbocharger S50ME-C S60ME-C, L60ME-C, S60ME, S65ME-C, L70ME-C, S70ME-C, K80ME-C, S80ME-C, K90ME-C, K90ME, S90ME-C, K98ME-C, K98ME, K108ME-C	 75 – 80 80 – 85	 85 90	°C		
TE 8411		Jacket cooling water outlet temp, exhaust valve	80 – 120		°C		
LS 8412	AL	Jacket cooling water de-aerating tank device		Low level			
PI 8413		Jacket cooling water outlet common pipe *	2.7 – 3.1		Bar		
PT 8421	I – AH AL	Cooling water inlet to air cooler(s) * Sea water cooling system Central cooling water system	 2.0 – 2.5 X 2.0 – 4.5 X	 3.5 5.5 1.0	 Bar Bar		
TE 8422	I – AH	Cooling water inlet to air cooler(s) Sea water cooling system Central cooling water system	 >10 – 32 >10 – 36	 40 40	 °C		

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
TI 8423	I	Cooling water outlet from air cool.					
		Sea water cooling system	>10 – 50		°C		
		Central cooling water system	>10 – 63				
PDT 8424	I	Pressure drop of cooling water across air cooler/air cooler	0.25 – 0.5		Bar		
TE 8431	I – AL	Cooling water inlet to lub. oil cool.	>10 – 32	10	°C		

PT 8401, PI 8413 — If the expansion tank is located more than 5 m above the engine outlet, the resulting increase in the static pressure must be added to the “normal service value” indicated here.

PS 8402 — X = With stopped cooling water pump, the set point for the sensor is the static pressure plus the stated value.

PDT 8403 — X = To be stated on sea-trial. Set point 0.2 and 0.4 bar lower.

PT 8421 — X = To be stated on sea-trial.

Compressed Air System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
PT 8501	I – AL	Starting air inlet pressure *	30	15	Bar		
PT 8503	I-C-AH AL	Control air inlet *	6.5 – 7.5	0.5 X 5.5	Bar Bar		
PT 8504	I-C-AH AL	Safety air inlet *	6.5 – 7.5	0.5 X 5.5	Bar Bar		

PT 8503, PT 8504, X = AH at finished with engine.

PT8501 Alarm handled by Main Operation Panel (MOP)

Scavenge Air System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
PT 8601	I	Scavenge air receiver pressure *			Bar		
		L60ME-C, L70ME-C, S90ME-C	X – 3.50				
		S60ME, S80ME-C	X – 3.55				
		K80ME-C, K90ME-C, K90ME, K98ME-C, K98ME	X – 3.60				
		S50ME-C, S60ME-C, S65ME-C S70ME-C, K108ME-C	X – 3.65				
TE 8605	I	Scavenge air temp. before each cooler *	170 – 210		°C		
PDT 8606	I – AH	Scavenge air pressure drop across each air cooler *	X	XX	Bar		
PDT 8607	I – AH	Scavenge air pressure drop across filter *	X	XX	Bar		
TE 8608	I	Scavenge air temperature after each air cooler *	X		°C		
TE 8609	I – AH	Scavenge air temperature in receiver *					
		Sea water cooling system	>25 – 47	55 X	°C		
		Central cooling water system	>25 – 51	55 X	°C		
	Y				°C	65 X	
TE 8610	AH	Scavenge air box-fire alarm/cyl.		80	°C		
	Y				°C	120	
LS 8611	AH	Water mist catcher - water level		High			
TE 8612	I	Compressor inlet temperature/ turbocharger	- 10 - + 45		°C		

PT 8601	The set point of scavenge air pressure depends on the engine load and shall be set during sea trial.
TE 8605	Value based on MCR, depending on engine load and ambient conditions.
PDT 8606, PDT 8607	X = According to shop-trial results. XX = at 50 % increase.
TE 8608	X = coolant inlet + 12 °C.
TE 8609	X = To be cut off during stop. To remain cut out until 3 – 5 minutes after start.

Exhaust Gas System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
TC 8701	I – AH	Exhaust gas temperature before turbocharger *		X	°C		
		S50ME-C, S60ME-C, L60ME-C, S60ME, L70ME-C, S65ME-C, S70ME-C,	380 – 500				
		K80ME-C, S80ME-C, K90ME-C, K90ME, S90ME-C, K98ME-C, K98ME, K108ME-C	380 – 460				
	Y			X		H	
TC 8702	I – AH	Exhaust gas temperature after valves * Average.			°C		
		S50ME-C, S60ME-C, L60ME-C, S60ME, S65ME-C, L70ME-C, S70ME-C, K80ME-C, S80ME-C, K90ME-C, K90ME, S90ME-C, K98ME-C, K98ME, K108ME-C	320 – 390	430			
	Y			450		H	
		Deviation from average		+/-50		+/-60	
TC 8704	I	Exhaust gas temperature in receiver	100 – 500		°C		

TC 8701

Normal exhaust gas temperatures depend on the actual engine load and ambient condition.

NOTE: Regarding alarm for high turbine inlet temperature:

This alarm is not an MAN B&W requirement, as alarms for high gas temperatures, are given by cylinder exhaust as well as for turbine outlet temperature alarms.

Some Classification Societies require alarm for high turbine inlet temperature. In such cases we recommend set point equivalent to the maximum temperature for continuous operation shown on the turbocharger name plate.

(Some Turbocharger manufacturers shows two (2) maximum temperatures on the name plate. It is the lowest shown temperature that must be used as set point - if alarm is required. The high maximum temperature is only allowed at short over-load tests at test-bed)

X = turbocharger dependent.

TC 8702

Normal exhaust gas temperatures depend on the actual engine load and ambient condition. When operating below 200 °C average temperature deviation alarm is cut off.

Exhaust Gas System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
PT 8706	I	Exhaust gas pressure in receiver *			Bar		
		S90ME-C L60ME-C, L70ME-C, S60ME, S80ME-C K80ME-C, K90ME-C, K90ME, K98ME-C, K98ME, K108ME-C S50ME-C, S60ME-C, S65ME-C, S70ME-C	3.25 3.30 3.35 3.40 3.45				
TC 8707	I – AH	Exhaust gas temperature after each turbocharger *	220 – 300	350	°C		
PT 8708	I – AH	Exhaust gas pressure after each T/C at MCR	300	450	mm – WC		
PDI 8709	I	Exhaust gas pressure drop across boiler at MCR	150		mm – WC		
ZT 8721	I	Exhaust gas by-pass valve angle position	0 – 90				

PT 8706 — Normal exhaust gas temperatures depend on the actual engine load and ambient condition.

TC 8707 — The service values apply under the following conditions: Ambient temperature in engine room 25 °C. Scavenge air temperature in receiver 35 °C.

Hydraulic Power Supply

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
XC 1231	A	Filter failure		alarm			
PT 1233	AH	Pressure in double pipe		50	Bar		
LS 1234	AH	Leakage from double pipes		High	L		
TE 1270	I-AH Y	Temperature HPS bearing *	55-60	70 80	°C	 H	

TE 1270 Only relevant for K98ME/ME-C engines

External Hydraulic Control Oil Supply System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
PI 1301	I	Fine filter unit indicator			Bar		
PDS 1302	AH	Lubricating oil difference pressure across filter		High	Bar		
PI 1303	I	Lubricating oil pressure at engine inlet	2.5		Bar		
TI 1310	I	Lubricating oil temperature at engine inlet	40-55		°C		
LS 1320	AH-AL	Level alarm in tank		Low High	L		

MECS to/from Safety System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
XC 2001	Z	Emergency stop to engine control units					
XC 2002	Z	Emergency stop to cylinder control units and InFi amplifier					
PT 2003	Z	Hydraulic oil, low pressure, shut-down			Bar		
XC 2010	Y	Slow-down from safety/alarm system					
XC 2020	Z	Non-cancellable shut-down					
XC 2021	Z	Cancellable shut-down					

MECS to/from Alarm System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
XC 2201	A	Power failure		alarm			
XC 2202	A	System		alarm			
XC 2205	A	Slow-down pre-warning		alarm			
XC 2206	A	Slow-down request		alarm			

Power Supply Units to Alarm System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
XC 2903	A	Earth failure ME power supply	70-1000	24	KOhm		

Tacho / Crankshaft Position System

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
ZT 4020	Z	Tacho for safety		r/min			MCR x 1.09

Miscellaneous

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
ZT 8801	I - AH	Turbocharger speed, each unit *	X	X	r/min		
PT 8802	I	Engine room pressure (bar abs.)	0.95 – 1.05		Bar		
PI 8803		Air inlet for dry cleaning, turbocharger	4.5 – 10		Bar		
PI 8804		Water for cleaning, inlet turbocharger *	min. 0.5 X		Bar		
WT 8805	AH	Vibration of turbocharger, each unit (option)		high	mm		
PI 8806		Speed setting to governor (air pressure)	0.5 – 5.0		Bar		
XC 8807	I	Pmax. control pressure	0.0 – 5.0		Bar		
XC 8808	I	Fuel injection pump index, each cylinder *	X				
XC 8809	I	VIT index, each cylinder *	X				
XC 8810	I	Governor index *	X				
XC 8811	I	Engine torque *	X		Nm		
WT 8812	I – AH	Crankshaft longitudinal vibration Axial vibration monitor Peak to peak					
	Y	6K108ME-C Monitoring equip. required	0.0 - 2.10	2.80	mm	3.50	
		7K108ME-C	0.0 - 2.45	3.26		4.08	
		8K108ME-C	0.0 - 2.79	3.72		4.65	
		9K108ME-C	0.0 - 3.13	4.18		5.22	
		10K108ME-C	0.0 - 3.48	4.64		5.80	
		11K108ME-C Monitoring equip. required	0.0 - 3.82	5.10		6.37	
		12K108ME-C	0.0 - 4.17	5.56		6.95	
		14K108ME-C Monitoring equip. required	0.0 - 4.86	6.48		8.10	
		6K98ME	0.0 - 2.28	3.05		3.81	
		7K98ME	0.0 - 2.66	3.55		4.43	
		8K98ME	0.0 - 3.03	4.05		5.06	
		9K98ME	0.0 - 3.41	4.55		5.68	
		10K98ME	0.0 - 3.78	5.05		6.31	
		11K98ME Monitoring equip. required	0.0 - 4.16	5.55		6.93	
		12K98ME	0.0 - 4.54	6.06		7.57	
		14K98ME Monitoring equip. required	0.0 - 5.30	7.06		8.83	
		6K98ME-C	0.0 - 1.88	2.51		3.13	
		7K98ME-C	0.0 - 2.19	2.92		3.65	
		8K98ME-C	0.0 - 2.49	3.33		4.16	
		9K98ME-C	0.0 - 2.80	3.74		4.67	
		10K98ME-C	0.0 - 3.11	4.15		5.18	
		11K98ME-C Monitoring equip. required	0.0 - 3.42	4.56		5.70	
		12K98ME-C	0.0 - 3.72	4.97		6.21	
		14K98ME-C Monitoring equip. required	0.0 - 4.34	5.79		7.24	

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
		6S90ME-C Monitoring equip. required	0.0 - 3.24	4.33		5.41	
		7S90ME-C	0.0 - 3.78	5.04		6.30	
		8S90ME-C	0.0 - 4.32	5.76		7.20	
		9S90ME-C	0.0 - 4.86	6.48		8.10	
		4K90ME	0.0 - 1.44	1.92		2.40	
		5K90ME	0.0 - 1.80	2.40		3.00	
		6K90ME	0.0 - 2.16	2.88		3.60	
		7K90ME	0.0 - 2.54	3.38		4.23	
		8K90ME	0.0 - 2.90	3.86		4.83	
		9K90ME	0.0 - 3.26	4.34		5.43	
		10K90ME	0.0 - 3.62	4.82		6.03	
		11K90ME Monitoring equip. required	0.0 - 3.98	5.30		6.63	
		12K90ME	0.0 - 4.34	5.78		7.23	
		6K90ME-C	0.0 - 1.95	2.60		3.25	
		7K90ME-C	0.0 - 2.28	3.04		3.80	
		8K90ME-C	0.0 - 2.61	3.48		4.35	
		9K90ME-C	0.0 - 2.94	3.92		4.90	
		10K90ME-C	0.0 - 3.26	4.34		5.43	
		11K90ME-C Monitoring equip. required	0.0 - 3.59	4.78		5.98	
		12K90ME-C	0.0 - 3.92	5.22		6.53	
		6S80ME-C Monitoring equip. required	0.0 - 2.99	3.98		4.98	
		7S80ME-C	0.0 - 3.45	4.59		5.74	
		8S80ME-C	0.0 - 4.06	5.40		6.75	
		6S80ME-C9	3.46	4.62		5.77	
		7S80ME-C9	4.03	5.37		6.71	
		8S80ME-C9	4.59	6.12		7.65	
		9S80ME-C9	5.16	6.88		8.60	
		6K80ME-C	0.0 - 1.73	2.30		2.88	
		7K80ME-C	0.0 - 2.03	2.70		3.38	
		8K80ME-C	0.0 - 2.31	3.08		3.85	
		9K80ME-C	0.0 - 2.61	3.48		4.35	
		10K80ME-C	0.0 - 2.90	3.86		4.83	
		11K80ME-C Monitoring equip. required	0.0 - 3.18	4.24		5.30	
		12K80ME-C	0.0 - 3.47	4.62		5.78	
		6K80ME-C9	2.28	3.03		3.79	
		7K80ME-C9	2.65	3.53		4.41	
		8K80ME-C9	3.02	4.03		5.03	
		9K80ME-C9	3.39	4.52		5.65	
		10K80ME-C9	3.77	5.02		6.28	
		11K80ME-C9	4.14	5.52		6.90	
		12K80ME-C9	4.51	6.02		7.52	
		4S70ME-C	0.0 - 1.77	2.36		2.95	
		5S70ME-C Monitoring equip. required	0.0 - 2.19	2.92		3.65	
		6S70ME-C Monitoring equip. required	0.0 - 2.62	3.50		4.37	
		7S70ME-C	0.0 - 3.05	4.07		5.08	
		8S70ME-C	0.0 - 3.58	4.78		5.97	

Sensor Code	Function	Designation	Normal Service Value	Set point	Unit	SLD	SHD
		4L70ME-C 5L70ME-C Monitoring equip. required 6L70ME-C Monitoring equip. required 7L70ME-C 8L70ME-C	0.0 – 1.41 0.0 – 1.74 0.0 – 2.08 0.0 – 2.42 0.0 – 2.76	1.88 2.32 2.78 3.23 3.68		2.35 2.90 3.47 4.03 4.60	
		4S65ME-C 5S65ME-C Monitoring equip. required 6S65ME-C Monitoring equip. required 7S65ME-C 8S65ME-C	0.0 – 1.84 0.0 – 2.28 0.0 – 2.72 0.0 – 3.17 0.0 – 3.61	2.46 3.04 3.63 4.23 4.82		3.07 3.80 4.53 5.28 6.02	
		4S60ME-C 5S60ME-C Monitoring equip. required 6S60ME-C Monitoring equip. required 7S60ME-C 8S60ME-C	0.0 – 1.52 0.0 – 1.88 0.0 – 2.25 0.0 – 2.61 0.0 – 3.07	2.03 2.51 3.00 3.49 4.10		2.53 3.13 3.75 4.36 5.12	
		4S60ME 5S60ME Monitoring equip. required 6S60ME 7S60ME 8S60ME	0.0 – 1.47 0.0 – 1.85 0.0 – 2.21 0.0 – 2.58 0.0 – 2.94	1.96 2.46 2.94 3.44 3.92		2.45 3.08 3.68 4.30 4.90	
		4L60ME-C 5L60ME-C Monitoring equip. required 6L60ME-C Monitoring equip. required 7L60ME-C 8L60ME-C	0.0 – 1.20 0.0 – 1.49 0.0 – 1.77 0.0 – 2.07 0.0 – 2.36	1.60 1.99 2.37 2.76 3.15		2.00 2.48 2.96 3.45 3.93	
		4S50ME-C 5S50ME-C Monitoring equip. required 6S50ME-C Monitoring equip. required 7S50ME-C 8S50ME-C	0.0 – 1.26 0.0 – 1.56 0.0 – 1.87 0.0 – 2.17 0.0 – 2.55	1.69 2.09 2.50 2.90 3.41		2.11 2.61 3.12 3.62 4.26	
XS 8813	AH – Y	Oil mist in crankcase, each cyl.		high density or 0.5	mg/l	high density or 0.5	
XS 8814	A	Oil mist detector failure (no value)					

ZT 8801	X = according to the manufacturer.
PI 8804	X = higher than exhaust gas pressure.
XC 8808, 8809, 8810 and 8811	X = Engine and load dependent.

Measuring Instruments, Identification

Remote Indication

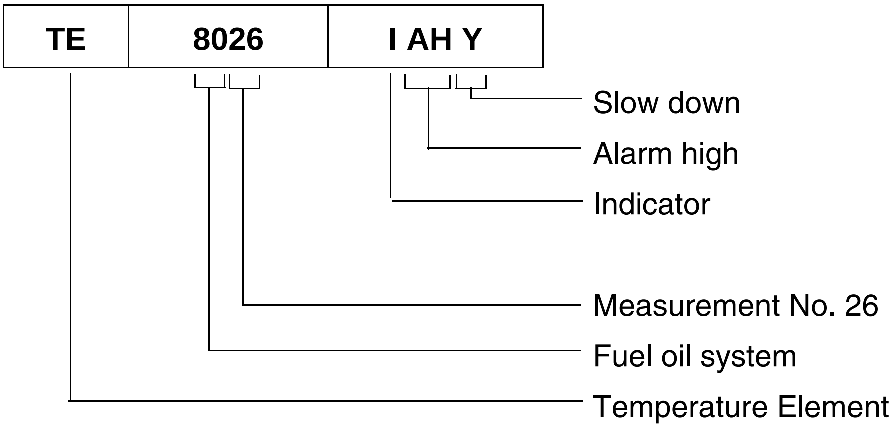
Codes for identification of instruments and signal-related functions

PT	**8108**	**AH**
First letter	**Ident. No.**	**Secondary letter(s)**

Measured or indicating variable (First letter(s))	Ident. number The first two digits indicate the point of measurement, the next two are serial numbers.	Function (Secondary letter(s))
DS: Density switch DT: Density transmitter GT: Gauging transmitter (load/index transmitter) FT: Flow transmitter FS: Flow switch LS: Level switch LI: Level indication (local) LT: Level transmitter PDI: Pressure difference indication (local) PDS: Pressure difference switch PDT: Pressure difference transmitter PI: Pressure indication (local) PS: Pressure switch PT: Pressure transmitter ST: Speed transmitter TC: Thermo couple (NiCr-Ni) TE: Temperature element (Pt-100) TI: Temperature indication (local) TS: Temperature switch WS: Vibration switch WT: Vibration transmitter VS: Viscosity switch VT: Viscosity transmitter ZV: Position valve (solenoid valve) ZS: Position switch (limit switch) ZT: Position transmitter (e.g. proximity sensor) XC: Unclassified control XS: Unclassified switch XT: Unclassified transmitter	11. Manoeuvring system 12. Hydraulic power supply 14. Combustion pressure supervision 20. ECS to/from safety system 21. ECS to/from remote control system 22. ECS to/from alarm system 30. ECS Miscellaneous input/output values 40. Tacho/crankshaft pos. system 41. Engine cylinder components 50. VOC: supply system 51. VOC: sealing oil system 52. VOC: control oil system 53. Other VOC related systems 54. VOC engine related components 80. Fuel oil system 81. Lubrication oil system 82. Cylinder lub. oil system 83. Stuffing box drain system 84. Cooling water system e.g. central cooling water e.g. sea cooling water e.g. jacket cooling water 85. Compressed air supply system e.g. control air e.g. starting air 86. Scavenge air 87. Exhaust gas system 88. Miscellaneous functions e.g. axial vibration 90. Project specific Note: ECS: Engine control system VOC: Volatile Organic Compound	A: Alarm C: Control H: High I: Indication (remote) L: Low R: Recording S: Switching Y: Slow-down X: Unclassified function Z: Shut-down

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

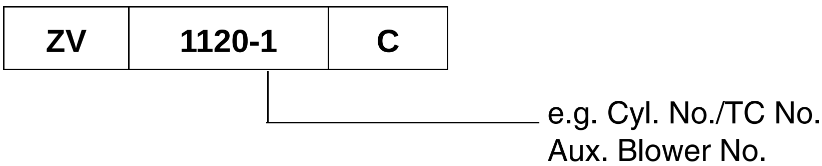


Repeated signals:

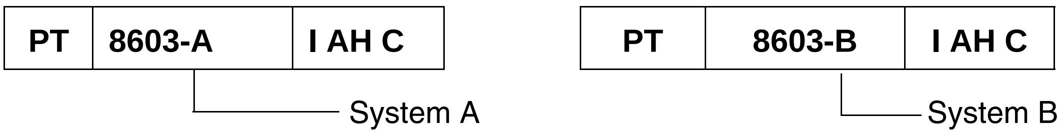
Signals which are repeated, such as per cylinder measurement or per turbocharger measurement, etc. are provided with a suffix number. The suffix number is identical with the place of measurement, such as 1 for cylinder 1, etc. Where signals are redundant, suffix A or B may be used.

Examples

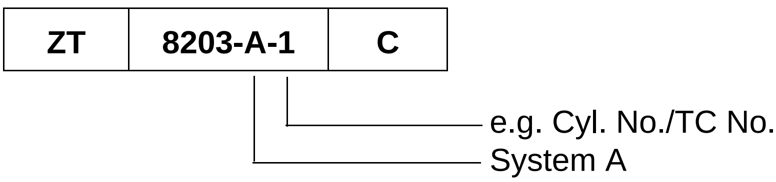
Cylinder or Turbocharger-Related Signals



Redundant Signals

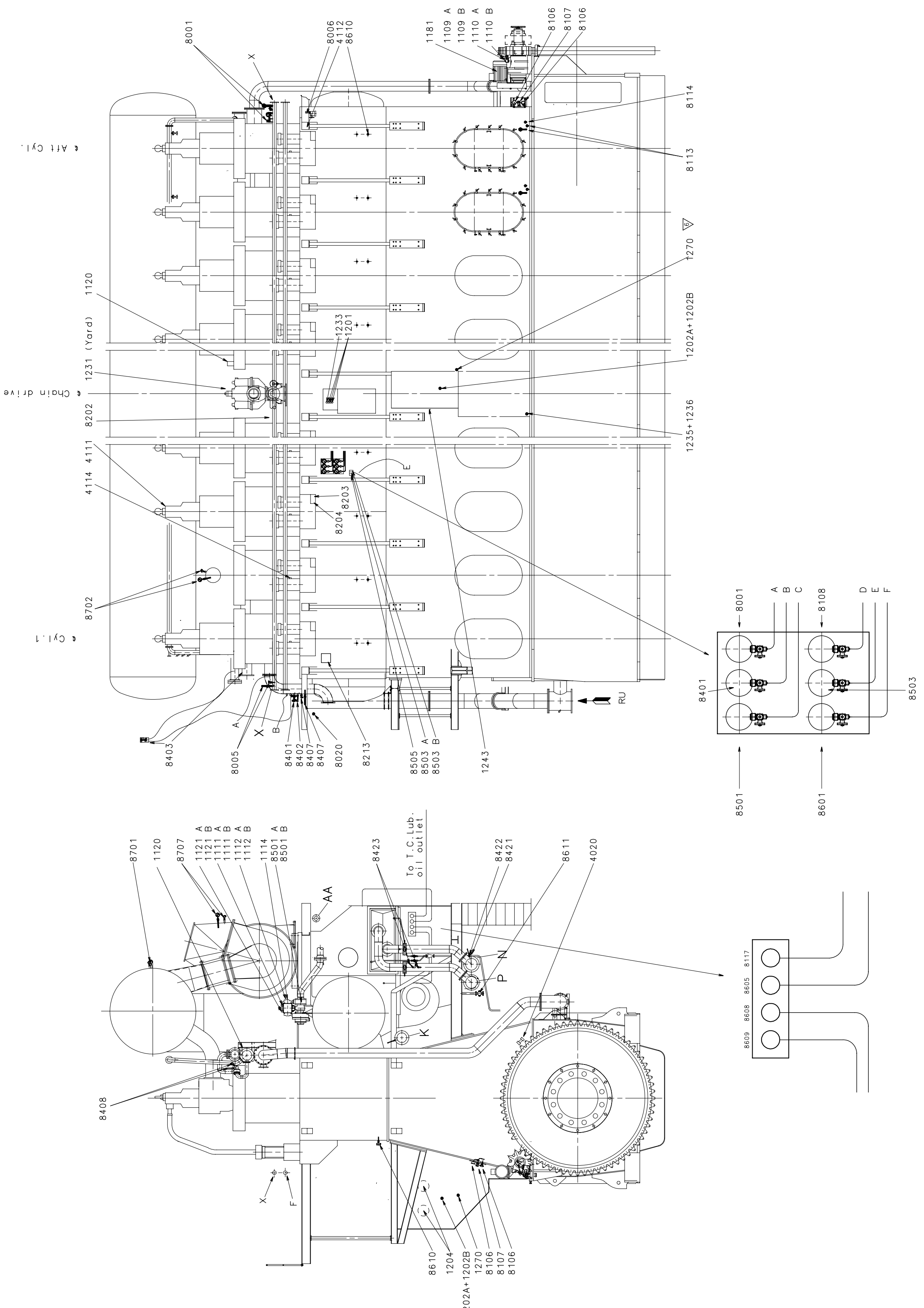


Cylinder-Related Redundant Signals

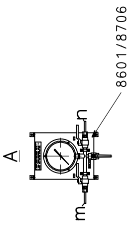


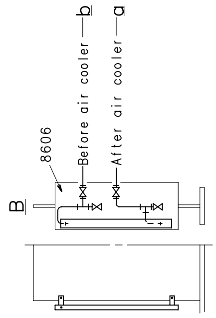
Graphical presentation in PI-diagrams according to ISO 1219 I - II

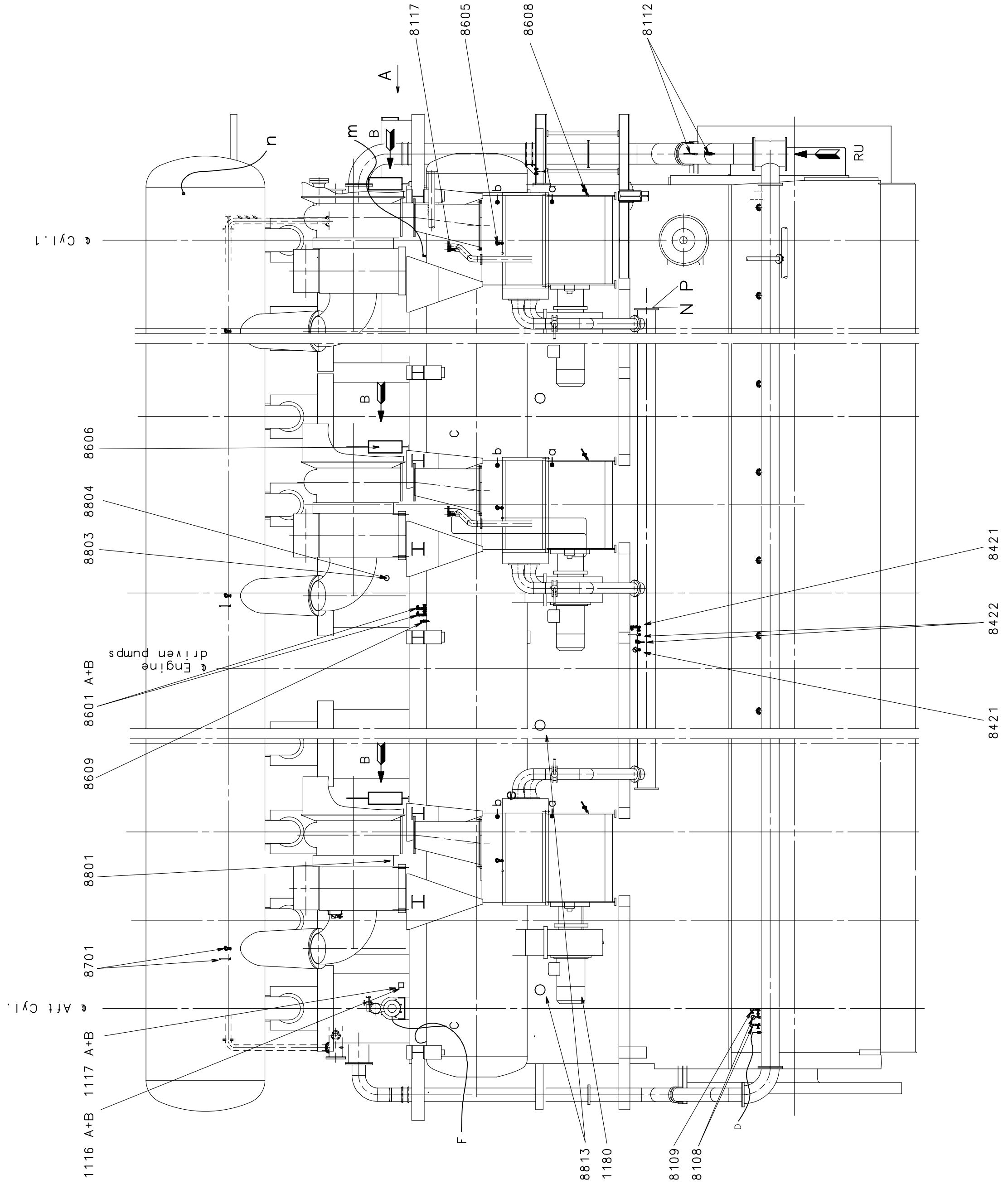
Location of Basic Measuring Points



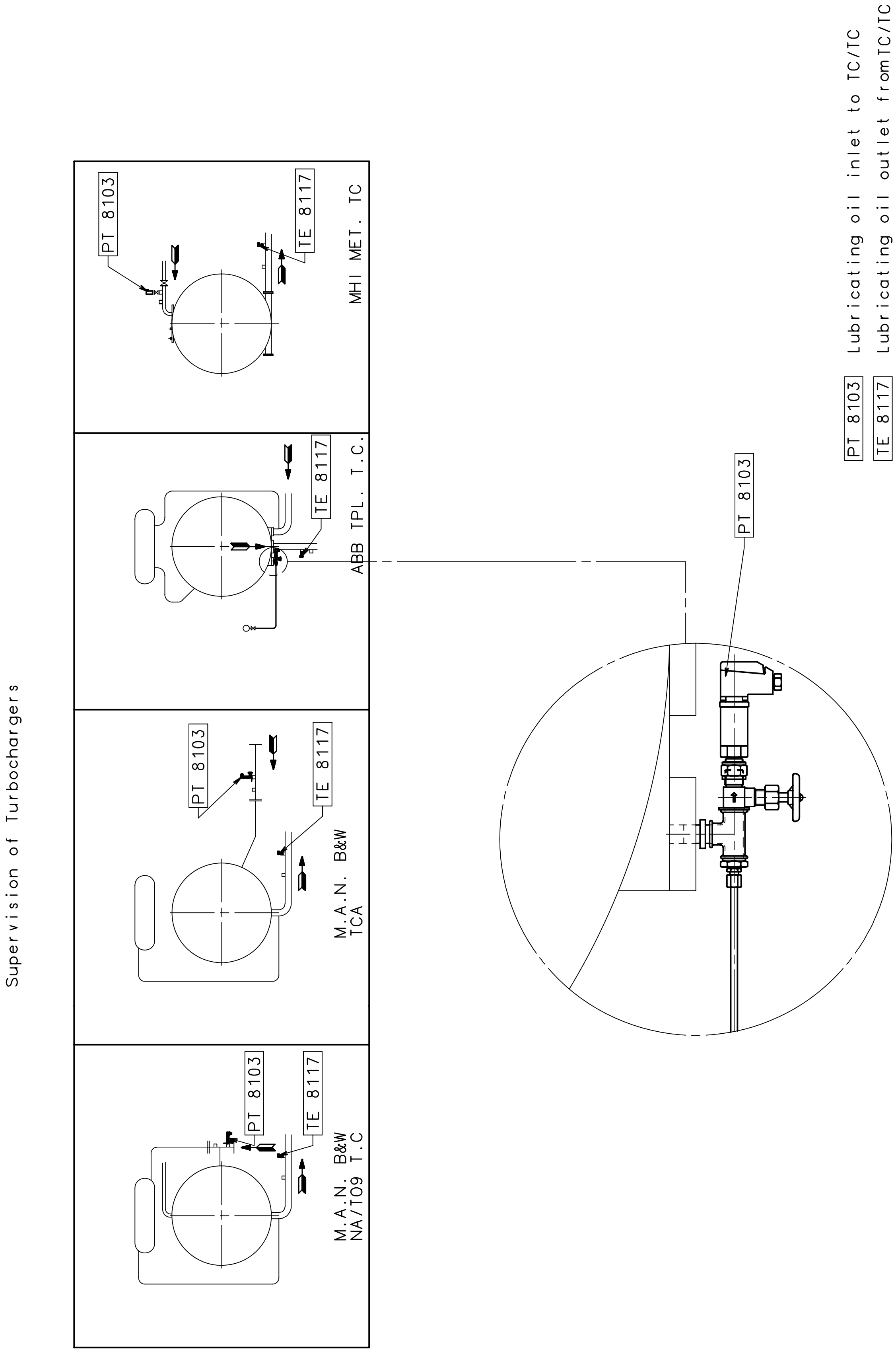
Location of Basic Measuring Points





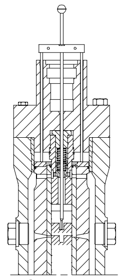


Location of Basic Measuring Points



M/V	**Engine Type:**		**Engine layout:**	**Checked by:**
Yard:	**Builder:**	**Engine No.:**	**BHP:**	
No.:	**Built year:**		**r/min.:**	**Date:**

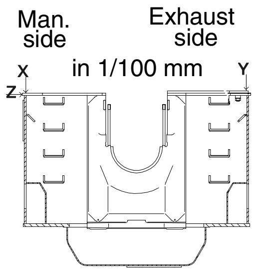
Fuel valve nozzle	Marked: .... holes of .... mm	Governor
Fuel valve	Opening pressure .... bar	Make: Type: No.:
Compression rate	Height of shims under piston rod .... mm	Serial No.:
Lubricator pumping stroke to be finished when the corresponding crankthrow is .... ° after BDC		



See Section 909-1.1 in Vol. II 'Maintenance'

Fuel pump No.	1	2	3	4	5	6	7	8	9	10	11	12
Reading A: Main piston in TDC												
Reading B: Plunger in lowest position												
Cam top lift, C: C = A-B (mm)												
VIT index on STOP												
Fuel index on STOP												
Fuel index on MAX.												

These measurements are taken with the staybolts tightened



Bedplate alignment	Crossgirder No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Optical measurements	X														
		Y														
		Z														
	Piano wire d = 0.5 mm load 40 kg	X														
		Y														
		Z														

Crankshaft deflection in 1/100 mm

Crank No.	1	2	3	4	5	6	7	8	9	10	11	12
Crank in bottom port side. Dial gauge set to 'Zero' in bottom port side Deflection to be measured in cold cond.												
Crank in port side												
Crank in top												
Crank in starboard side												
Crank in bottom starboard side												

Total clearance at thrust bearing B+C = ... mm (max. .... mm)	
To ensure correct crankshaft position relative to bedplate, check that A+B = ... mm	
'A' to be taken as shown, i.e. between upper edge of lower shell and the crank web, with aftmost crank in BDC.	S/K/L-MC

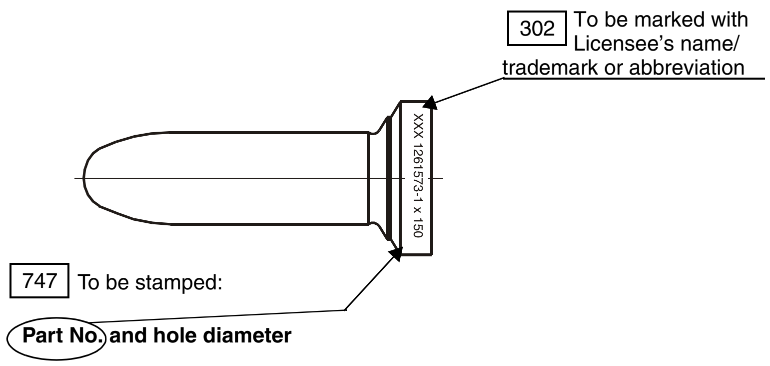
1. Check of IMO-ID, Markings on Components

The components described in Items 1.1 to 1.6 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. Information on the important dimensions for each component type in respect to the NO_x characteristic can be found in the engine instruction book, see references in footnotes **) to TF Chapter 1.4.

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 Drawing No. 0741260-8 regarding marks and stamps on components for MAN B&W two-stroke diesel engines.

1.1 Fuel Valve Nozzle



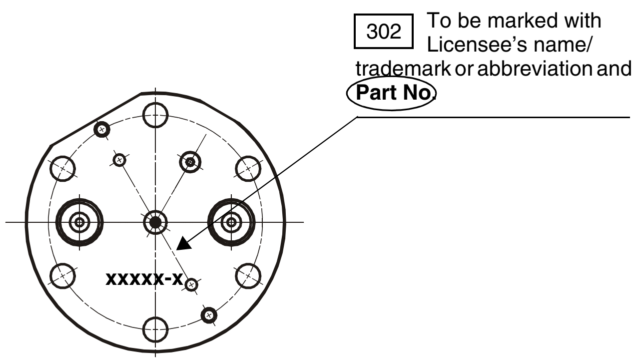
Certified markings:

Part No.

Marking instruction:

No. 0742639-1

1.2 Pressure Booster Top Cover



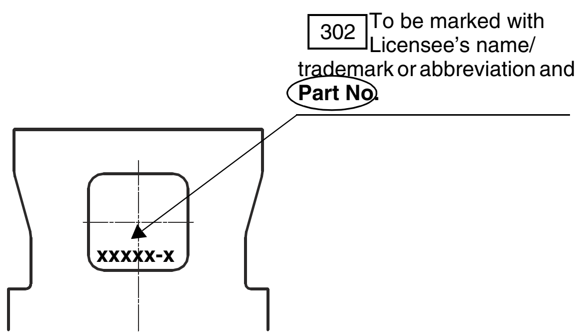
Certified markings:

Part No.

Marking instruction:

No. 0742962-4

1.3 Hydraulic Piston Housing



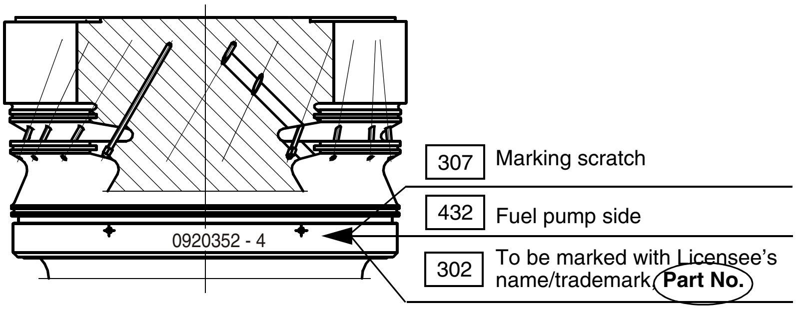
Certified markings:

Part No.

Marking instruction:

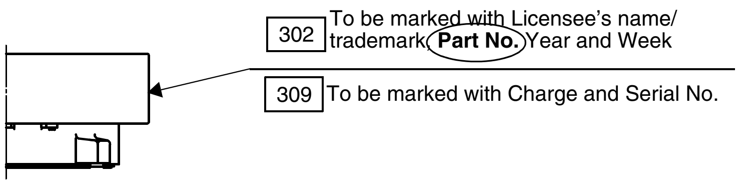
No. 0742960-0.1

1.4 Cylinder Liner



Certified markings:	Part No.
Marking instruction:	No. 0742637-8

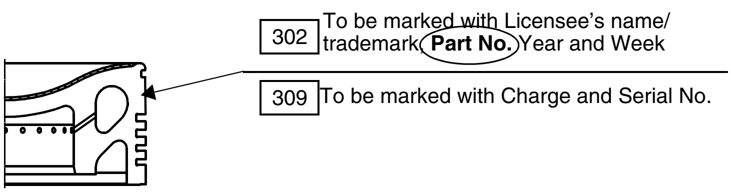
1.5 Cylinder Cover



On fuel pump side

Certified markings:	Part No.
Marking instruction:	No. 0742634-2

1.6 Piston Crown



On fuel pump side

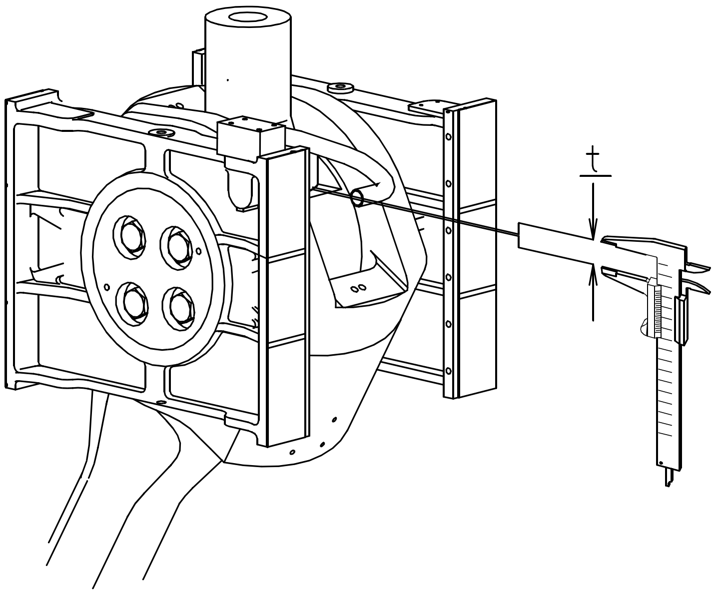
Certified markings:	Part No.
Marking instruction:	No. 0742392-0

2. Checking Setting Values

2.1 Checking the 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. *See figure below.*



3. Nameplates

3.1 ELFI Valve

Manufacturer
Type
Serial number(s)
Manufacturing date
Specification
Max. cont. speed
Max. cont. gas temperature

3.2 Air Cooler Specifications (Nameplate)

Manufacturer			
Type			
Contract Number			
Year build			
	Water side	Air side	
Operational Gauge Pressure			bar
Test Gauge Pressure			bar
Operational Temperature			deg. C
Content			L

3.3 Auxiliary Blower Specifications (Nameplate)

Manufacturer:	
Model:	Serial number(s):
Capacity:	Speed:
Pressure:	Power:
Temp.:	Elec. source:
Density:	Mfg. date:

4. Survey methods including on-board verification

4.1 IMO surveys

Figure B.1 shows a flow chart for all the survey methods used in connection with IMO certification of a MAN B&W two-stroke engine.

a. test-bed survey (engine pre-certification survey)
b. sea-trial survey (initial survey on board), and
c. on-board surveys (intermediate and periodical surveys)

On test bed, parent and the member engines are surveyed by the same procedures, except for the important difference that emission measurements are performed and surveyed on the parent engine, only. *(The emissions data measured on the parent engine are used to establish the emission simulation for the on-board survey code to verify compliance based on standard performance data.)*

On board, only the 'on-board' survey method shall be used for future 'intermediate' and 'periodical' surveys. *(Provided that the required IMO certificates have been issued based on the engine 'pre-certification' and 'initial' surveys.)*

The standard MAN B&W *on-board survey method* 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 1.3 and no component changes have been made to the engine.

The necessary performance parameters and corrections are specified in Chapter B.2. And a description with step-by-step procedures of the actual survey is presented in Chapter B.3.

4.2 Definitions and Corrections

4.2.1 Definitions

4.2.2 'Standard MAN B&W performance check'

Table B.2.1 lists the parameters necessary as input for the survey code from a standard MAN B&W performance check.

Table B.2.1: Input data for survey code *)

Engine Number	-
Vessel Name	-
T/C inlet temperature **	deg.C
Ambient temperature **	deg.C
Ambient pressure **	mbar
Relative humidity of ambient air	rel.%
Scavenging-air temperature **	deg.C
Scavenging-air pressure **	bar
Sea-water (inlet) temperature **	deg.C
Turbine back pressure **	mmWC
Max. cylinder pressure **	bar
Max. compression pressure	bar
Power **,***	kW
Engine speed	r/min
Turbocharger speed	r/min
Fuel pump index	-
VIT index *(if applicable)*	-

* See foot notes **) to TF Chapter 1.4 Comments on calibration of sensors and apparatus, and correction to ISO ambient conditions for these measurements.
** These items are required in order to calculate the NOx emission.
*** See comment in text on power estimation (Section B.2.1.3.)

4.2.3 Tolerances for 'load points'

The actual load points are attached a certain tolerance (see 'NOx Technical Code,' Appendix 4.) However, due to propeller lay out or vessel trim a 'light or heavy propeller' may be experienced. In these cases MAN B&W recommend to select the load point according to the actual measured mean effective pressure corresponding to the specified load point.

4.2.4 Power

The power is usually derived from torque and speed. If the torque is difficult to measure directly through torsion measurements, the Charts added in Fig. B.2 or B.3, can be used to estimate the brake power. Alternatively the load could be derived from a MAN B&W PMI system.

4.2.5 Back pressure

The usual variations in turbine back pressure have been shown only to have a minor influence on the NOx emission and the measurement of the turbine back pressure, therefore, could be omitted during a NOx compliance survey. However, the influence has been included in the survey code as well as in the following example due to the influence on the ISO correction on Pmax.

4.3 Survey cases

The different load points and cooling conditions lead to the following survey cases:

4.3.1 Load-point 'corrections'

4.3.2 Test-bed survey – All engines

Includes all four E3/E2-ISO cycle load points.

4.3.3 On board – Engine without VIT

The actual NOx compliance is estimated from performance data at 75% load only, assuming that the $NOx_{(test\ bed\ 75\%)}$ / $NOx_{(estimated\ 75\%)}$ ratio is identical for the ratio of the remaining load points, also.

4.3.4 On board – Engine with VIT

The actual NOx compliance assumes that the 25 to 75% load points contribute as without VIT, based on the 75% performance data. The 100% load point contribution is estimated from the actual performance at the measured load above the break point (from 85 to 100% loads), adjusting the $NOx_{(test\ bed\ 100\%)}$ for the same Pmax difference as the measured load, but for a Tscav and Pturb.back reflecting the 100% load:

1. $Pmax_{(100\%)} = Pmax_{(meas\ load\%)}$

2. $Tscav_{(100\%)} = Tscav_{(meas\ load\%)} + (100 - meas\ load\%) \times (Tscav.ref_{(100\%)} - Tscav.ref_{(75\%)}) / 25$

3. $Pturb.back_{(100\%)} = Pt.back_{(meas\ load\%)} + (100 - meas\ load\%) \times (Ptback.ref_{(100\%)} - Ptback.ref_{(75\%)}) / 25$

(If the VIT break point can not be reached, case B.2.2.1.3 is handled identical to case B.2.2.1.2.)

4.3.5 Scavenging-air temperature corrections on board

The correction for cooling-water temperature depends on the actual cooling system. In all cases, TF Table 1.3 specifies the actual reference scavenging-air temperature.

4.3.6 Sea-water cooling system (SW)

4. Relative scavenging-air temperature change
= (Tmeas.scav.air – Tref.scav. air) – (Tmeas.sea-water inlet – Tref.sea-water inlet)

4.3.7 Central cooling system – Optimal cooling (CC-O)

5. Relative scavenging-air temperature change
= (Tmeas.scav.air – Tref.scav. air) –
(Tmeas.sea-water inlet – Tref.sea-water inlet)

4.3.8 Central cooling system – Fixed cooler out temperature (CC-F)

6. Relative scavenging-air temperature change = Tmeas.scav.air – Tref.scav. air

4.3.9 Test-bed cooling system

The scavenging-air temperature is on test bed always adjusted similar to a CC-F cooling system with the appropriate Tscav.ref., since the actual cooling system is not available and different cooling-water adjustment possibilities usually exists on a test bed. *(The actual air-cooler performance can be evaluated based on a heat balance for the system.)*

All assumptions have been built into the MAN B&W survey code.

4.4 Correction to ISO ambient conditions

4.4.1 Performance parameters correction to ISO ambient conditions

Some of the measured performance parameters need to be corrected to ISO ambient conditions in order to perform a reliable evaluation and compare with reference conditions. These parameters are Pmax, Pcomp and Pscav.

Correction equations:

7. $$CorrP\max = P\max,m \cdot (100 - 0.2198 \cdot \Delta Tinl + 0.081 \cdot \Delta Tsc + 0.022 \cdot \Delta Pamb - 0.005278 \cdot \Delta Pback)/100$$

8. $$CorrPcomp = Pcomp,m \cdot (100 - 0.2954 \cdot \Delta Tinl + 0.153 \cdot \Delta Tsc + 0.0301 \cdot \Delta Pamb - 0.007021 \cdot \Delta Pback)/100$$

9. $$CorrPsc = Psc,m \cdot (100 - 0.2856 \cdot \Delta Tinl + 0.222 \cdot \Delta Tsc + 0.0293 \cdot \Delta Pamb - 0.006788 \cdot \Delta Pback)/100$$

where: Δ refers to (reference – measured)

subscript m	measured
Tinl	T/C inlet temperature (deg.C)
Tsc	scavenging-air temperature (deg.C)
Pamb	ambient pressure (mmHg)
Pmax	maximum pressure (bar)
Pcomp	compression pressure (bar)
Psc	scavenging-air pressure (bar)
Pback	back pressure (mmWC)

4.4.2 NOx emission correction to ISO ambient conditions

Based on simultaneous measurements of NOx emission and performance parameters from several different MAN B&W two-stroke engines, a special ‘NOx function’ has been formulated to calculate NOx as a function of specific engine parameters. Together with the MAN B&W cycle simulation to predict dependent engine parameters (or simplified in the form of performance correction factors,) the ‘NOx function’ can be used to calculate the tolerances on the most common performance parameters.

The measured data have also been used to formulate an equation to correct emissions at the given ambient conditions to the specified ISO ambient conditions in order to compare emission values at the same conditions (see Equation (10).)

10. $$CorrNO_x(H_a, T_{amb}, p_{amb}) = \frac{1}{1 + C1 \cdot (H_a - 10.71) + C2 \cdot (T_{amb} - 298.15) + C3 \cdot (p_{amb} - 1000)}$$

where:
- H_a water content in scavenging air (gH2O/kg dry air)
- T_{amb} ambient-air temperature (K)
- p_{amb} ambient pressure (mbar)
- C1 to C3 coefficients depend on engine load (given in Table B.2.2)

Table B.2.2: ISO ambient correction coefficients

Engine load - %	C1	C2	C3
100	-0.00994	0.00144	-0.00007
75, 50 and 25	-0.00505	0.00145	-0.00011

H_a can be calculated the following way:

11. $$H_a^* = \frac{6.220 \cdot R_a \cdot p_a}{p_b - p_a \cdot R_a \cdot 10^{-2}}$$

12. $$H_{sc} = \frac{6.220 \cdot p_{sc} \cdot 100}{p_c - p_{sc}}$$

13. If $H^*_a \geq H_{sc}$ then $H_a = H_{sc}$ else $H_a = H^*_a$

where:
- H^*_a water content at ambient-air condition (gH2O/kg dry air)
- R_a relative humidity of intake air (rel.%)
- p_a saturation vapour pressure at ambient-air condition (kPa)
- p_b total barometric pressure (kPa)
- H_{sc} water content at scavenging-air condition (gH2O/kg dry air)
- p_c scavenging-air pressure (kPa)
- p_{sc} saturation vapour pressure at scavenging-air condition (kPa)

The saturation vapour pressure is only a function of temperature and can be calculated the following way:

14. $$p = 1.013 \cdot e^{19.008 - \frac{5325.35}{T}}$$

where T is the temperature in Kelvin (K).

The ISO corrected NOx value is calculated using the equation for the average weighed NOx emission (IMONOx) given in the 'IMO-NOx Technical Code:'

15. $$IMONOx = \frac{\sum_{i=1}^{i=n} Specific\_emission(i) \cdot Power(i) \cdot WF(i)}{\sum_{i=1}^{i=n} Power(i) \cdot WF(i)}$$

where n=4 represents the 4 load points of the E3/E2 cycle (please refer to the 'IMO-NOx Technical Code' for definition of E3/E2.) Using the weight factor (WF), the power (in kW) and the specific NOx emission (in g/kWh) for the 4 load points, the equation can also be written as Equation (16). However, for Equation (16) to be valid, the load points of the E3/E2 cycle must correspond exactly to 100, 75, 50 and 25% of MCR.

16. $$IMONOx = 0.2909 \cdot NO_x(100\%) + 0.5455 \cdot NO_x(75\%) + 0.1091 \cdot NO_x(50\%) + 0.0545 \cdot NO_x(25\%)$$

4.5 Correction to reference performance conditions

The NOx function has also been used to derive a simplified method to calculate the variation in the ISO corrected NOx value as function of maximum cylinder pressure, scavenging-air temperature and turbine back pressure. The relative changes are shown in Table B.2.3 at the four specific cycle-load conditions. *However, the simplified method will predict a slightly higher NOx emission than the NOx function.*

Table B.2.3: Relative changes in NOx for Pmax, Tscav and Pturb.back

Power (%)	ΔNOx, Pmax [1)] (gNOx/kWh pr. bar)	ΔNOx, Tscav [2)] (gNOx/kWh pr. deg.C)	ΔNOx, Pturb.back [3)] (gNOx/kWh pr. mmWC)
100	0.1816	0.0224	0.0004
75	0.1760	0.0209	0.0006
50	0.1760	0.0209	0.0006
25	0.1760	0.0209	0.0006

1. Relative increase in NOx value (corrected to ISO ambient conditions) resulting from a one bar increase in the cylinder maximum pressure.
2. Relative increase in NOx value (corrected to ISO ambient conditions) resulting from a one degree increase in the scavenging-air temperature.
3. Relative increase in NOx value (corrected to ISO ambient conditions) resulting from a one mmWC increase in the turbine back pressure.

5. MAN B&W survey procedures

MAN B&W has defined a combination of performance parameter checks and, component and setting verification as the *on-board survey method*. TF Fig. 1 shows a flow chart of the on-board survey procedures only, whereas Fig. B.1 also shows the applications for test-bed and sea-trial surveys.

On board, the 'on-board 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, VIT, compression shims and exhaust-valve timing, through the scavenging-air temperature: a deteriorated scavenging-air cooler performance, and through the back pressure: eventually blocking up of the exhaust heat exchanger.

5.1 On-board survey code

The on-board survey (parameter check) can be performed using the manufacturer supplied survey code as an easy tool to calculate and present the expected NOx emission. If a computer is not available, a manual evaluation can be performed following Section B.3.2. The procedure is based on a 'standard MAN B&W performance check' (see necessary parameters in Table B.2.1 and the comments in TF Chapter 1.4.)

Two versions of the code exist. The 'on-board' version is used as the standard survey method on board. And, the 'test-bed' version, a more detailed version, is used to show compliance on test bed for member engines. As described in Chapter B.2, the on-board version differs slightly for a sea-water and a central cooling-water system and, for an engine without VIT or with VIT.

To perform the survey, the following steps are to be taken (see flow Chart Fig. 1 or Fig. B.1,) independent of the survey-code version:

a. Inspect 'Technical File' (TF) and 'record book' *(or pre-TF on test bed.)*
b. Perform a 'performance check' *(the extend follows the survey-code requirement) (for a load* estimate see B.2.1.3.)
c. Estimate NOx for verifying compliance using the dedicated 'survey code.'
d. Check fuel nozzle *(a spare fuel nozzle may suffice.)*
e. Check other NOx components on test bed or in dock *(or if considered necessary.)*
f. Check setting adjustments on test bed or in dock *(or if considered necessary.)*
g. Add output from the survey code to the 'record book.'

The Tables in Enclosure 1 show input and output from the survey code based on the parent engine test-bed data, as an example. The actual estimated NOx will be compared in the plot with the measured (and corrected) parent engine data.

5.2 Manual procedure

All the steps in Section B.3.1 are followed except for execution of the survey code (B.3.1.c.)

To evaluate manually the NOx compliance, the following two steps have to be performed:

a. Evaluate the performance influence on the ISO corrected NOx values for each load condition (as specified in Chapter B.2 or in the following example in Section B.3.4 based on the parent engine data.) Performance data are corrected manually using Equations (7) to (9) in B.2.3.1 (or from Charts in the instruction book specified in foot notes **) to TF Chapter 1.4 Comments.)

b. Calculate the final average IMO NOx (Equations (15) or (16).)

5.3 Comments on component checks

The actual NOx components are specified in TF Chapter 1.1 (or in Enclosure 1, the last output page from the survey code,) and Appendix A specifies the necessary verification procedures. The extend of the component verification is discussed above.

Turbocharger, air cooler and auxiliary blower are verified through their nameplates *(also included in Appendix A.)* To verify the turbochargers internal parts (marked by the turbocharger manufacturer) dismantling is necessary (*procedures are not included.*)

To verify the setting values, a performance check has to be performed using the on-board survey code (as described in the previous Section B.3.1.) When the specified performance data (see Table 1.3) 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 1.1 are allowed) a review of the record book would normally be sufficient. Although a standard performance check will reveal changes to many NOx 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 NOx 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.

5.4 Survey example

Details of the NOx estimate to verify compliance for a <u>test-bed survey using a test-bed cooling-water system</u> are described in this Chapter as an example. The earlier Chapters describe modifications necessary for the slightly different survey cases.

The NOx emission can be estimated at each load conditions using the following calculation method:

1. Measure the maximum pressure, scavenging-air temperature, turbine back pressure and ambient conditions (see example in Table B.3.1) at the required load points.
2. Correct maximum pressure to ISO conditions using Equation (7).
3. Derive the equivalent relative change in NOx emission (g/kWh) using Table B.2.3 based on the actual performance in step 1 and reference conditions in TF Table 1.3.

Table B.3.1: Calculation of expected NOx ‘at site’ performance and ISO ambient condition – test bed cooling-water system *(example only – identical to the results in Enclosure 1)*

Power (%)	Meas-ured max. pressure (barabs)	Relative change in NOx (g/kWh)	Meas.‘sea-water’ temp. (deg.C)	Meas. scav.air temp. (deg.C)	Relative change in NOx (g/kWh)	Meas.turbback pressure (mmWC)	Relative change in NOx (g/kWh)	Expected site ISO-NOx (g/kWh)
100	*148.8*	*-0.400*	*29*	*41*	*0.090*	*230*	*-0.028*	*13.83*
75	*130.7*	*-0.232*	*27*	*33*	*0.021*	*121*	*-0.035*	*14.70*
50	*99.3*	*-0.300*	*26*	*29*	*0.021*	*63*	*-0.014*	*12.32*
25	*70.8*	*-0.215*	*25*	*32*	*-0.021*	*19*	*-0.003*	*12.56*
E3 cycle value								*14.07*

Example of calculation for 100% engine load and test bed cooling (the approach is similar for the other load conditions:)

Measured scavenging-air temperature	(Table B.3.1)	*41*	deg.C
Reference scavenging-air temperature	(TF Table 1.3)	*37*	deg.C
Measured ‘sea-water’ inlet temperature	(Table B.3.1)	*29*	deg.C
‘Sea-water’ reference temperature	(TF Table 1.3)	*25*	deg.C
Relative scavenging-air temperature change= *Tmeas.scav.air – Tref.scav. air *)*	*= 41 – 37 =*	*4*	deg.C
Delta NOx, Tscav	(Table B.2.3)	0.0224	g/kWh pr. deg.C
Relative change in NOx due to Tscav difference	*4 * 0.0224 =*	*0.090*	g/kWh
Measured maximum pressure	(Table B.3.1)	*148.8*	barabs
Reference maximum pressure	(TF Table 1.3)	*151*	barabs
Difference (measured – reference)		*-2.2*	barabs
Delta NOx, Pmax	(Table B.2.3)	0.1816	g/kWh pr. barabs

Relative change in NOx due to Pmax difference	*-2.2 * 0.1816 =*	*-0.400*	g/kWh
Measured turbine back pressure	(Table B.3.1)	*230*	mmWC
Reference turbine back pressure	(TF Table 1.3)	*300*	mmWC
Difference (measured – reference)	*230 – 300 =*	*-70*	mmWC
Delta NOx, Pturb.back	(Table B.2.3)	0.0004	g/kWh pr. mmWC
Relative change in NOx due to Pturb.back difference	*-70 * 0.0004 =*	-0.0280	g/kWh
Measured NOx, corr. ISO ambient and ref. performance	(TF Table 4.2.2)	14.17	g/kWh
NOx value, at ISO ambient and reference site conditions	*14.17 + 0.090 – 0.400 – 0.028 =*	13.83	g/kWh

*) Remember to change to the actual cooling-water system for on-board surveys

4. Estimate the expected NOx emission at measured site performance but ISO ambient conditions for each load condition as a summation of the ISO corrected NOx value and the relative changes (see last column in Table B.3.1) using Equation (16) to verify compliance.

IMONOx = 0.2909* *13.83* + 0.5455* *14.70* + 0.1091* *12.32* + 0.0545* *12.56* = **14.07 g/kWh**

This method is used to check NOx compliance for varying measured values of maximum pressure, scavenging-air temperature and turbine back pressure. Since the maximum IMO-NOx value for this engine group is *15.1 g/kWh,* the engine fulfils the requirements. This is of course equivalent to the performance parameters being within the specified tolerances.

It should be emphasized that the survey code, unlike this example, uses Equation (15) (i.e. the measured load-point powers) to calculate the simulated NOx emission. And, the survey code will issue a warning, if the performance parameters are outside the allowed ranges, or the load point is more than ±5% off the ideal E3/E2 cycle value.

Performance check:
1) 4 load points (E2/E3 cycle)
2) For engines with VIT: 75% load and one load point above the break point. Without only the 75% load point.

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702-01 Checks during Standstill Periods

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 *Chapter 706, '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 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 *Chapter 703.*

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 Vol. II Introduction 'Checking and Maintenance Programme'.

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.

Check 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 also Section 708-01.*

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.

! *After a major overhaul of pistons, bearings, etc.,*
this check 2.1 should be repeated before starting the engine.

Check 2.2: Oil Pan, and Bearing Clearances

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 *Section 708-01.*

Check 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.

Check 2.4: Scavenge Port Inspection

Inspect the condition of the piston rings, cylinder liners, pistons, and piston rods, as detailed in *Section 707-01.*

Note down the conditions as described in *Section 707-01.*

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).

Check 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.

Check 2.6: Crankshaft

Take deflection measurements as described in *Section 708-02.*

Check 2.7: Circulating Oil Samples

Take an oil sample and send it to a laboratory for analysis and comments.
(See Section 708-04).

Check 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 also Check 4.4 regarding precautions to avoid turbocharger bearing damage during engine standstill.*

Check 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 double wall pipes and alarm function.
10. Visual inspection of the inside of the electronic boxes and check of the tightening torque of the terminals

The tests are performed in the following way:

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 (the pilot valves are seen on Plate 70318 "Diagram of Manoeuvring System" pos. 30 and 32) one by one via the MOP (Screen: Engine Status Plate 70325) and confirm that the main start valve opens. (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 Plate 70324), 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 HPS Plate 70329)	
5	Every 6 month	Engine stopped. MOP Access level = Chief HPS Mode must be = manual Start-up pumps running.	Open manual connection valve 316 (P1-P2) **NOTE: Valve 316 must be closed after the test is completed.** At the MOP (Screen: Auxiliaries HPS), open Pump Bypass from ACU1 At the MOP, close Pump Bypass from ACU1 At the MOP, open Pump Bypass from ACU3 At the MOP, close Pump Bypass from ACU3	Pressure drops towards zero Pressure increases to 230 bar Pressure drops towards zero 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. (Screen: Alarms Alarm List Plate 70320)	
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 Lubricators Plate 70331) the Lubricator Test Sequence for all cylinders. **NOTE: Lubricator Test Sequence must be <u>All Off</u> when checked**	Cylinder lube oil alarm for all cylinders. Slow Down request activated
8	Every 6 month		See Procedure M90622-xxxx and Datasheet D10622-xxxx for detailed test. (version number relates to procedure/datasheet in VOL 2 maintenance and is engine specific)	
9	Every 6 Month		See Procedure M90622-xxxx and Datasheet D10622-xxxx for detailed test. (version number relates to procedure/datasheet in VOL 2 maintenance and is engine specific)	
10		Engine stopped	As described above. See chapter 701-01 Safety Precautions this book regarding general cleanliness, order and tidiness.	

3. Checks at Engine Standstill during Repairs

Check 3.1: Bolts, Studs and Nuts

Check all bolts, studs and nuts in the crankcase 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 also Vol. II 'Maintenance', Procedure 912. Check all locking devices.*

Check 3.2: Leakages and Drains
Remedy any water or oil leakages. Clean drain and vent pipes of possible blockages by blowing-through.

Check 3.3: Pneumatic Valves in the Control Air System
Clean the filters.

Check 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.

4. Checks at Engine Standstill after Repairs

If repair or alignment of bearings, crankshaft or pistons has been carried out, repeat Checks 2.1, 2.2 and 2.6.

Check 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 *Chapter 708*.
Continue the flushing until all dirt is removed.

Check 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.

Check 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.

! *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 also Section 703-01.

Check 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.

Check 4.5: Cylinder Lubricators
Check that all pipe connections and valves are tight.

Press the ‘pre-lubrication’ button on the HMI panel 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.

Check 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.

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PLATES

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General:

The following descriptions cover the standard manoeuvring system for the 50-108ME/ME-C engines.

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 Section 705-03 regarding correct fuel oil temperature before starting.

Regarding checks to be made before starting, when cylinders are out of operation, see Section 704-04.

1. Air Systems

- Drain water, if any, from the starting air system. *See also Plate 70304.*
- Drain water, if any, from the control air system at the receivers.
- Pressurise the air systems. Check the pressures. *See also Section 701-01.*
- Pressurise the air system to the pneumatic exhaust valves.

! Air pressure must be applied **before** the lube oil pump is started. This is to prevent the exhaust valves from opening too much. *See also Section 702-01.*

The exhaust valve activation is controlled by the On/Off ELVA 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 the exhaust valve is open or closed. The exhaust valve must be closed.

2. Lube Oil Systems

1. Start the lube oil pumps for:
   - 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 also Section 701-01.*

2. Check the oil flow, through the sight-glasses, for:
   - Piston cooling oil
   - Turbochargers
3. Check that the cylinder lubricator tank is filled with the correct type of oil. *See also Plate 70713.*

> ! *Is the regulating handle put on STAND-BY, the ECS automatically initiates a prelubrication sequence, from the cylinder lubricators. When the MOP is set in PREPARE START mode the auxiliary blowers and the cylinder prelubrication is started.*

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 also Sections 703-03 and 703-07.*

- Start the cooling water pumps.
- Check the pressures. *See also Section 701-01.*

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.

> ! *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.
   Check that the indicator lamp for TURNING GEAR DISENGAGED extinguishes.
2. Regulating handle is put 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 position during running.
   - The locking plate must remain in the lower position during repairs.
4. Open the indicator valves.
5. Turn the slow-turning switch to SLOW-TURNING position.
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 moved one revolution, move the handle back to STAND-BY position.
8. Turn the slow-turning switch back to NORMAL position.
9. Close the indicator valves.

4.2 Slow-turn with Turning Gear

1. Regulating handle must be in FINISHED WITH ENGINE state.
2. Open the indicator valves.
3. Turn the engine one revolution with the turning gear in the direction indicated by the regulating handle. Check to see if fluid flows out of any of the indicator valves.
4. Close the indicator valves.
5. Disengage the turning gear.
6. Check that it is locked in the out position. Check that the indicator lamp for TURNING GEAR ENGAGED extinguishes. This is seen on the MOP-panel in the control room.

5. Fuel Oil System

Regarding fuel oil temp. before starting, see Section 705-03.

- 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 also Section 701-01.

6. Hydraulic System. HPS – Hydraulic Power Supply

- Start the electrical driven hydraulic pumps. This is done via the MOP in the control room. The ECS states if the oil pressure is correct.

7. Miscellaneous

Check that all drain valves from scavenge air receiver and boxes to drain tank are open and that test cocks are closed. *See Plate 70402.*

1. Starting

Start the engine as described in MOP description *Section 703-09*.

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-trial.*
2. *The moorings are sufficient.*
3. *A watch is kept on the bridge.*

2. Starting Difficulties

Starting Difficulties *– See also Item 3, 'Supplementary Comments'*

Difficulty	Point	Possible Cause	Remedy
Engine fails to turn on starting air after START order has been given. **Points marked with ★ is all monitored by the ECS and an error report occurs.**	★1	Shut-off valve for solenoid valves is closed	Open the valve.
	★2	Pressure in starting air receiver too low	Start the compressors. Check that they are working properly.
	★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 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 also Section 703-07.*

Starting Difficulties *(Continued) – See also Item 3, 'Supplementary Comments'*

Difficulty	Point	Possible Cause	Remedy
Engine does not reverse when order is given. Engine turns too slowly (or unevenly) on starting air	9	Propeller blades are not in zero-pitch (CPP-plants)	Set pitch to zero position.
	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)	*See the 'Bridge Control' instructions.*
	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	Shut-down of engine (no rotation present)	Check pressure and temperature. Reset 'shut-down
	★16	Fuel pumps sticking	Check fuel pumps.
	★17	NC valves not functioning	Check NC valves.
	★18	Fuel pressure missing (an error is reported in the ECS)	Check fuel pressure.
Engine turns on fuel, but runs unevenly (unstable) and will not pick-up rpm	★19	Auxiliary blowers not functioning	1. Stop the engine 2. Start the auxiliary blowers for 10 min. 3. Slow-turn the engine by air 4. Start the engine.
	★20	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 seatrial observations.
	21	Fuel filter blocked	Clean the filter.
	★22	Too low fuel pressure	Increase the pressure.
	★23	One or more cylinders not firing	Check suction valves in fuel pumps. See MOP- panel description. If fault not found, check/change fuel valves.

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 2
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 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 *Section 703-07*. 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 4
Examine whether there is voltage on the solenoid valve which controls the starting signal.

If the solenoid valve is correctly activated, 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 15.

Point 15
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**:

! *The start/stop logic in the ECS has already, before start, checked that the direction of rotation is corresponding to the telegraph order.*

An alive signal from the ELVA valves to the ECS states whether the exhausts valves are operating correctly. If an error occurs an alarm will occur.

Check 1: Turbochargers
Ensure that all turbochargers are running.

Check 2: Circulating Oil

Check that the pressure and discharge are in order (main engine and turbochargers).

Check 3: Cylinders

Check that all cylinders are firing.

Check 4: Starting Valves on Cylinder Covers

Feel over the pipes. A hot pipe indicates leaking starting valve.
See also Vol. III, Chapter 911, 'Safety Cap in Starting Air Line'

Check 5: 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 and safety air.

Check 6: Cylinder Lubricators

! *Make sure that all lubricators are working by checking the feedback LED's on the intermediate boxes.*
Check the oil level in the feeder tank.
Follow the Alpha lubricator manual for checking and adjustment of the oil feed rate.

1. Loading Sequence

Regarding load restrictions after repairs and during running-in, see Item 2.

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.
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.
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. *See also Section 703-01.*

2. Checks during Loading

Check 7: 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.

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 this procedure also mentioned in *Section 702-01*: "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".
See also Section 704-02.

Check 8: 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 Section 703-04.* Regarding liners/rings: *See Section 707-01.*

1. Running Difficulties

Running Difficulties – *See also Item 2. 'Supplementary Comments'*

Difficulty	Point	Possible Cause	Remedy
Exhaust temperature rises **a) all cyl.**	1	Increased scavenge air temperature owing to inadequate air cooler function.	*See Section 706-02.*
★)	2	Fouled air and gas passages.	Clean the turbine by means of dry cleaning/water washing. Clean the blowers and air coolers, *see Section 706-03.* 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.	*See Sections 705-01 and 705-03.*
b) single cyl.	4	Defective fuel valves, or fuel nozzles.	★)
	5	Leaking exhaust valve	Replace or overhaul the valve.★)
	6	Blow-by in combustion chamber.	★)
Exhaust temperature decreases. **a) all cyl.**	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.
b) single cyl.	9	Defective fuel oil pressure booster suction valve.	Repair the suction valve.
	10	Fuel oil pressure booster plunger sticking or leaking. (an alarm will occur in the ECS)	Replace the fuel oil pressure booster plunger/barrel.
★ *See Section 706-02 in particular the fault diagnosing table.*			

Running Difficulties *(Continued) – See also Item 2. 'Supplementary Comments'*

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.	*See point 8.*
	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.	*See Section 706-01.*
	16	Water in fuel oil.	Drain off the water and/or clean the fuel more effectively.
	17	Fire in scavenge air box.	*See Chapter 704.*
	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 pump index. Fuel index (MEP%) must be rectified with the fuel quality, so that correct MEP can be obtained.
	20	Fouling of hull. Sailing in shallow water.	*See Section 706-01.*
Smoky exhaust	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.	*See reference quoted under point 1.* Check engine room ventilation.
	23	Defective fuel valves (incl. nozzles).	*See point 4, and Section 706-05, (incl. Plate 70618).*
	24	Fire in scavenge air box.	*See Chapter 704.*

2. Supplementary Comments

Item 1. '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 Section 704-04.*

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 also Section 707-01.*

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_{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, section 703-15.*

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 also Section 704-01.*

In case of severe 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 Chapter 707*, 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 oil pressure 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 plunger edge shows a dark-coloured eroded area, the fuel oil pressure booster plunger/barrel should be replaced.

3. Check during Running

Check 9: Thrust Bearing
Check measuring equipment.

Check 10: Chain Tighteners (if installed)
Check the chain tighteners for the moment compensators (if installed). The combined chain tighteners and hydraulic damping arrangements should be readjusted, when the red-coloured part of the wear indicators is reached. *See Vol. II, Maintenance, Chapter 906.*

Check 11: Shut Down and Slow Down
Check measuring equipment.

Check 12: 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 13: Temperature Alarms (Thermostats)
See also Check 12, '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 14: 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 15: Observations
Make a full set of observations, by means of the PMI-system, *see Plate 70603 and Section 706-04.* Check that pressures and temperatures are in order.

Check the load distribution between the cylinders, *see Section 706-02.*

See Section 707-01 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 also Section 705-03.*

   Change-over should be carried out **one hour** before the first manoeuvres are expected. *See Section 705-03.*

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 are working.*

4. Blow-off any condensed water from the starting air and control air systems just before the manoeuvres.

Always perform a stop manoeuvre before entering harbour/pilot at arrival, to state that the ECS is functioning as intended.

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.

     This 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 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. *The circulating oil temperature may be reduced during engine standstill, as described in Section 705-03.* ! *Cold heavy fuel oil is difficult or even impossible to pump*
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. *However, see Sections 706-01 and 706-03.*
NO	• Keep the engine preheated to minimum 50°C. *This counteracts corrosive attack on the cylinder liners during starting-up.* • Use a built-in preheater or the auxiliary engine cooling water for preheating of the engine. *See also Section 709-01.*

7. Switch-off other equipment which need not operate during engine standstill.
8. Regarding checks to be carried out during engine standstill, *see Chapter 702.*

1. General

The Engine Control System (ECS) consists of a set of controllers, *see Plate 70317.*

Briefly described, the functions of the controllers are:

EICU The Engine Interface Control Units handle the interface to external systems.

ECU The Engine Control Units perform the engine control functions: engine speed, running modes and start sequence.

ACU The Auxiliary Control Units control the pumps of the hydraulic system unit and the auxiliary blowers.

CCU The Cylinder Control Units control the FIVA valves, starting air valves, and the ME cylinder lubricators.

MOP The engineers' interface to the ECS.

Normal Working Sequence

The following is an example of how the control units of the ECS work together during normal operation.

EICU

The EICUs receive navigational inputs from the control stations and select 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.

ECU

The engine speed control 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 tacho 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.

CCU

In appropriate time for the next firing, the CCU ensures that it has received new valid data. Where after the injection profile start angle is set up using the tacho function.

On the correct start angle the injection is initiated and is controlled according to the fuel amount command and the injection profile command.

When the injection is completed, the exhaust open and close angles are set up using the tacho function and 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. (Running with cylinders out of operation is explained in Chapter 704-04 in this book).

ACU

The ACUs 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 among three (four) ACUs so that, in the event of a failure of one unit, there is sufficient redundancy to permit continuous operation of the engine.

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 over the Control Network. However, the running of the engine is not dependant on the MOP, as all the commands from the local control stations 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 is also placed in the engine control room *(see Section 703-09 for detailed MOP-description).*

Control Stations

During normal operation the engine can be controlled from either the bridge, the engine control room or the Local Operation Panel (LOP).

The LOP control is to be considered as a substitute for the previous Engine Side Control console mounted directly onto the MC-engine.

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.

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 Operation 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.

Main engine start with stopped or running auxiliary blowers:

1. **Activate start**
2. **If the engine do not start within 30 seconds, return to stop command and activate start again.**

If the auxiliary blowers are running, the first start activation will probably cause the Engine Control System to start the main engine automatically.

If the auxiliary blowers are stopped, the first start activation will cause the Engine Control System to prepare start. During start preparation the auxiliary blowers are started and, if necessary, the hydraulic system is started in order to rebuild the hydraulic high-pressure. When the auxiliary blowers are started and running, the second start activation will probably cause automatic start of the main engine.

Please note, after a shut-down the hydraulic pressure must be rebuilt to a level (approximately 140 bar) where operation of the fuel injection and exhaust valves are possible before the automatic main engine start itself can take place. This pressure rebuild may last 60-120 seconds.

1. Main Operation Panel (MOP) (Overview)

The MOP is the Human Machine Interface (HMI), through which the Engine Control System (ECS) and thus the ME engine is operated. The HMI is described in sections 703-14 through 703-18.

The MOP is basically a marine approved and certified PC. The PC may be one of two types:

1. An integrated unit with touch-screen.
2. A standard PC

An actual installation comprises of two MOPs (type 1 is usually used for MOP A and type 2 for MOP B) where both are placed in the engine control room (ECR). Each MOP may be any of the two types; typically MOP A is placed in a console opposite the manouvring handle (the normal operation position) and MOP B on a desk (as a backup MOP). The two MOPs are operationally fully redundant to each other.

1.1 MOP A

1.1.1 Description

This MOP type has no ordinary keyboard or mouse. Both may optionally be equipped; a trackball typically replaces the mouse.

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.

The touch-screen is a frame in which an infrared grid is used for detecting touches to the screen. The operator does not need to actually touch the screen as the grid is displaced from the screen surface.

Instead of traditional use of a mouse, the operator touches the graphic elements on the screen in order to interact with the ECS.

1.1.2 Service kit

The MOP comes with a service kit. The kit comprises of a CD-ROM drive, a keyboard and a CD with the operating system, and is setup specifically for this PC-type. The CD-ROM drive and keyboard should not be connected during normal operation.

1.2 MOP B

1.2.1 Description

This MOP type is based on standard PC technology, and with a keyboard, mouse and CD-ROM drive.

1.2.2 Service Kit

The kit comprises a CD with the operating system and is setup specifically for this PC-type *(see Section 1.5)*

1.3 Issues to both MOP types

1.3.1 Ethernet connections

Only MOP B may be equipped with an Ethernet card for 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. Connection to other systems is illustrated on plate **70319 fig 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 disclamer, 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 that interconnect the nodes in the ECS. Control Network is implemented as two independent networks for redundancy as shown on Plate **70319 Fig. 1**

1.3.4 Maintenance

Normal PC maintenance tools and cleaning detergents apply.

1.4 Preparations made by MAN Diesel

The CD's mentioned in Sections 1.1.2 and 1.2.2 are a part of a CD set installed on the MOPs on the ECS at engine commissioning. This CD set (normally four) is kept onboard as back-up.

The commissioning procedure is as follows.

An engineer from MAN Diesel or the Licensee installs the CD's in the following way:

1. Program Disc 1 named:

   > Disc 1 of 3 < Operating System Main Operation Panel > A <

   is installed in MOP A (via the connected CD-ROM drive).

2. Program Disc 2 named:

   > Disc 2 of 3 < Operating System Main Operation Panel > B <

   is installed in MOP B (the standard PC).

3. Program Disc 3 named:

   > Disc 3 of 3 < Engine Control System Main Operation Panel > A and B <

   is the ME-System Software, installed on both MOP A and B.

4. Data Disc named:

   > Service Parameter Set <

   The parameter is loaded to the MPC's via MOP B.

After Sea Trial a copy of the > Service parameters < is stored on board.

1. HMI (Human Machine Interface)

The HMI consists of four fixed areas always shown. *See Plate 70319 Fig. 2*

1. An Alarm Status Bar showing the oldest non-Acknowledged 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)

The HMI operates with two user levels, which are Operator level and Chief level.

- Operator level: From the Operator level it is not allowed to set any parameters. It is for normal operation and monitoring only.
- Chief level: in addition to the Operator level, the operator has privileges to set parameters. 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. The password is to be thought of as an aid to the operator, in order to prevent unintended input to the ECS.

2. Alarm System

The alarms displayed on the MOP panel are all related to the ME Engine Control System and thereby surveillance of the engine condition. As seen on Plate 70319 Fig. 1, the ordinary alarm system and the ME-ECS alarm system are connected and able to interact. This is caused by the use of common sensors for engine monitoring, i.e. common sensors are used for indicating and detecting alarm as well as slow down.

Especially alarms interacting with the engine safety system are common for the Engine Control System and the ordinary alarm system. As an example could be mentioned alarms giving Slow Down and Shut Down.

When a Slow Down has been detected by the external Slow Down function, this is signalled to the ECS by a binary signal. When the binary signal is high, the resulting speed set point is forced to the preset Slow Down level.

3. Alarm Handling

Alarm handling is carried out from one of the following four screens

1.1 Alarm List

1.2 Event Log

1.3 Manual Cut-Out List

1.4 Channel List

These four Alarm Handling screens can be accessed via the secondary navigator by pressing the “ALARM” 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 Plate 70320)*

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. 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 seen on the Toolbar at the bottom of the Screen.

Alarms presented in the alarmlist can be found in three states:

1. Alarm non acknowledged
2. Alarm acknowledged
3. Normal non acknowledged

An alarm can only appear as one line in the alarm list. An acknowledged alarm going into normal or an alarm changed to normal being acknowledged, is immediately removed from the list.

Acknowledgement of a single or all alarms is allowed on both levels (operator or chief) from the “Ack/Ack All” buttons on the toolbar at the bottom of the screen. (By pressing “Ack/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 dotted line, and giving the impression that a “light is switched on behind the field. By pressing the button “Info” on the Toolbar, a window will appear just above the Toolbar. This window contains:

Description – Cause – Effect - Suggested Action of the alarm, so that 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 Plate 70320)*

Each alarm line is divided into the following fields:

ID. This field contains a unique alarm identity. (e.g. CCU1_031220). 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. (13:47:02.56)

Description. This field contains the alarm text.
(e.g. HCU oil leakage)

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

Limit. This feature is not available in this software version.

Current. This feature is not available in this software version.

Ack. The acknowledgement status field of non-acknowledged alarms contains an icon toggling between two states, alerting the operator of a non-acknowledged 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

Alarm Status	Acknowledge Status	Background Colour	Acknowledgement Field Graphics
Alarm	Non-Acknowledged	RED	
Alarm	Acknowledgement in progress	YELLOW	
Alarm	Acknowledged	YELLOW	
Non-Alarm	Non-Acknowledged	GREEN	
Non-Alarm	Acknowledgement in progress	GREEN	
Cut-Out Not Available	Non-Acknowledged previous alarm	LIGHT GREY	
Cut-Out Not Available	Acknowledgement of previous Alarm in progress	LIGHT GREY	

At the upper right corner of the screen four (4) small icons are shown which are (from left to right):

A triangle (red) with a number = Number of Non-Acknowledged alarms

A triangle (yellow) with a number = Acknowledged alarms

A triangle (yellow) with a number = Number of Manual Cut-Out alarms

A square (yellow) with a number = Number of Input Channels Cut-Out.

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.

3.2 Event Log *(See Plate 70321)*

The event log is, for instance, 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 and Filtering Event Log Records.

When using the Event Log to help analysing an event, different search and filter facilities are available to narrow the search. Explaining in brief, the facilities are (one button for each):

Go to Date/Time:
This feature is used to scroll the list to a certain date and time, when the specific Date or Date/Time is known.

When pressing the Go to Date/Time button an on-screen keyboard occurs with two button/fields for Date and Time respectively. Press the button to be specified and enter the value. The Date field is obligatory, while the Time field is optional. Press “Apply” to execute the search. The selection will be the first event after the specified date (and time).

The scroll buttons on the physical keyboard can be used afterwards to scroll line by line, in order to make the search even more specific.

Time Span Filter:
This feature can be used if only a part of the list is interesting, e.g if a certain range of the Event Log list is to be printed or exported for e.g trouble shooting assistance at MAN Diesel.

Enter the From/To Date and time in the Time Span Filter toolbar by using the on-screen keyboard. If only the From Date is entered, the To Date is automatically set to the current date. Also if only the To Date is entered, the From Date is automatically set to 1900-01-01. From Time/To Time is optional. Press “Apply” to execute the selection.

The time entered MUST be UTC time.

Unit/Tag Filter:
When an alarm occurs, it is stored in the Event Log by its ID (Unit/Tag number). It is possible to filter for a specific cause of event or a group of events by pressing the Unit/Tag Filter button, e.g if one wants to see how often a specific event occurs or if e.g only events related to a specific unit are interesting.

Three Criteria buttons (filter buttons) occur in the on-screen keyboard to define the filter:

Unit: The Unit name, e.g CCU.

Index: The Unit number, e.g CCU1 (only available if a Unit has been entered).

Tag: The alarm tag name, e.g 031220

The fields are all optional. Fields that are not filled in, means ‘any text’. Press “Apply” to execute the search and filtering.

Export:
This button is used when saving the displayed Event Log Record on a USB mamory stick, on the hard disk drive (HDD) or when printing a hard copy of the displayed data - see next section.

3.2.2. Saving Event Log Records.

Printing:
If a printer is connected to the MOP B hub, printing the displayed data is possible.

1. Press the Export button.

2. Press Print on the pop-up screen.

To limit the amount of lines being printed, see *Time Span Filter.*

For trouble shooting purposes, MAN Diesel may request an Event Log Record. The Event Log Record can be stored as a compressed file (.zip) on a USB memory Stick or on the hard disk drive (HDD), by the engine crew. The .zip file is then to be sent by e-mail from the ship's ordinary PC to MAN Diesel.

Save to USB Memory Stick:
This is most likely the option to use if MAN Diesel requests an Event Log Record for trouble shooting purposes.

1. Insert the USB memory stick into MOP-B.

2. On the Event Log screen, press the Export button and the Export Event Log tool bar shows up. Destination field will read USB.

3. On the Event Log tool bar, press the Save button.

4. When the saving is finished, the destination field will read SAVED and the USB memory stick can be removed.

The data displayed on the Event Log screen, is now stored on the USB memory stick. The output will be a comma separated file with the name: **EventLog<date, time>.zip.**

To limit the file size to be exported see *Time Span Filter.*

Save to Hard disk:
If a USB memory stick is not available, the Event Log data can be saved onto the Hard disk.

1. On the Event Log screen, press the Export button and the Export Event Log tool bar shows up. Destination field will read HDD, as no USB memory stick is plugged in.

2. On the Export Event Log tool bar, press the Save button.

3. When the saving is finished, the destination field will read SAVED. The data displayed on the Event Log screen, is now stored on HDD.

The output will be a comma separated file with the name: **EventLog<date, time>.zip.**

To limit the file size to be exported, see *Time Span Filter.*

Dump:
Dump and Save have the same functionality, except for the actual output i.e when the Dump button is pressed, the displayed Event Log is saved to the location shown in the Destination field. The data however, will be saved as an SQL script and compressed to a .zip file. The file name will be: **EventLogDump <date, time>.zip.**

<Date, Time> is the current UTC time when the file was saved.

3.3 Manual Cut-Out List *(See Plate 70322)*

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 in the parenthesis) 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 may be cut-out automatically. Automatic cut-out may be used to suppress alarms which is unimportant in specific states, e.g. when the engine is stopped, or when a sensor is detected as being faulty).

The manually cut-out alarms are shown in a separate list, which can be accessed from the navigation bar. The manual cut-out screen is in functionality equivalent to the alarm 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 screen.

Removing (“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.

3.4 Channel List *(See Plate 70323)*

The alarm channel 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 alarm channel screen, it is possible to cut out (and 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 Cylinder Load

1.5 Cylinder Pressure

Screens 1.1 and 1.2 are related to engine start-up preparations and daily running, and 1.3, 1.4 and 1.5 relate 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 Plate 70324)*

Operation is the main screen for control of the engine during voyage. This screen is active most of the time between “Engine ready” and FWE (Finished With Engine).

On this screen, “prepare start” and “slow turn” can be performed before start of the engine.

Plate 70324 shows the full screen. In the following, a detailed description of the individual fields will be given.

1.1.1 Main State

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 (background yellow: if top field is in FWE condition)
- Engine not ready (background yellow: if top field is in STAND-BY or AT SEA CONDITION

The cause of the states “Engine not blocked” or “Engine not ready” can be seen in the Status screen, Plate 70325, in the field Start Conditions.

The bottom field indicates, via yellow or red warnings, why the engine is not ready:

- (Blank) (engine is ready)
- Increased limiter (yellow) is shown when active, and engine status is not FWE, and neither Start Blocked or Shut down status is active. Increased limiter 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-comb., ECR-sep. 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 Comb. 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.

1.1.2.1 RPM Fine Adjust

By pressing the Command [RPM] button, 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 119.5 RPM, it can be fine adjusted to 120 RPM. Moving the handle will disable the fine adjustment mode. Maximum fine adjustable speed is +/- 2 RPM.

Note: RPM fine adjustment can only be performed in ECR Command mode (ECR Sep with CPP).

1.1.3 Running Mode and Governor Mode

The engine running mode and governor mode buttons each contains a status field indicating the current active running and governor modes.

The running mode can be either Economy or Emission; two additional modes may be available. If only Economy mode is available, the mode selection is not usable (dimmed).

The governor mode can be either RPM Control, Torque Control or Index Control.

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. Pressing a button representing any available mode will issue a command to the control system requesting a change to the corresponding mode.

Changing governor mode is done similar to changing running mode.

1.1.4 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.

1.1.5 Auxiliary System Status Indicators

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 panels for the actual systems. Indicators are:

- HPS (Hydraulic Power Supply): Manual, Auto
- Lubricator: Running Stopped, Prelube, LCD (Load Change Dependent) On
- PTO (Power Take Off): Off, Request, Permit, Request (yellow and warning, if a parameter for switching on the PTO is not fulfilled). Optional, only if the engine has PTO.
- 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.
- Var.XBP (Variable Exhaust Gas Bypass): percentage open.
  Optional, only if XBP is installed.
- On/Off XBP (Exhaust Gas Bypass): Open or Closed. Optional, only if XBP is installed.

1.1.6 Start Status Indicator

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)

1.1.7 Speed [RPM]

The speed indicator consists of a bar graph. The bar graph is centred at 0 and positive and negative is up and down, respectively.

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:

Start / stabilizing	The stabilizing modifier defines a speed set point that ensures the starting of the engine.
Stopped	The stopped modifier sets the speed set point to zero.
Minimum Speed Command	The minimum speed command modifier defines a minimum speed set point during operation of the engine.
Maximum Speed Command	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	
Slow down	
PTO	The speed is kept higher than ordered to keep the shaft generator connected during start up of the auxiliary engines.
Speed Ramp	Increase of speed is limited by the ramp, and by the load program.
Load Control 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.

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).

1.1.8 Pitch Indicator

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.

1.1.9 Fuel Index Indicator [%]

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	The chief limiter defines a maximum amount of fuel to be injected according to the settings done by the operator at the screen Cylinder Load.
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. The limit is defined in the load program.
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 power supply pressure does not drop below a minimum operation limit. This limiter is only active in case of malfunction of the HPS.
Blank	When no index limiter is active the field is blank.

Below the limiter status field is a set of dynamic labels displaying the actual fuel index and the current fuel index limit.

1.1.10 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.

The command is available only when the engine is stopped and the prepare start procedure is not running.

1.1.11 Slow Turn Button

Manual slow turn is used during preparations before start of the engine, and is normally to be used with the indicator cooks open. Slow turn is used for visual inspection of the blow out. When the button is selected, the engine is operated on starting air through the slow turn valve as long as the control handle is activated.

1.1.12 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.

1.1.13 Air Run Button

The air run button function is only available in Chief level.

The air run button 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 function is similar to the slow turning, except that the main starting valve is open and the engine is running faster (still without fuel injection).

Slow Turn and Air Run are activated when the handle is in “run” position. This will rotate the engine until the handle is set to "stop" (or the engine is started by pressing the Auto button).

1.2 Status *(See Plate 70325)*

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 Field

The main state field shows exactly the same information as the main state field in the operation screen view, Plate 70324. For detailed explanation, see 1.1.1 Main State Field, page 1(12) in this chapter.

1.2.2 Start Conditions

The Start Conditions field is a status list, showing whether the engine is ready for start or not. The conditions shown with a green checker mark must be present before starting of the engine is possible.

If a condition is shown with a red background and a white exclamation mark or an exclamation mark on a yellow background, 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 not OK (Low and bridge control).
  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.
  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.
- Auxiliary Systems (Standby or At Sea) (optional – currently not in use)
  Yellow, if auxiliary systems are not OK.
  Green, if auxiliary systems are OK.

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 Blowers

Shows the status of the auxiliary blowers, which is either:

- Stopped
- Running
- Starting
- Failed

1.2.6 Hyd. Oil

The hydraulic oil pressure indicator displays the system hydraulic oil pressure continuously.

1.2.7 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.

When the engine is running, the field display shows “Running”.

1.2.8 Control Air Pressure

The control air pressure indicator displays the system control air pressure continuously.

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 Indicator

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 stylish 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 thightness of the starting air valves in the cylinders. (This test is performed regularly with stopped engine, see Chapter 702-01).

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 Plate 70326)*

This screen gives the user a quick overview of the possible limiters/governors used.

The screen always shows the values currently in use.

1.3.1 Running Mode

This field is the same as described in 1.1.3 Running Mode and Governor Mode Field.

An engine running mode is based on an algorithm which continuously determines the fuel injection and exhaust parameters that influence the cylinder process. By controlling the cylinder process (maximum cylinder pressure, compression ratio and blow back), fuel efficiency and emissions can be controlled to a certain extent.

For the ME engine, several running modes may exist. These contain different algorithms, and provide various fuel efficiency and emission characteristics. The running modes are configured for each engine type by MAN Diesel.

1.3.2 Speed Control

This field is the same list of speed modifiers described in Section 1.1.7 Speed Indicator.

The Index Limiter field is the same list of index limiters described in Section 1.1.9 Fuel Index Indicator.

1.4 Cylinder Load *(See Plate 70327)*

In Chief level, the operator can adjust the balance of the engine related to MIP and Fuel Oil Properties.

In Chief level, the operator can adjust the load limit on one or more cylinders, adjust the cylinder load balance as well as cut out one or more cylinder units. Before taking a cylinder out of operation the restrictions in section 704-04 must be taken into consideration. The operator can adjust the settings on all cylinders at one time, or adjust settings on each individual cylinder.

1.5 Cylinder Pressure *(See Plate 70328)*

The settings of the Maximum Pressure Level and Balance, Compression Ratio and Exhaust Valve open timing are combined into a single screen view called Cylinder Pressure.

In Chief level, the adjustment ranges are:

- p_{max} +/– 20 Bar
- p_{comp} ratio +/– 2
- Valve timing 0 to –2°, earlier than the engine mode's requested value.

1. Auxiliaries

The Hydraulic System, Scavenge Air, Exhaust Gas Bypass if installed 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 (Exhaust Gas Bypass)

1.3 Cylinder Lubricators

1.1 Hydraulic System *(See Plate 70329)*

This screen is a simple schematic drawing of the hydraulic system. The screen shows from 3 (three) to 5 (five) engine-driven pumps (depending on engine layout) and 2 (two) electrically driven start-up pumps.

A bypass valve from pump pressure side to suction side is also shown.

The following screens can also be activated directly from the screen:
The operating mode must be chief level.

- HPS (Hydraulic Power Supply) Mode
- Pump Torque Limiter
- Set Point
- Bypass

On the screen, the displays which can be activated 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

At the bottom of the screen the details button is placed. Activation of this button reveals a view with all individual pressure readings available on the system. (Pressing the button a second time brings you back to the default screen).

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 Section 1.1.4 in this Chapter).*
3. Start/stop of the electric start-up pumps.

If, for some reason, automatic control of an engine-driven pump cannot be maintained, the pump swash plate is deflected to 100% in ahead direction only.

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).

! *If for instance an engine-driven pump-shaft is broken, the limiter could be helpful. However, it is recommended to contact MAN Diesel, if a situation like this should occur.*
At risk of mechanical overload: cancellation of the torque limiter must only be selected, when it has been confirmed, that the engine-driven pump is not working.

1.1.3 Set Point and Hyd. 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 Hyd.Oil.

! 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 150-210 bar range and is set at commissioning. The engine shutdown level is approximately 150 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 at normal engine running.

1.1.4 Double Pipe

This 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 section 708-08 for more details of the hydraulic system.

1.1.5 Bypass

On the main pressure line from the engine-driven pumps, a bypass 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, you are always sure that the valve is working properly. (The valve is to be checked manually every 6 months.)

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 Plate 70330)*

The scavenge air screen contains information and controls for monitoring and operating the auxiliary blowers and exhaust gas bypass (engine dependent).

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 (engine start is delayed until blowers are running and pressure is correct)
- when 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 (adjustable) after engine has been stopped

- engine is running and the scavenge air pressure is above a specified level *(See Guidance Values Automation Chapter 702-02 in this book)*

If a switch to manual operation is required, this is done via the toolbar *(see Plate 70330).* By pressing the blower 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.

By pressing the details button, indication of the current scavenge air pressure is shown for each individual scavenge air sensor.

1.3 Exhaust Gas Bypass (engine dependent)

Monitoring of the Exhaust gas bypass is performed from the Scavenge air screen.

The actual positions and settings of the on/off bypass and the proportional controlled bypass valves are always shown on the screen.

By pressing the bypass display buttons (chief level), the bypass valve modes can be changed between automatic and manual.

In manual mode (chief level), the on/off bypass can be opened or closed.

In manual mode (chief level), the proportionally controlled bypass valve can be opened/closed or set to the angle desired.

1.4 Cylinder Lubricators *(see Plate 70331)* ME Lube

The ME lube Control System (LUBECS) 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 <u>be monitored</u>:

1.4.1 Flow

1.4.2 Total

1.4.3 LCD

1.4.4 Basic Feed Rate

1.4.5 Actual Feed Rate (each cylinder)

1.4.1 Flow

The Flow display shows the ordered lube oil amount in litres/hour.

! *If one or more lubricators are malfunctioning (e.g. Feedback Failure) the actual amount applied will differ.*

1.4.2 Total

The Total display shows the total ordered amount of lubricating oil used since last power up of the ECU involved.

Both of the values Flow and Total are based on the counted numbers of lubrication strokes and the displaced amount per stroke.

1.4.3 LCD

The LCD display shows whether the LCD (Load Change Dependent) lubrication is on or off.

1.4.4 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 = S% x (FEED RATE FACTOR).

1.4.5 Actual Feed Rate (each cylinder)

The bar graphs for each individual cylinder shows the actual feed rate per cylinder, after the influence of limiters, load control, etc. If the feed rate due to low load exceeds the maximum display capacity (1, 45 g/kWh), the full bar is barred and the upper display on the bar graph shows “Low Load”.

The following displays can be operated (at chief level):

1.4.6 Prelube

1.4.7 S %

1.4.8 Feed Rate Factor

1.4.9 Min. Feed Rate

1.4.10 Feed Rate Adjust Factor

1.4.11 Running in %

1.4.12 Lubricator Test Sequence

1.4.6 Prelube (for test purpose)

As stated above this button is only used for test purposes.

When the “Prelube” button is pressed a toolbar is shown on the screen *(see Plate 70331)* Pressing the button “ON” triggers a prelubrication on all cylinders and evaluates feedback from the lubricators.

As default, each lubricator is activated 20 times at the fastest possible speed.

! *Prelubrication can only be activated if hydraulic pressure is present. This demands that the engine (Telegraph) is put in the state “Standby” or that the Hydraulic start-up pumps are set at manual operation and started.*

1.4.7 S %

Activating the display S % (Chief level) enables adjustment of the Sulphur content equal to the sulphur content in the HFO used. The principle of how to adjust the feed rate according to the sulphur content is explained in Section 707-02 in this book.

The range in the LUBECS is between 0.00 to 5.00 S % and is not adjustable outside this range.

1.4.8 Feed Rate Factor

Activating the display Feed Rate Factor (Chief level) enables adjustment of the feed rate for all cylinders. The display shows the feed rate with 2 decimals and “g/kWh%S”.

1.4.9 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 (chief level).

1.4.10 Feed Rate Adjust Factor

Activating the display Feed Rate Adjust Factor (chief level) enables adjustment of the feed rate for every single cylinder.

1.4.11 Running in %

When a single cylinder is under run-in, the feed rate is adjusted at this display (chief level). Running-in of a single cylinder is described in Section 707-01 in this book.

1.4.12 Lubricator Test Sequence

Pressing the Lubricator Test Sequence (chief level) starts a continuous activation of the lubricator at normal injection rate (different from “Prelube” 1.4.6 where the injection of oil is made at the fastest possible speed and 20 times)

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 *(see Plate 70331).* The toolbar enables the engineer to start lubrication on the particular cylinder concerned or on all lubricators.

! *The lubricator test can only be activated if hydraulic pressure is present. This requires that the engine (Telegraph) is put in state “Standby” or that the Hydraulic start-up pumps are set at manual operation and started.*

1. Maintenance

The maintenance screens give an overall view of the status of the ECS system seen on the following three screens. Plates 70332 – 70333 – 70334.

1.1 System View I/O Test

1.2 Invalidated Inputs

1.3 Network Status

The above-mentioned three maintenance screens 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.

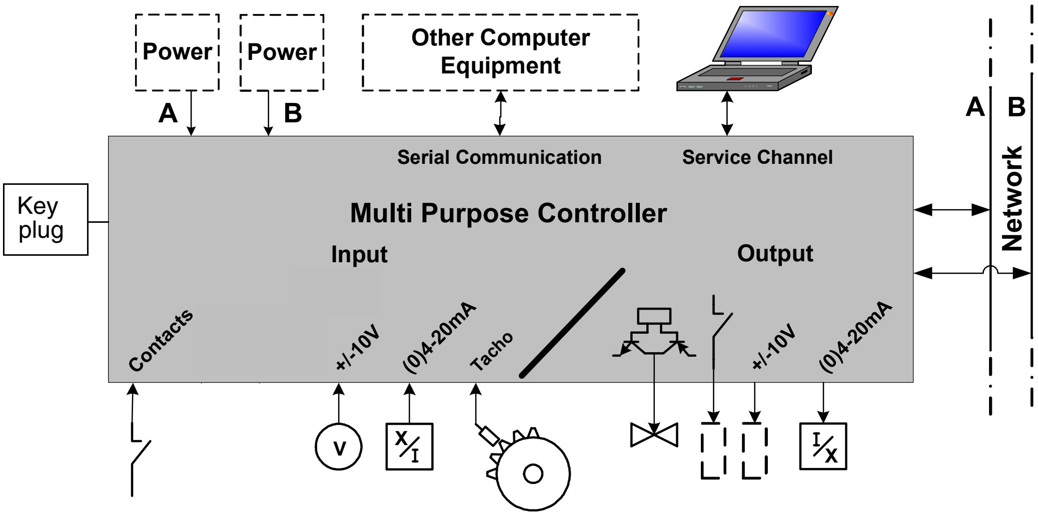
MAN B&W Diesel does not currently recommend “Preventive Replacement of Electronics”, and there is no urgent reason to introduce such recommendation as aging failures do not have any critical consequences for the operation of the engine. However, we will consider and evaluate this continuously in preparation for setting a future upper limit of when the electronics are to be considered ready for replacement.

1.1 System View I/O Test *(See Plate 70332)*

To understand the use of this screen, 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 drawing next page).

- Inputs for e.g. tacho signals, standard (0)4-20mA transducers, ±10V signals, switches and 24V binary signals
- Outputs such as (0)4-20mA and ±10V signals, contacts and high-speed semiconductor switches for activation of the exhaust valve of the ME Engine for instance
- 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.



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 coprocessor 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 harddisk 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.

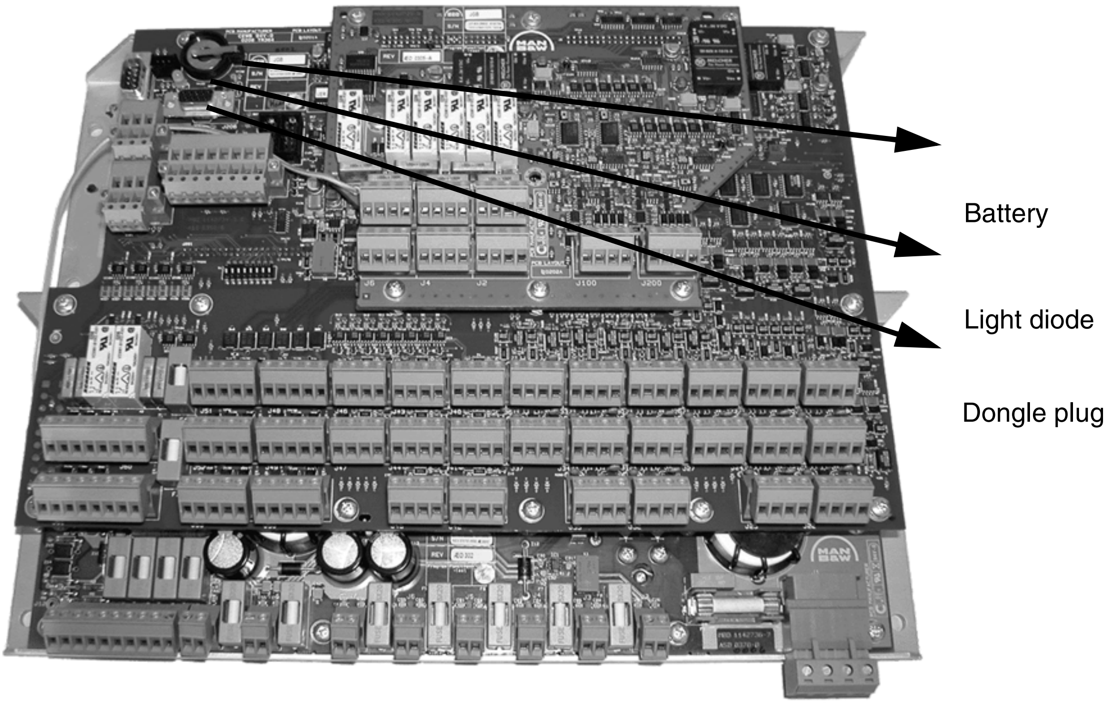
The MPC is, as shown on the picture below equipped with a battery. This battery is used for Back-up power to the clock – watch of the MPC in the event that the 24 V power is turned-off. All clocks of all MPC’s are synchronised via the network. Synchronisation is done regularly and always after power is on after a possible power off. Regarding battery in MPC: *See S-instructions S906-0039 and S906-0040.*

When a new MPC is mounted in the cabinet, the dongle in the cabinet is mounted in the dongle plug-in, after reconnection of all wires. The dongle tells the “new” MPC in which cabinet it is mounted and, in that way, which software and parameters it should upload from the MOP harddisk (e.g. CCU1, ACU 3 or EICU1).

The MPC is also equipped with a light diode, capable of showing green, yellow or red light. This light tells the engineer in what status the MPC is.

During normal running the diode is green.
When the diode is yellow, the MPC is uploading engine running parameters from the harddisk in the MOP. Normally, this takes a few minutes.

When the diode is red, the MPC is unavailable.



The use of the screens on Plates 70332, 70333 and 70334 also becomes relevant. When MPC change is to be done, detailed LED (light-diode) indications are shown in the maintenance Procedure M906-xxxx, Multi Purpose Controller, Appendix.
A red light diode is not clearly the situation/status that triggers a replacement of an MPC, but only a hint in that direction.

If in doubt, the engineer can use the screens to explain the status to skilled personnel at MAN B&W Diesel. The communication with engineers at MAN B&W Diesel is less complicated, and various opinions are ruled out when exact pictures are communicated to MAN B&W Diesel.

The idea of the Maintenance screens is to help the engineer run and monitor the ECS of the engine.

The icons (plate 70332 1(3)) shown on the controllers, show the status of each single controller, e.g. whether it is in mode:

Active
Controlling
Configuration
Test
Blocked
Not accessible

By pressing the single controller (Chief Level) on this screen (in this case ACU-3 is pressed and shown on page 2(3)), the actual inputs/outputs on the selected controller ACU-3 are shown.

The screen shows Info, ID and Descriptions and processes values of each single channel on the MPC.

To perform a view of each single channel, the button “MPC Mode” must be pressed (Chief Level). Doing this, reveals a toolbar at the bottom of the screen. On this toolbar “Test” must be chosen.

CAUTION: Changing to TEST Mode will STOP the MPC from controlling the system.

By pressing the channel number to the left on the individual channel, for instance screen 3(3) on Plate 70332 is shown. Here we see a single channel (in this case, channel 80 on CCU-12). The status and values of this channel is listed on this screen.

From this screen, input channels can be invalidated and validated again (Chief Level).

CAUTION: Changing the status of a channel may cause the system to malfunction.

It may be relevant to invalidate an input channel on an MPC if the sensor linked to the channel, for some reason or another, occasionally or continuously is giving alarm.

The reason for alarm could for instance be a defective sensor or loose wiring from the sensor to the MPC.

We recommend that channels only are invalidated in agreement with skilled personnel from MAN B&W Diesel.

If a channel is invalidated, the channel involved will go into a continuous alarm state. At the same time, the ECS will continue to operate in the best possible way, without the invalidated input sensor value.

1.2 Invalidated Inputs *(See Plate 70333)*

If an input channel is invalidated (as described in Section 1.1 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 “Invalidated Inputs” screen is a “Quick View” helping the engineer look through and control which channels to invalidate. This could be helpful, for instance after an MPC change.

Input Channels Invalidated can be validated from this screen (Chief Level).

CAUTION: Changing the status of a channel may cause the system to malfunction.

1.3 Network Status *(See Plate 70334)*

This screen gives the engineer an overall view and exact status of the Control Network of the ECS (opposite screens 70332 and 70333 that shows the status of each single MPC).

From this screen, it is possible to see the status of the Network using the icons named below: (Icons are visible at Plate 70334, 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. The use of the screen becomes especially relevant when manual checks for earth fault is performed.

CAUTION: Engine must be stopped when check for earth fault is performed.

1. System

In the Admin main navigator, time set and in table format, all controllers in the ECS are listed and version numbers displayed.

The screens are:

1.1 Set Time

1.2 Version (software and IMO Check Sum)

1.1 Set Time *(See Plate 70335)*

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.

Pressing on either button “UTC Date/Time” or button “Local Date/Time” will display toolbars (shown on Plate 70335). From these toolbars, Date and Time can be set.

Pressing the buttons “UTC Time displayed” or “Local Time Displayed” gives you the opportunity to choose between the time you want displayed at the MOP panel (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 you set as default.

1.2 Version *(See Plate 70336)*

1.2.1 Background

This screen displays the version type of the ECS controlling the ME engine. It is used to obtain the configuration information of the Electronic Control System (ECS) in an ME engine. It displays, in table format, all the controllers that comprise the system, including specific information relating to each controller.

1.2.2 Screen Items

In the upper system information line, general information of the ECS system for this particular engine is shown. The fields are: (No data shown on Plate 70336)

Type	The engine classification name
Version	Version number of entire system
BES Vers.	Software version of the Basic Electronic System
Engine Group No.	Engine builders engine number
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 pane, 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, ECU or EICU)

1.2.5 Parameters Check Sums (No data shown on Plate 70336)

User
Chief
Service
Design
IMO Design
IMO Chief

No data is shown, because specific data may vary.

1.2.6 Using the Screen

When the screen is first displayed, no information appears on the table. Press the “Refresh” button to retrieve the system information and parameter checksums of all controllers connected to the ECS. *(See plate 70336.)* (No data is shown on the plate, because specific data may vary).

If at least one controller supplies information on the system that does not agree with the other controllers, a warning message is displayed in yellow at the tool bar (below on the screen) *(see plate 70336).*

Pressing the Print button generates a hardcopy of the information displayed in the table (if a printer is connected to the MOP).

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. 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.

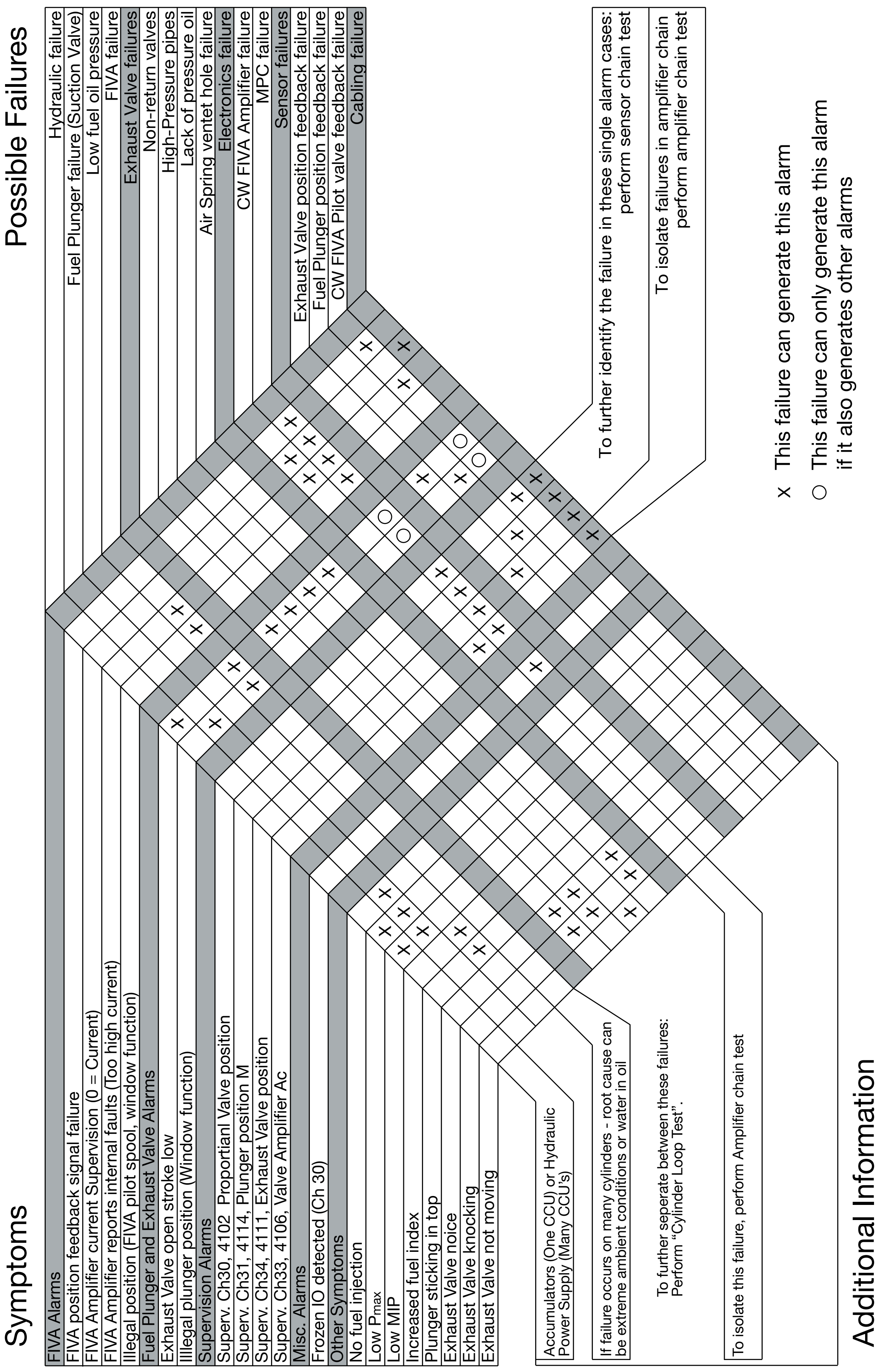
The test is only applicable on systems with Curtiss Wright FIVA valves.

Sensor Chain Test (flowchart)

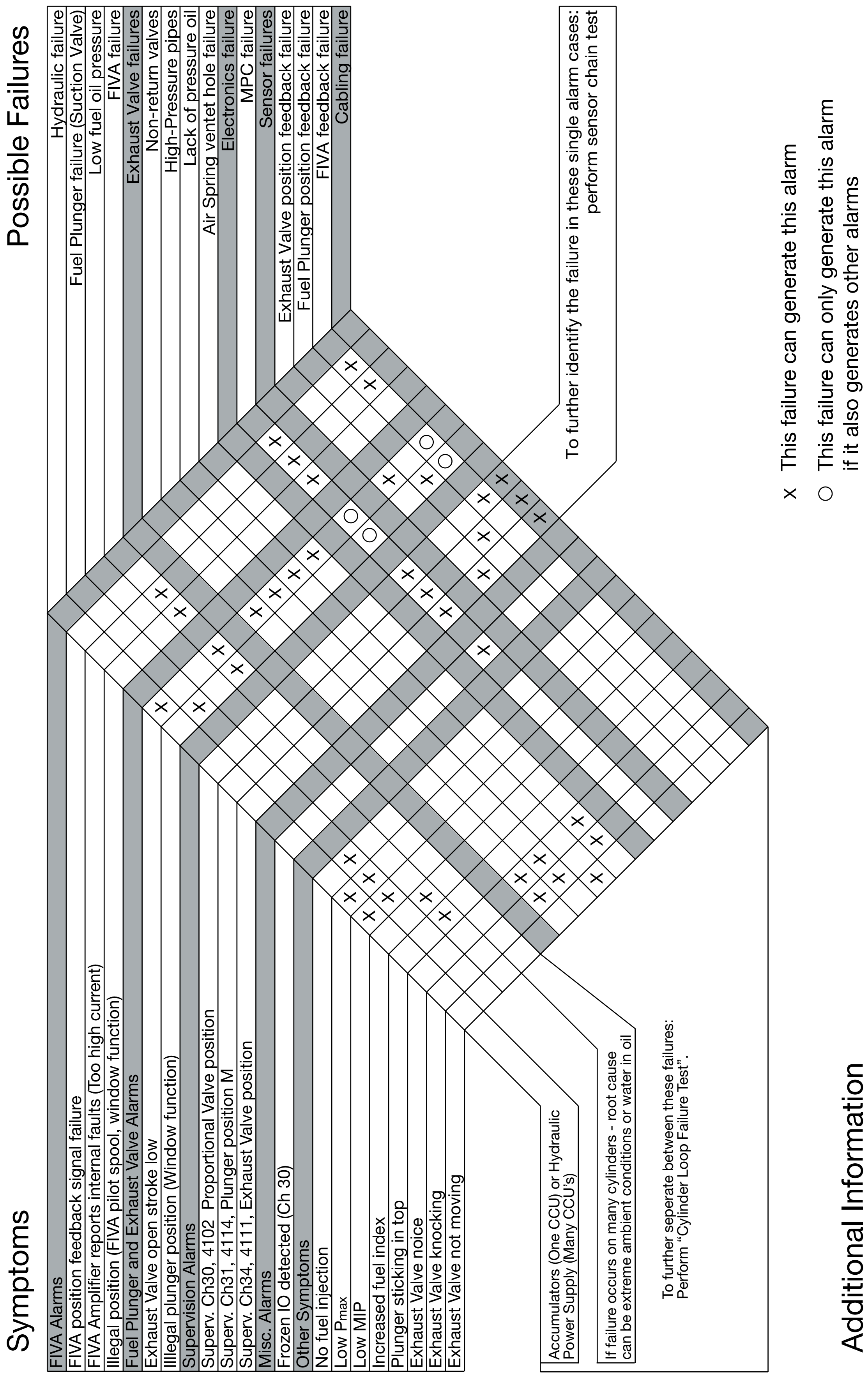
The Sensor Chain Test (SCT - page 7 this section) is a description of a test procedure. The SCT should be used to isolate failures in sensor chains where there is a supervision alarm or another error.

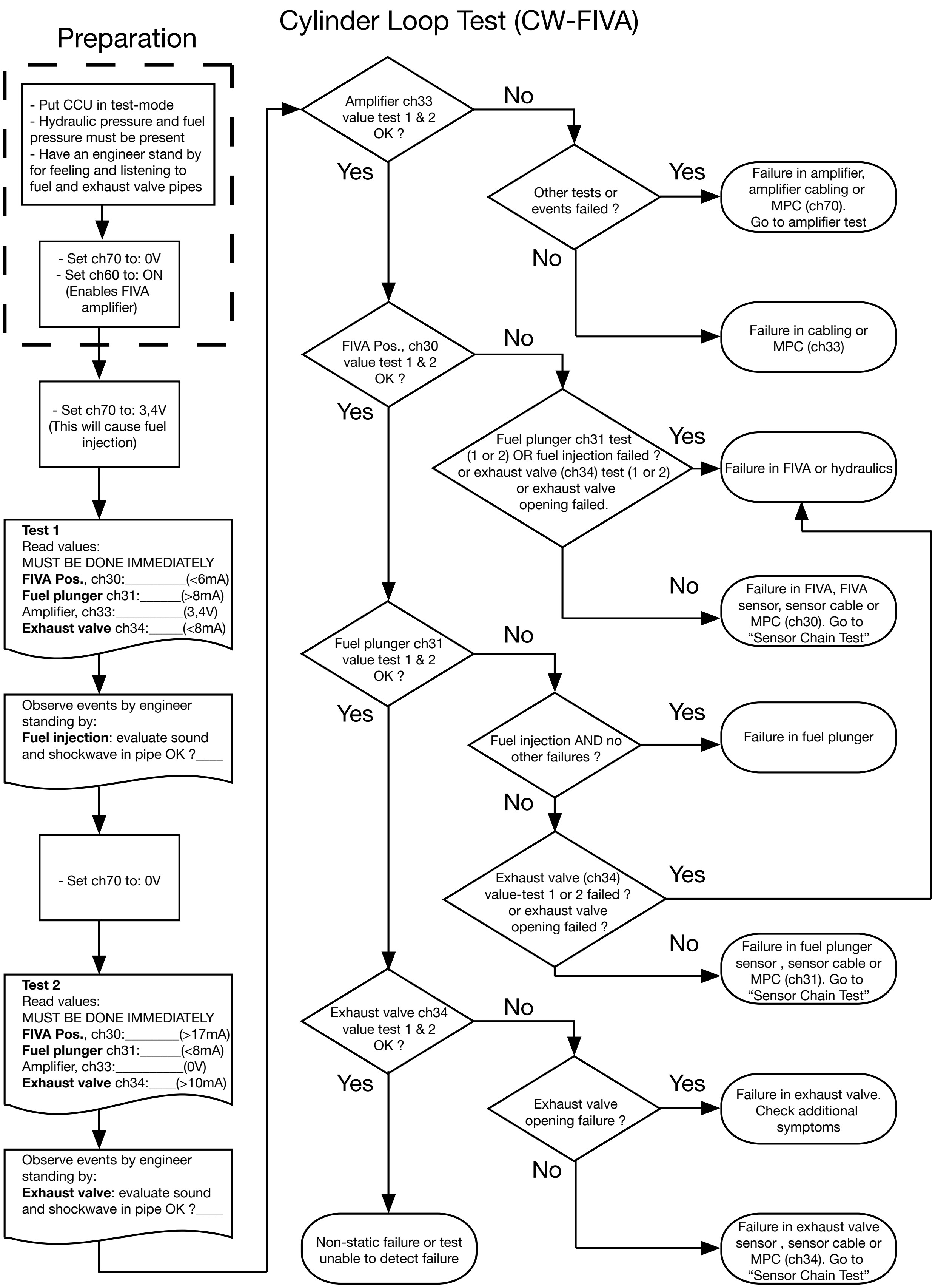
The test categorises failures in: sensor, cabling, MPC.

Cylinder Components Failure Tree (CFD – Curtiss Wright FIVA)

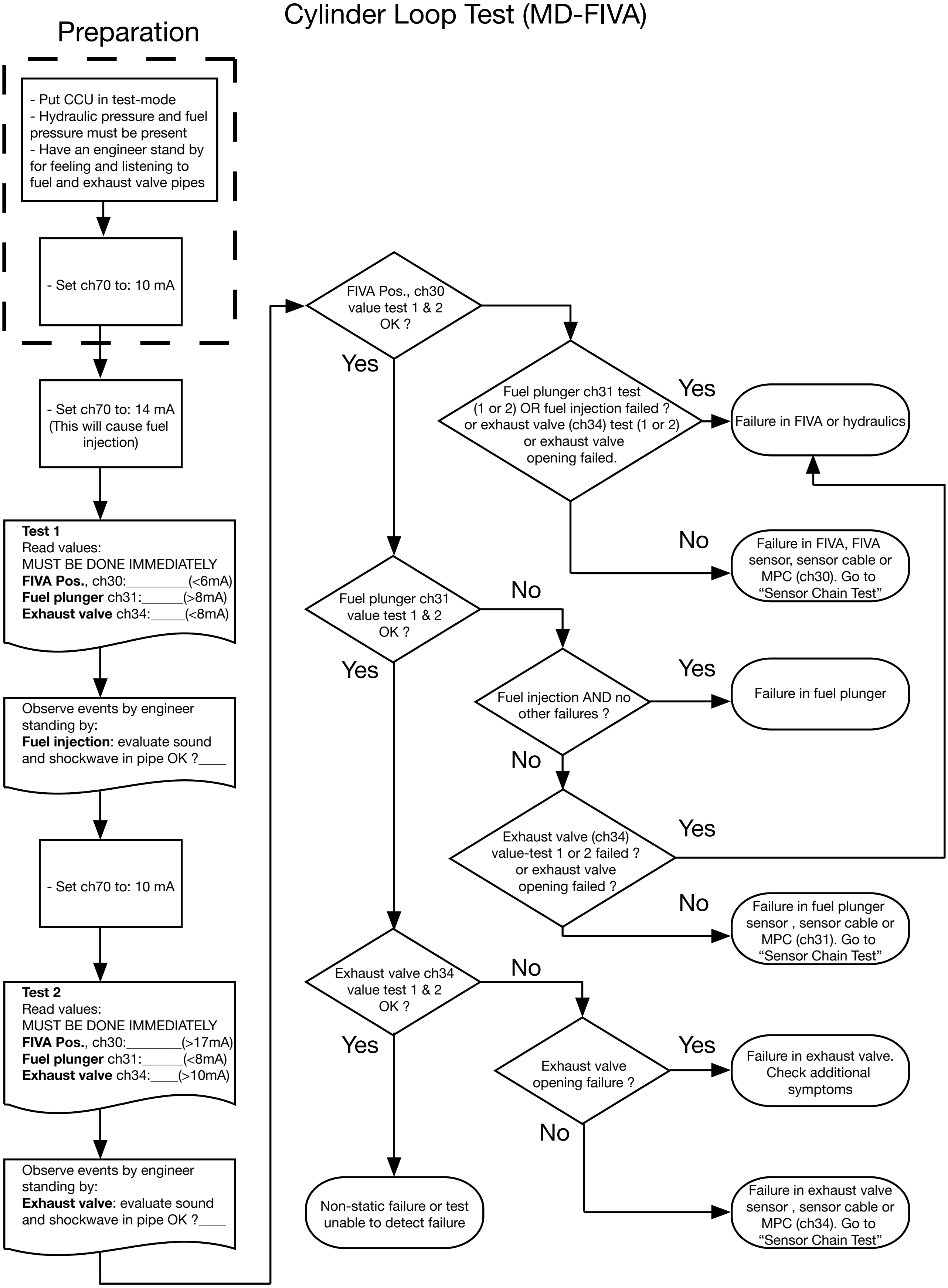


Cylinder Components Failure Tree (CFD – MBD Parker FIVA)

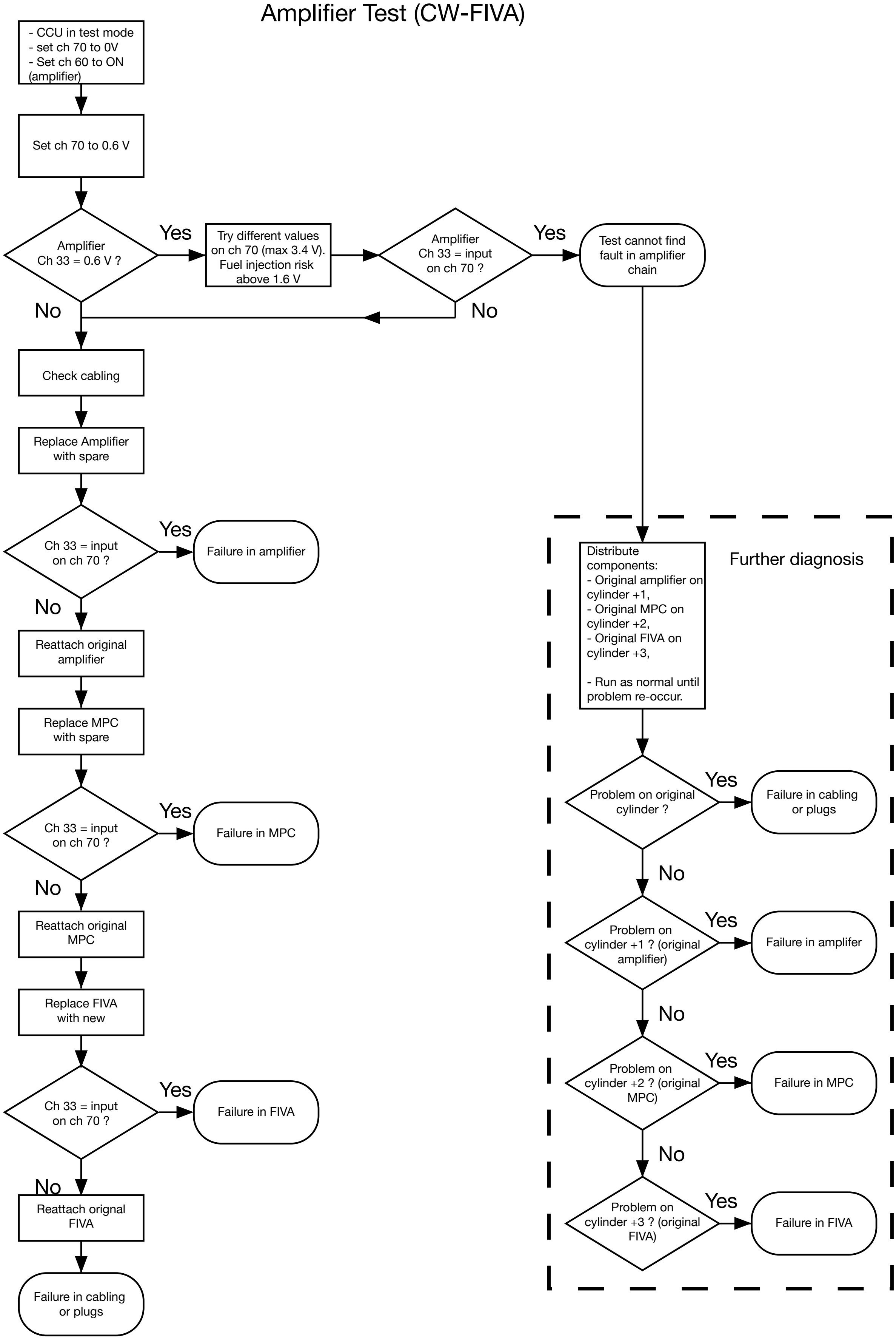



Cylinder Loop Test (CW-FIVA)
Preparation
- Put CCU in test-mode
- Hydraulic pressure and fuel pressure must be present
- Have an engineer stand by for feeling and listening to fuel and exhaust valve pipes
- Set ch70 to: 0V
- Set ch60 to: ON
(Enables FIVA amplifier)
- Set ch70 to: 3,4V
(This will cause fuel injection)
Test 1
Read values:
MUST BE DONE IMMEDIATELY
FIVA Pos., ch30:________(<6mA)
Fuel plunger ch31:______(>8mA)
Amplifier, ch33:__________(3,4V)
Exhaust valve ch34:_____(<8mA)
Observe events by engineer standing by:
Fuel injection: evaluate sound and shockwave in pipe OK ?____
- Set ch70 to: 0V
Test 2
Read values:
MUST BE DONE IMMEDIATELY
FIVA Pos., ch30:________(>17mA)
Fuel plunger ch31:______(<8mA)
Amplifier, ch33:__________(0V)
Exhaust valve ch34:____(>10mA)
Observe events by engineer standing by:
Exhaust valve: evaluate sound and shockwave in pipe OK ?____
Amplifier ch33 value test 1 & 2 OK ?
No
Yes
Other tests or events failed ?
Yes
No
Failure in amplifier, amplifier cabling or MPC (ch70). Go to amplifier test
Failure in cabling or MPC (ch33)
FIVA Pos., ch30 value test 1 & 2 OK ?
No
Yes
Fuel plunger ch31 test (1 or 2) OR fuel injection failed ? or exhaust valve (ch34) test (1 or 2) or exhaust valve opening failed.
Yes
No
Failure in FIVA or hydraulics
Failure in FIVA, FIVA sensor, sensor cable or MPC (ch30). Go to “Sensor Chain Test”
Fuel plunger ch31 value test 1 & 2 OK ?
No
Yes
Fuel injection AND no other failures ?
Yes
No
Failure in fuel plunger
Exhaust valve (ch34) value-test 1 or 2 failed ? or exhaust valve opening failed ?
Yes
No
Failure in fuel plunger sensor , sensor cable or MPC (ch31). Go to “Sensor Chain Test”
Exhaust valve ch34 value test 1 & 2 OK ?
No
Yes
Exhaust valve opening failure ?
Yes
No
Failure in exhaust valve. Check additional symptoms
Non-static failure or test unable to detect failure
Failure in exhaust valve sensor , sensor cable or MPC (ch34). Go to “Sensor Chain Test”

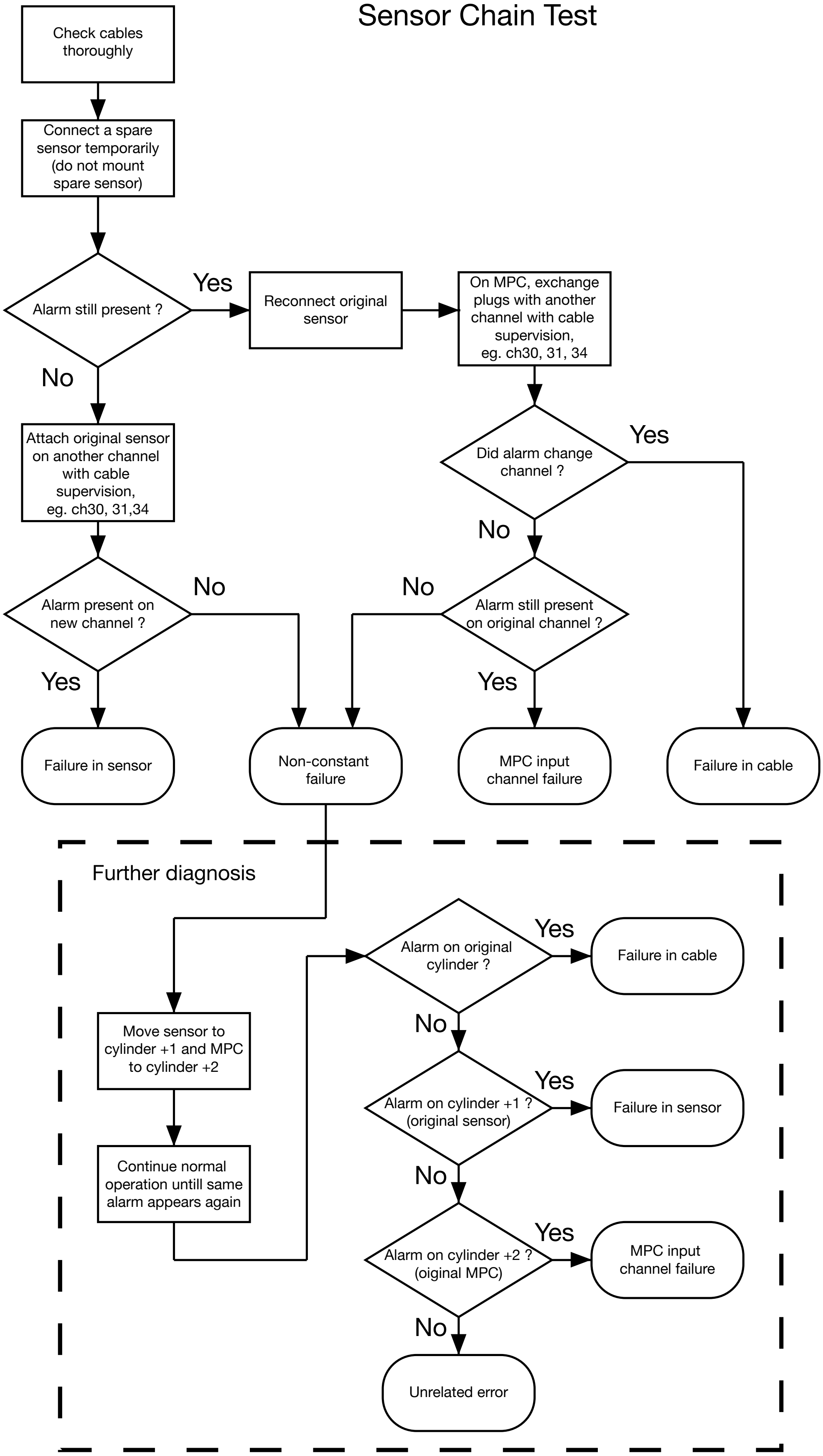
Cylinder Loop Test (MD-FIVA)



Amplifier Test (CW-FIVA)



Sensor Chain Test



2. Test for Earth Failure in the ECS System

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 steal 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).

Method 2

A certain but slow method.

Precondition: The engine must be stopped and in FWE.

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 and alarm (note that failures might be present in more than one unit (MPC) at a time).

Method 3

A faster, but uncertain method.

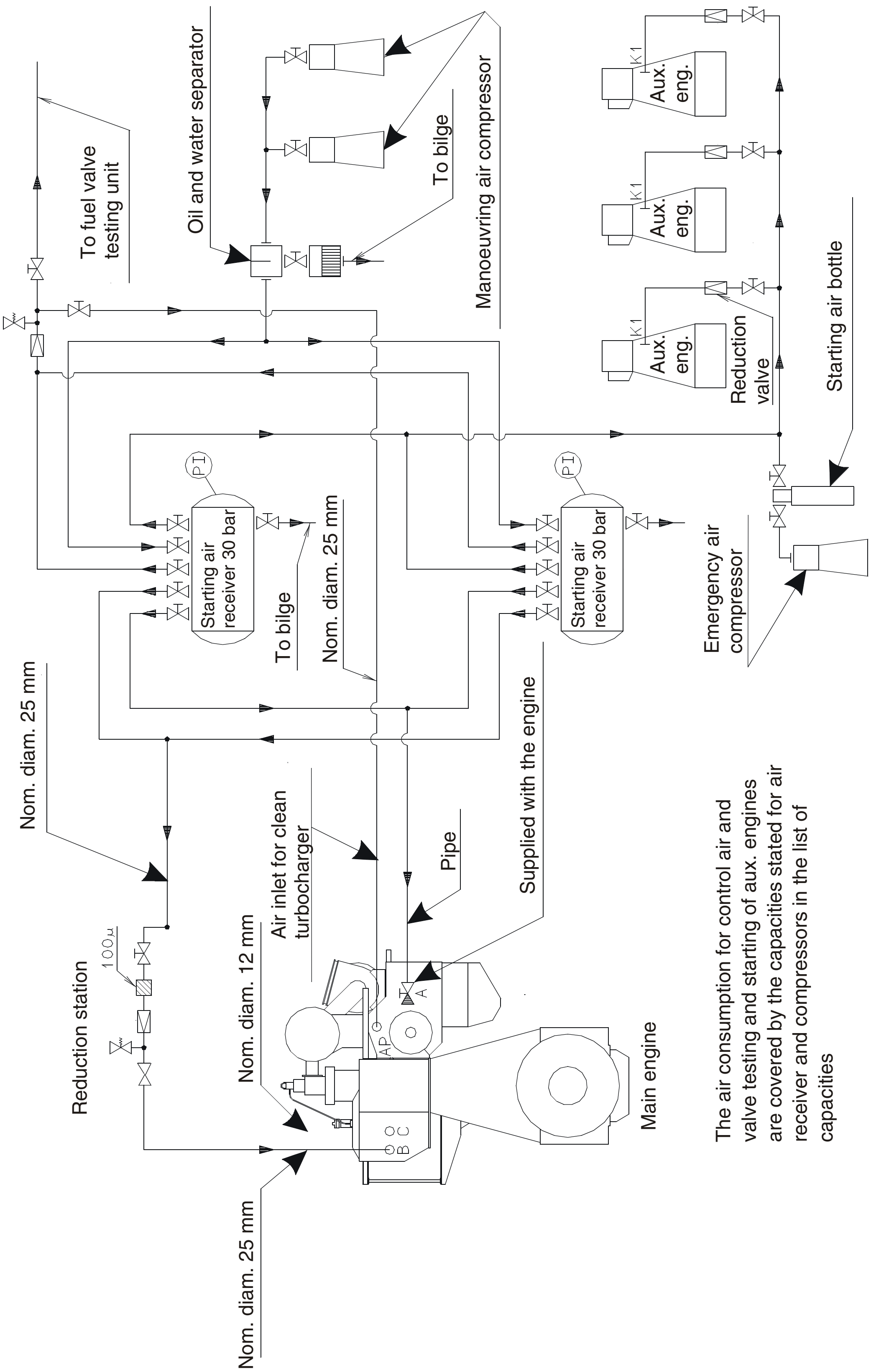
Precondition: The engine must be stopped and in FWE.

1. Disconnect the isolation monitor unit (e.g. Bender xxxx) from the power supply.

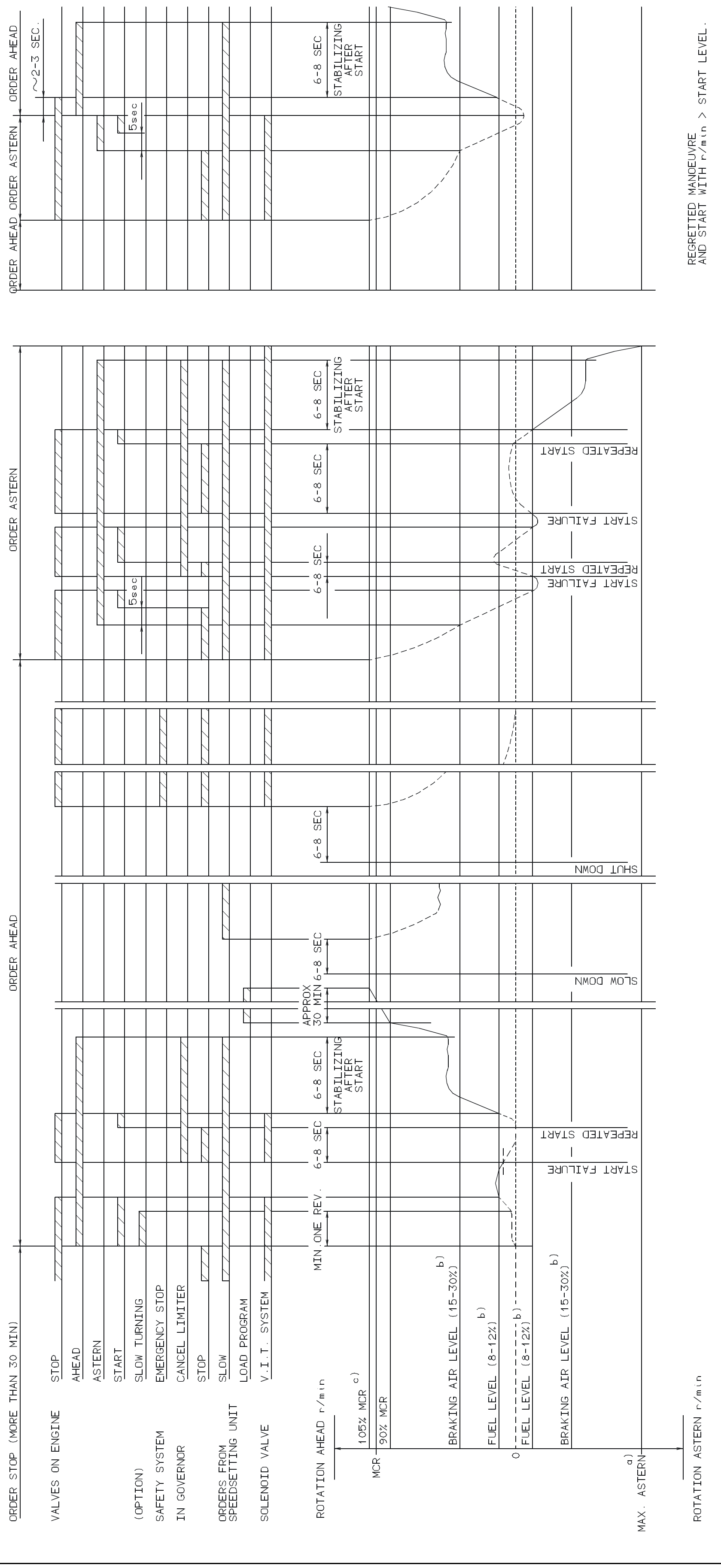
2. Connect a voltmeter between the 0 Volt and ground (a non-isolated point of the engine or ship steel structure) and, if possible, another voltmeter between 24 Volt and ground. Alternatively one voltmeter must be connected alternately between 0 Volt and 24 Volt.
   The measurement can practically be 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).



The air consumption for control air and valve testing and starting of aux. engines are covered by the capacities stated for air receiver and compressors in the list of capacities



——— ENGINE RUNNING WITH FUEL ON.

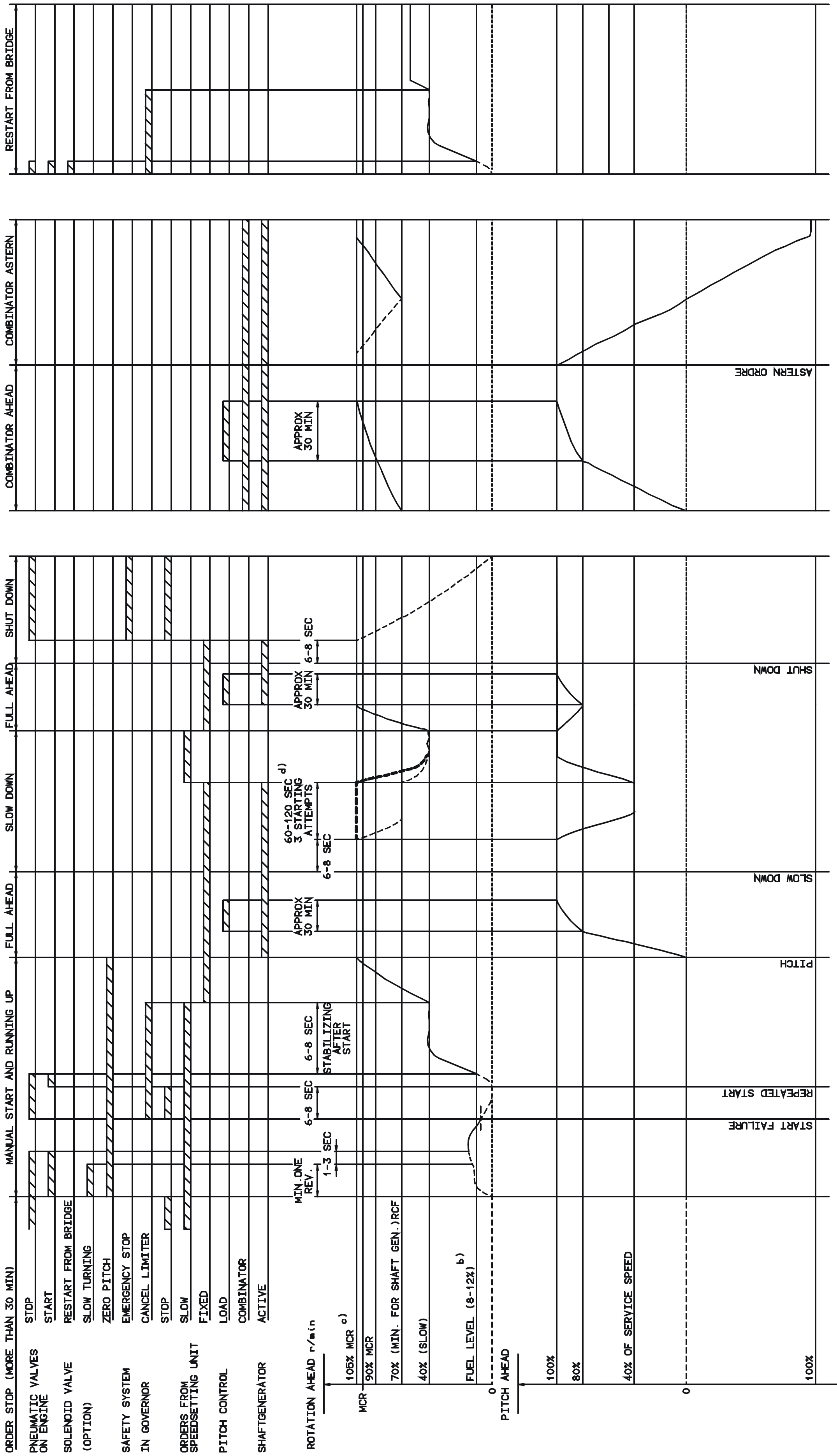
- - - - - ENGINE RUNNING WITH FUEL OFF.

a) MAX.ASTERN: 90% SPECIFIED MCR r/min FOR PLANTS WITH STANDARD EXHAUST CAMS.
80% SPECIFIED MCR r/min FOR PLANTS WITH LONG EXHAUST CAMS.

b) THESE VALUES GIVEN IN % REFER TO NOMINAL MCR r/min, (IF NOTHING ELSE STATED VALUES REFER TO SPECIFIED MCR r/min.)

c) ONLY PERMISSIBLE FOR LIGHT RUNNING PROPELLER. REF. LOAD DIAGRAM FOR ACTUAL ENGINE.

Sequence Diagram for Fixed Pitch Propeller Plant



b) THIS VALUE GIVEN IN % REFER TO NOMINAL MCR r/min. (IF NOTHING ELSE STATED VALUE REFER TO SPECIFIED MCR r/min.)

c) ONLY PERMISSIBLE FOR LIGHT RUNNING PROPELLER, REF. LOAD DIAGRAM FOR ACTUAL ENGINE.

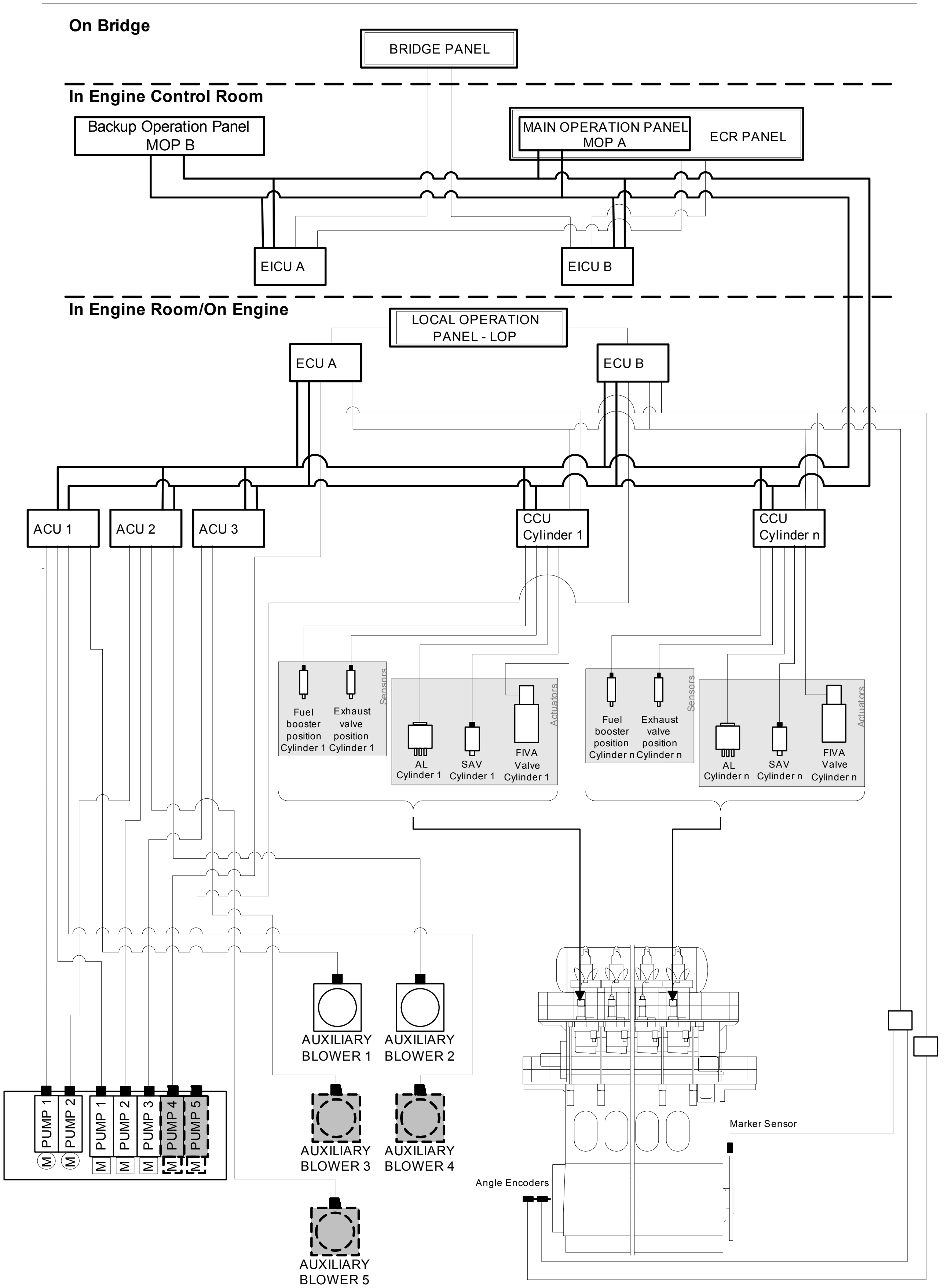
d) WHEN SHAFT GENERATOR IS DISCONNECTED, SLOW DOWN WILL BE EFFECTED AFTER THE PREWARNING OF 6-8 SEC.

NB: A DEMAND FOR QUICK PASSING OF BARRED SPEED RANGE WILL INFLUENCE ON THE SLOW DOWN PROCEDURE.

——— ENGINE RUNNING WITH FUEL ON.

- - - - ENGINE RUNNING WITH FUEL OFF.

▬▬▬ FIXED SPEED SHAFT GENERATOR.


On Bridge
BRIDGE PANEL
In Engine Control Room
Backup Operation Panel
MOP B
MAIN OPERATION PANEL
MOP A
ECR PANEL
EICU A
EICU B
In Engine Room/On Engine
LOCAL OPERATION
PANEL - LOP
ECU A
ECU B
ACU 1
ACU 2
ACU 3
CCU
Cylinder 1
CCU
Cylinder n
Sensors
Fuel booster position Cylinder 1
Exhaust valve position Cylinder 1
Actuators
AL Cylinder 1
SAV Cylinder 1
FIVA Valve Cylinder 1
Sensors
Fuel booster position Cylinder n
Exhaust valve position Cylinder n
Actuators
AL Cylinder n
SAV Cylinder n
FIVA Valve Cylinder n
AUXILIARY BLOWER 1
AUXILIARY BLOWER 2
AUXILIARY BLOWER 3
AUXILIARY BLOWER 4
AUXILIARY BLOWER 5
PUMP 1
PUMP 2
PUMP 1
PUMP 2
PUMP 3
PUMP 4
PUMP 5
M
Marker Sensor
Angle Encoders

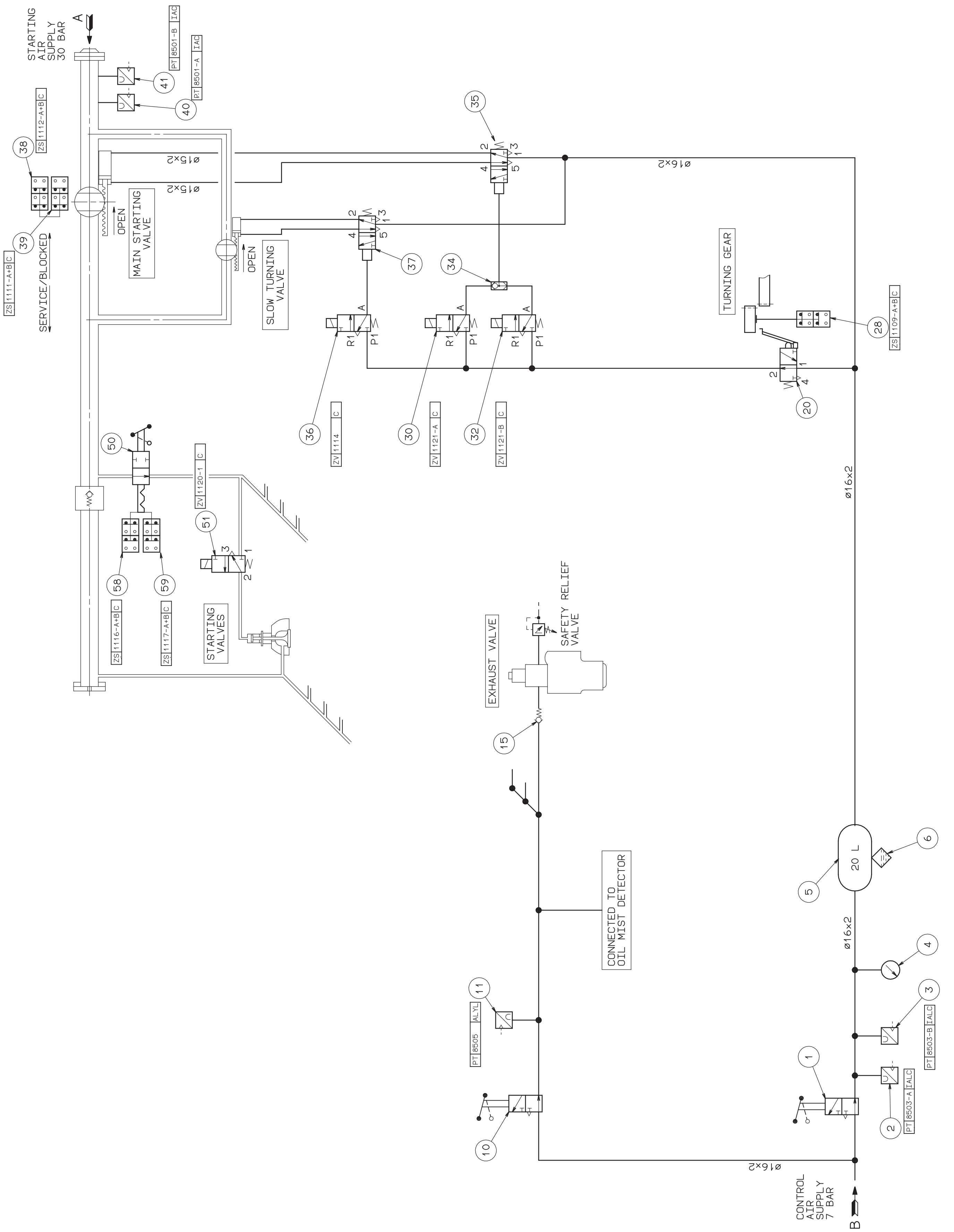

STARTING AIR SUPPLY 30 BAR
A
MAIN STARTING VALVE
OPEN
SLOW TURNING VALVE
OPEN
SERVICE/BLOCKED
TURNING GEAR
STARTING VALVES
EXHAUST VALVE
SAFETY RELIEF VALVE
CONNECTED TO OIL MIST DETECTOR
20 L
CONTROL AIR SUPPLY 7 BAR
B
ø15x2
ø15x2
ø16x2
ø16x2
ø16x2
ø16x2
PT 8501-B IAC
PT 8501-A IAC
ZS 1112-A+B C
ZS 1111-A+B C
ZS 1109-A+B C
ZV 1114 C
ZV 1121-A C
ZV 1121-B C
ZV 1120-1 C
ZS 1116-A+B C
ZS 1117-A+B C
PT 8505 ALYL
PT 8503-B IALC
PT 8503-A IALC
1
2
3
4
5
6
10
11
15
20
28
30
32
34
35
36
37
38
39
40
41
50
51
58
59

Fig. 1

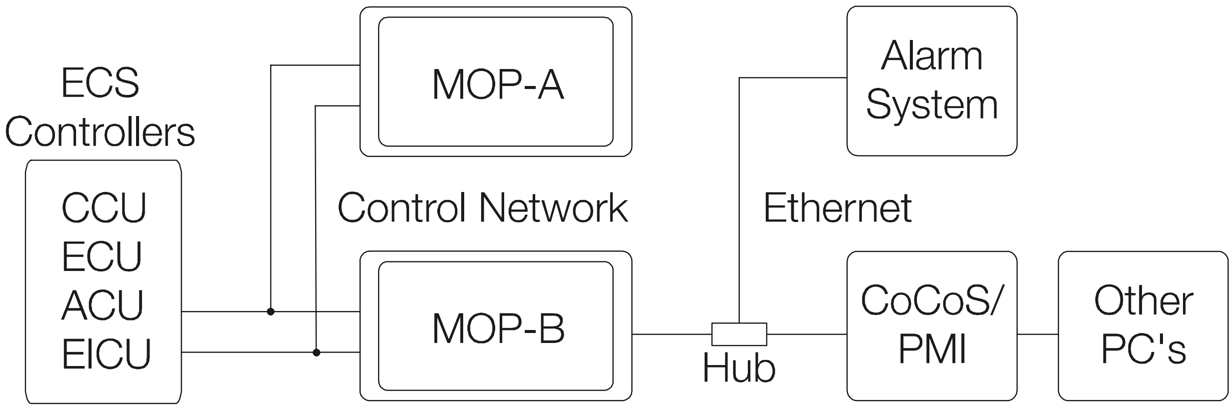
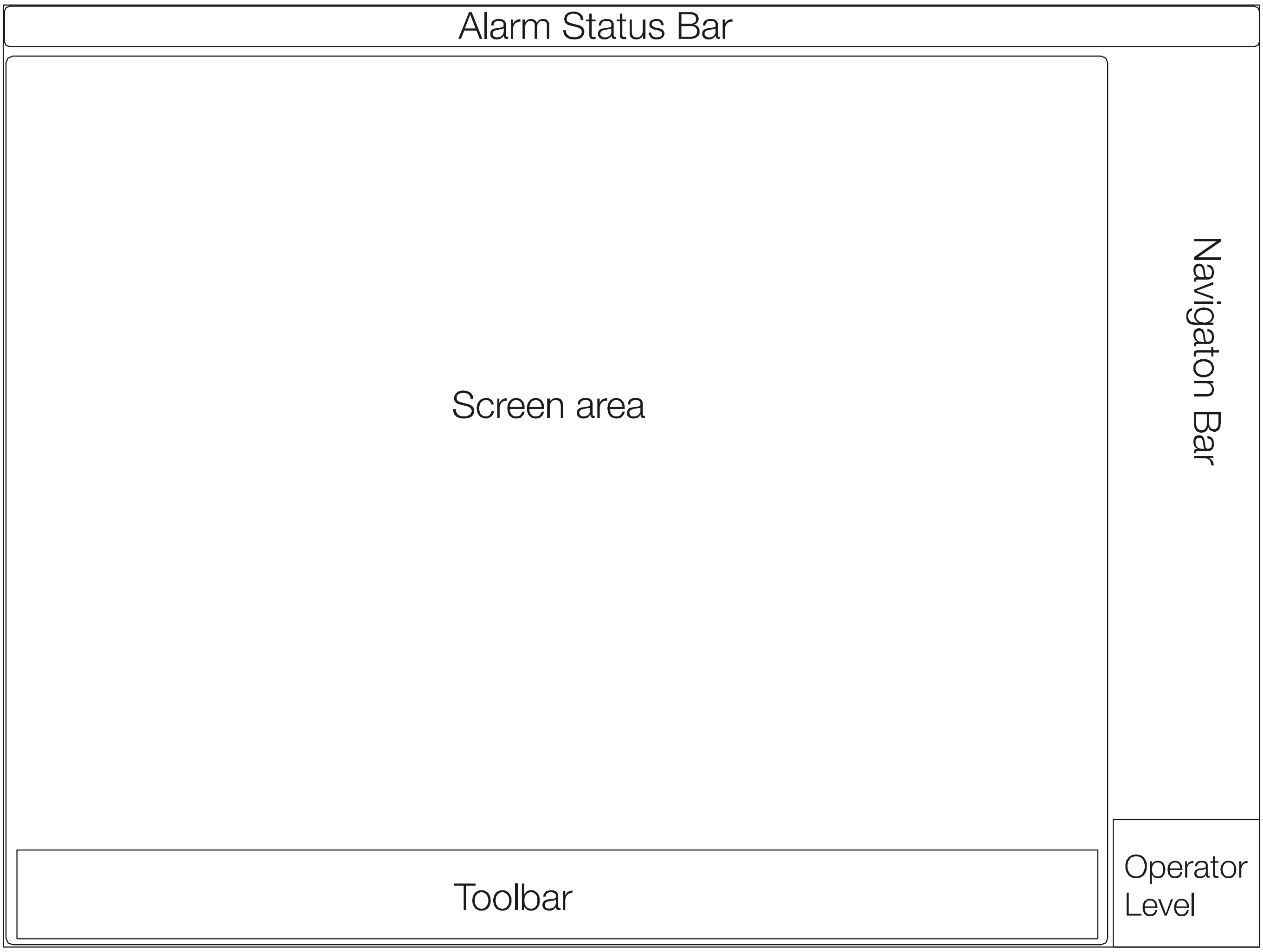
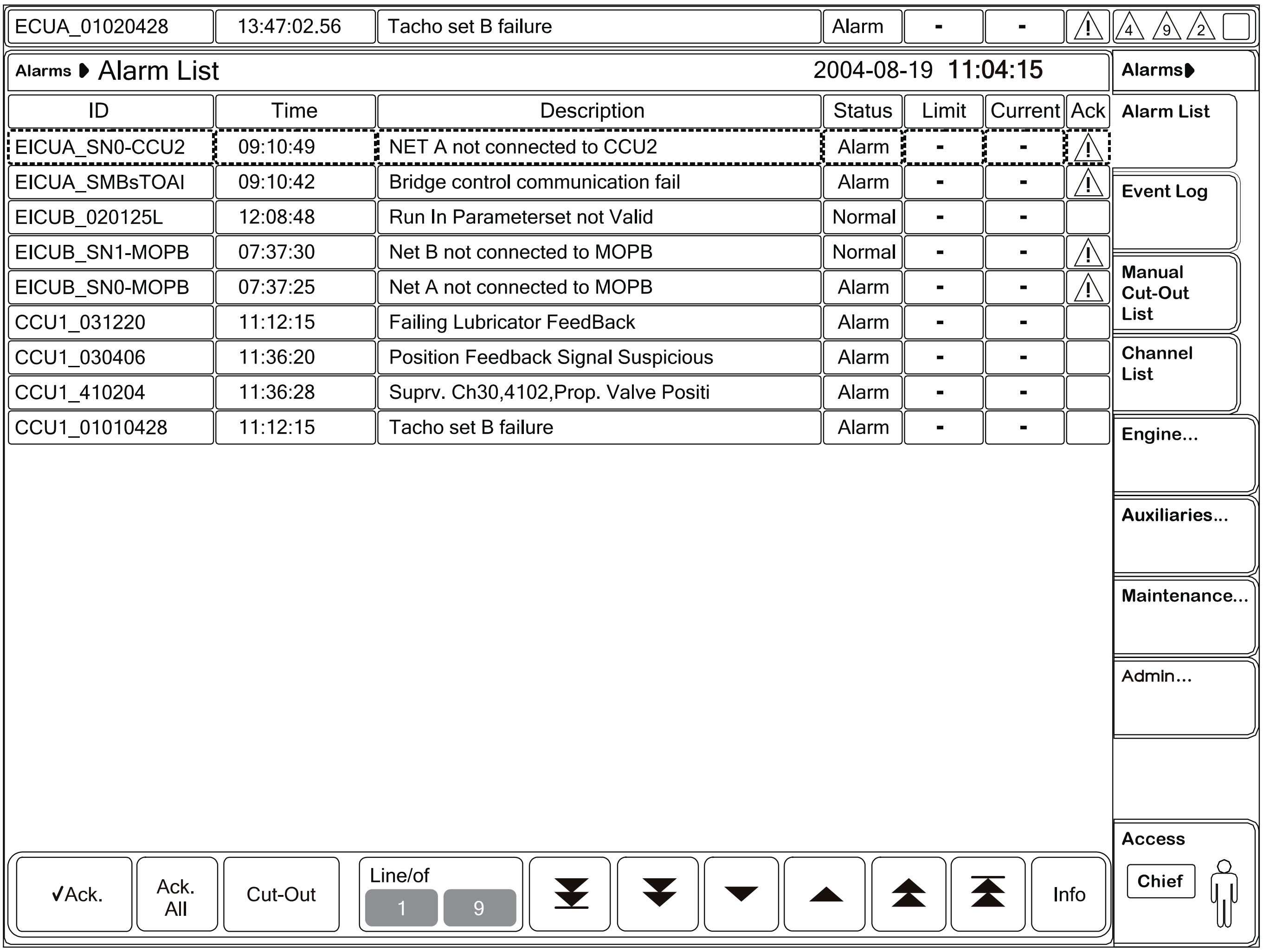

ECS
Controllers
CCU
ECU
ACU
EICU
MOP-A
Control Network
MOP-B
Alarm
System
Ethernet
Hub
CoCoS/
PMI
Other
PC's

Fig. 2


Alarm Status Bar
Screen area
Navigaton Bar
Toolbar
Operator
Level



ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
4
9
2
Alarms
Alarm List
2004-08-19 11:04:15
ID
Time
Description
Status
Limit
Current
Ack
EICUA_SN0-CCU2
09:10:49
NET A not connected to CCU2
Alarm
EICUA_SMBsTOAI
09:10:42
Bridge control communication fail
Alarm
EICUB_020125L
12:08:48
Run In Parameterset not Valid
Normal
EICUB_SN1-MOPB
07:37:30
Net B not connected to MOPB
Normal
EICUB_SN0-MOPB
07:37:25
Net A not connected to MOPB
Alarm
CCU1_031220
11:12:15
Failing Lubricator FeedBack
Alarm
CCU1_030406
11:36:20
Position Feedback Signal Suspicious
Alarm
CCU1_410204
11:36:28
Suprv. Ch30,4102,Prop. Valve Positi
Alarm
CCU1_01010428
11:12:15
Tacho set B failure
Alarm
Alarm List
Event Log
Manual Cut-Out List
Channel List
Engine...
Auxiliaries...
Maintenance...
Admin...
Access
Chief
✓Ack.
Ack. All
Cut-Out
Line/of
1
9
Info

ECUA_01020428	13:47:02.56	Tacho set B failure	Alarm	-	-

Alarms ▶ Event Log   2004-08-19 **11:04:13**

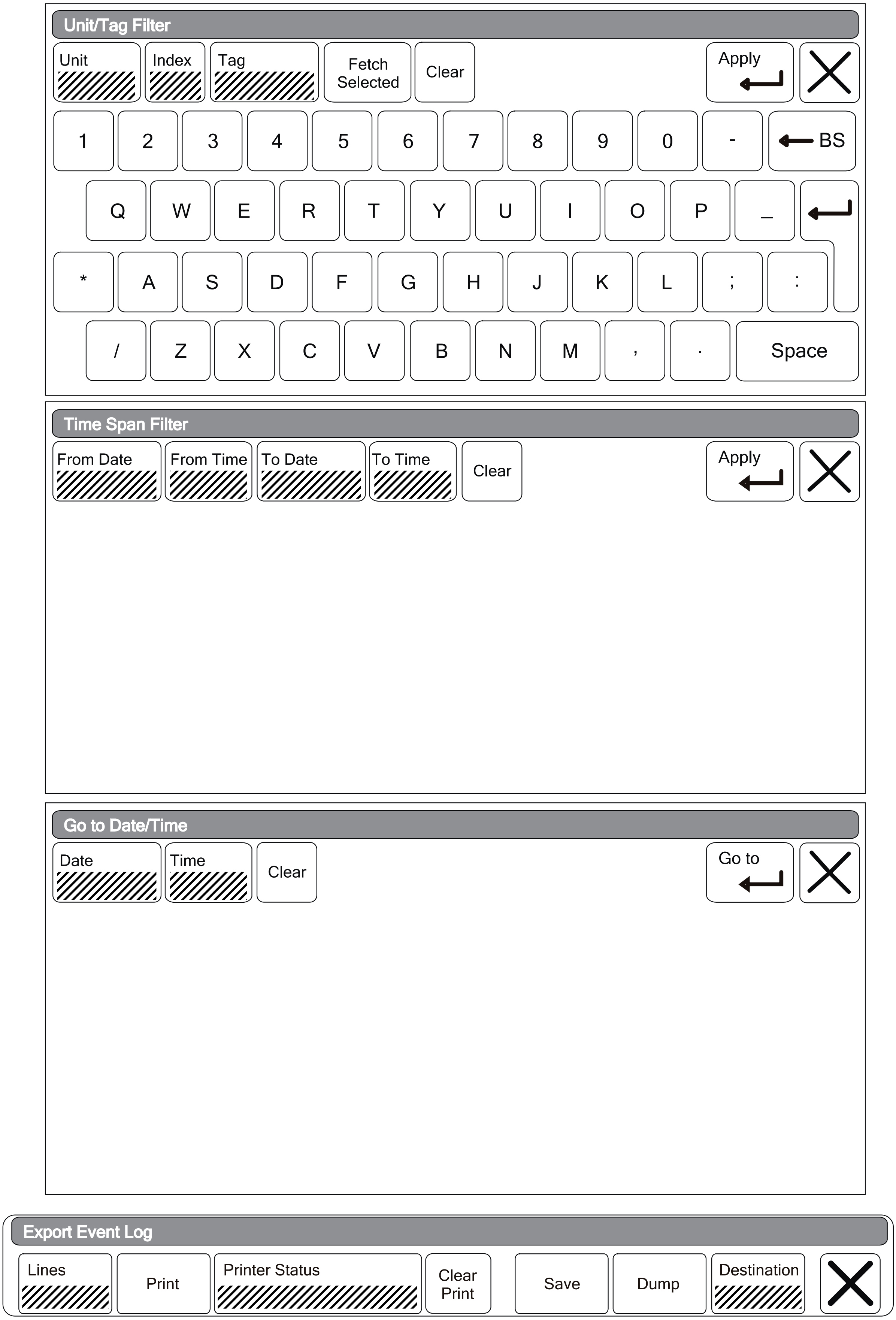
ID: Unit_Tag	Date	Time	Description	Status	MCo	ACo	Ack
UNDEF_WATCHDOG	*2004-08-18*	*11:53:44,83*	*Watchdog enabled*	*Normal*			
UNDEF_WATCHDOG	2004-08-18	11:53:37,76	Contact with hardware establishedl	Normal			
UNDEF_WATCHDOG	2004-08-18	11:49:04,19	Closing network channel 1 succeeded	Alarm			
UNDEF_WATCHDOG	2004-08-18	11:49:03,19	Thread failed in program <*>	Normal			
UNDEF_WATCHDOG	2004-08-18	11:49:03,19	Closing network channel 0 succeeded	Normal			
UNDEF_WATCHDOG	2004-08-18	11:44:33,18	Watchdog enabled	Normal			
EICUA_SN1-MOPB	2004-08-18	11:44:30,27	Net B not connected to MOPB	Normal			
EICUA_SN0-MOPB	2004-08-18	11:44:29,52	Net A not connected to MOPB	Normal			
EICUA_SN1-MOPB	2004-08-18	11:44:29,52	Net B not connected to MOPB	Normal			
EICUA_SN0-MOPB	2004-08-18	11:44:26,13	Net A not connected to MOPB	Normal			
UNDEF_WATCHDOG	2004-08-18	11:43:01,69	Contact with hardware established	Normal			
UNDEF_WATCHDOG	2004-08-18	11:43:00,69	Closing network channel 1 succeeded	Normal			
UNDEF_WATCHDOG	2004-08-18	11:43:00,69	Closing network channel 0 succeeded	Normal			
UNDEF_WATCHDOG	2004-08-18	11:42:24,70	Thread failed in program <*>	Alarm			
UNDEF_WATCHDOG	2004-08-18	11:42:22,70	Watchdog enabled	Normal			
EICUA_SN0-MOPB	2004-08-18	11:42:20,53	Net A not connected to MOPB	Normal			

Unit/Tag Filter | Time Span Filter | Go to Date/Time | Export | Info

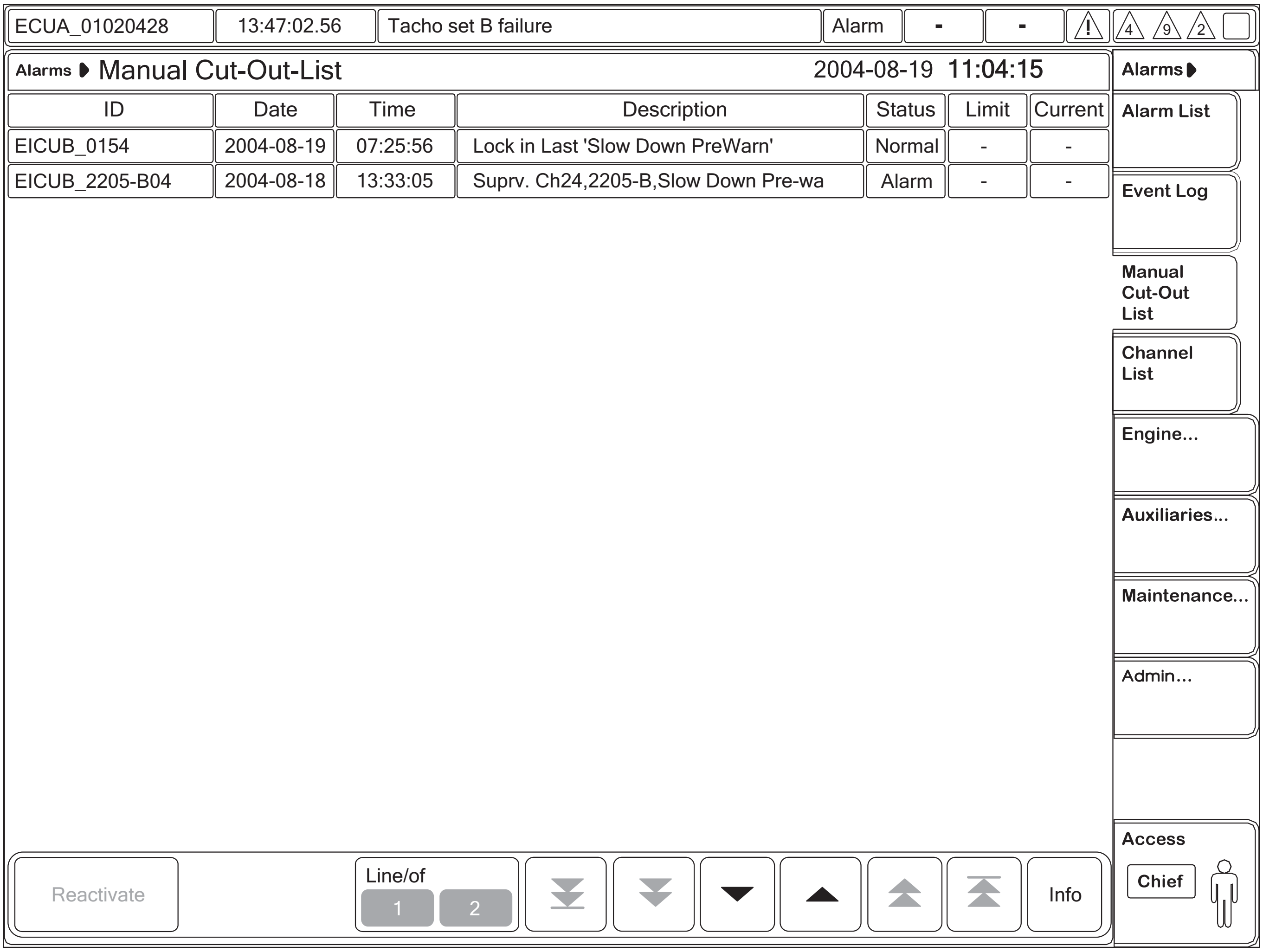
Alarms:

- Alarm List
- Event Log
- Manual Cut-Out List
- Channel List
- Engine...
- Auxiliaries...
- Maintenance...
- Admin...

Access: Chief


Unit/Tag Filter
Unit
Index
Tag
Fetch Selected
Clear
Apply
1 2 3 4 5 6 7 8 9 0 -
BS
Q W E R T Y U I O P _
* A S D F G H J K L ; :
/ Z X C V B N M , .
Space
Time Span Filter
From Date
From Time
To Date
To Time
Clear
Apply
Go to Date/Time
Date
Time
Clear
Go to
Export Event Log
Lines
Print
Printer Status
Clear Print
Save
Dump
Destination

MOP Manual Cut-Out List



ECUA_01020428	13:47:02.56	Tacho set B failure	Alarm	-	-	4	9 2

Alarms ▶ Channel List 2004-08-19 **11:04:18**

ID	Date	Time	Description	Status	MCo	ACo	Ack
ACU1_009904	2004-08-19	11:03:50	Suprv. Ch35,0099,Prop. Valve Test S	Alarm			X
ACU1_010110	2004-08-19	11:03:50	No Commands from ECU A	Normal			X
ACU1_010111	2004-08-19	11:03:50	No commands from ECU B	Normal			X
ACU1_0210	2004-08-18	12:45:07	Blower 1 Ctrl Failed	Normal			X
ACU1_070119	2004-08-19	11:03:58	Pump ctrl failure	Normal			X
ACU1_07013604	2004-08-18	12:45:09	Watchdog enabled	Normal			X
ACU1_07013605	2004-08-18	12:45:09	PV_AMP Amp. Current Supervision	Normal			X
ACU1_070210	2004-08-18	12:45:09	PV_AMP Amp. Reports Internal Fault	Normal			X
ACU1_0708	2004-08-18	12:45:10	Startup Pump Ctrl Failed	Normal			X
ACU1_1109-A4	2004-08-18	12:45:04	Hydraulic leakage (high level)	Normal			X
ACU1_1110-A4	2004-08-18	12:45:04	Suprv. Ch23,1109-A, Turning gear dis	Normal			X
ACU1_1111-A4	2004-08-18	12:45:04	Suprv. Ch22,1110-A, Turning gear eng	Normal			X
ACU1_1112-A4	2004-08-18	12:45:04	Suprv. Ch21,1111-A, Main start valve	Normal			X
ACU1_1116-A4	2004-08-18	12:45:04	Suprv. Ch24,1112-A, Main start valve	Normal			X
ACU1_1201-104	2004-08-18	11:03:50	Suprv. Ch25,1116-A, Start air dist I	Normal			X
ACU1_1202-A03	2004-08-18	12:45:06	Suprv. Ch31,1201-1, Hydraulic Pressure	Normal			X
ACU1_1204-104	2004-08-19	11:03:50	Suprv. Ch80,1202-A, System bypass op	Normal			X
ACU1_1222-104	2004-08-18	12:45:06	Suprv. Ch32,1204-1, Lube oil pressur	Normal			X
ACU1_123604	2004-08-18	12:45:05	Suprv. Ch34,1222-1, Swash-Plate Posi	Normal			X
ACU1_1238-104	2004-08-18	12:45:06	Suprv. Ch27,1236-1, Hyd. leak shutdown	Normal			X
ACU1_8501-A04	2004-08-19	11:03:50	Suprv. Ch30,1238-1, Prop. valve Feed	Normal			X

Cut-Out | Reactivate | Line/of --- --- | Info

Alarms ▶

Alarm List

Event Log

Manual Cut-Out List

Channel List

Engine...

Auxiliaries...

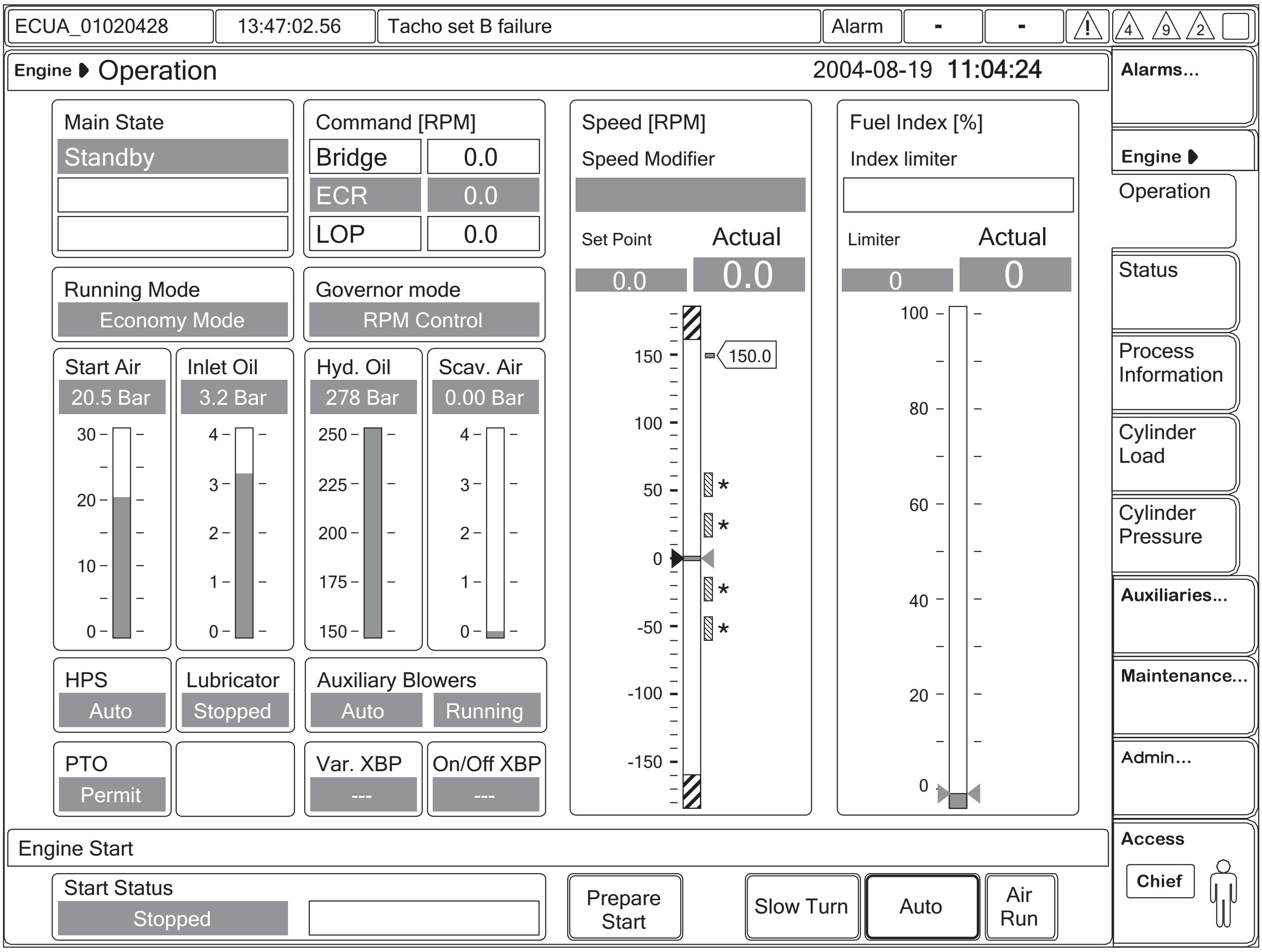
System...

Admin...

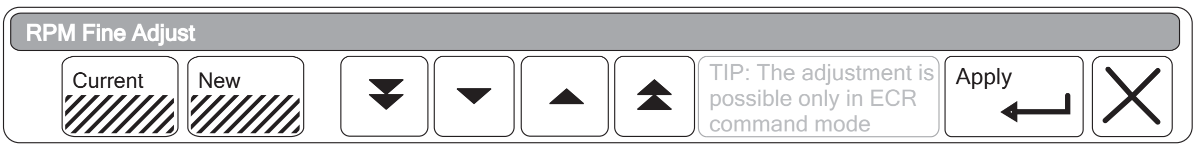
Access

Chief

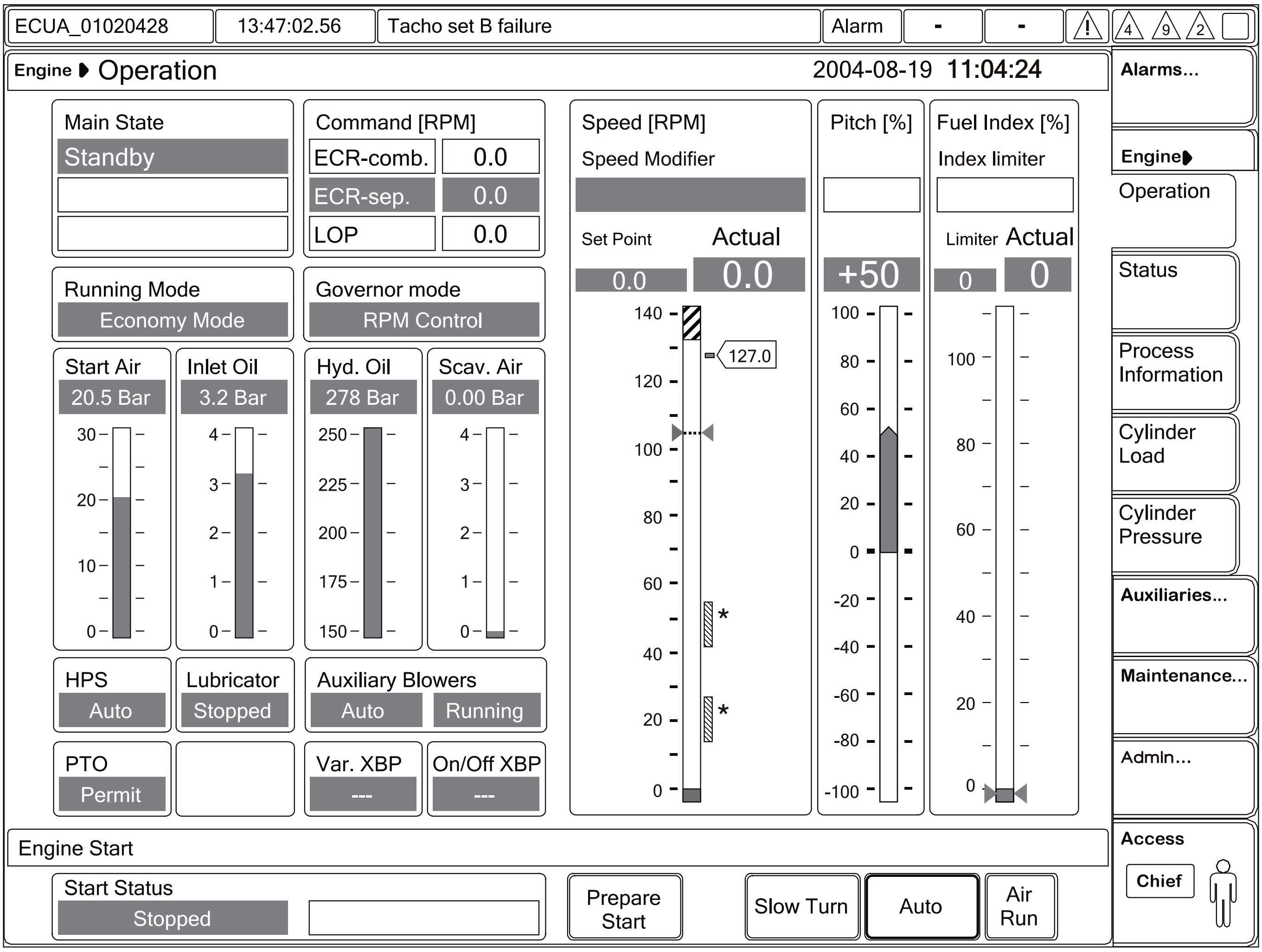
FPP = Fixed Pitch Propeller



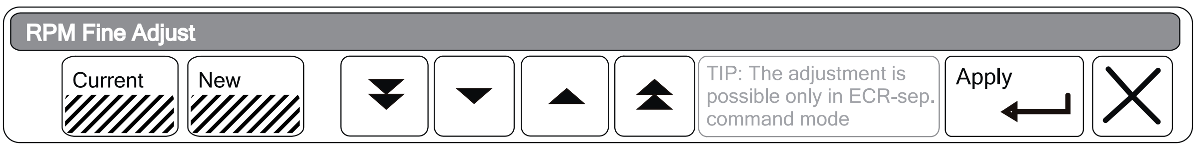
* Barred Speed Range may vary depending on engine setup

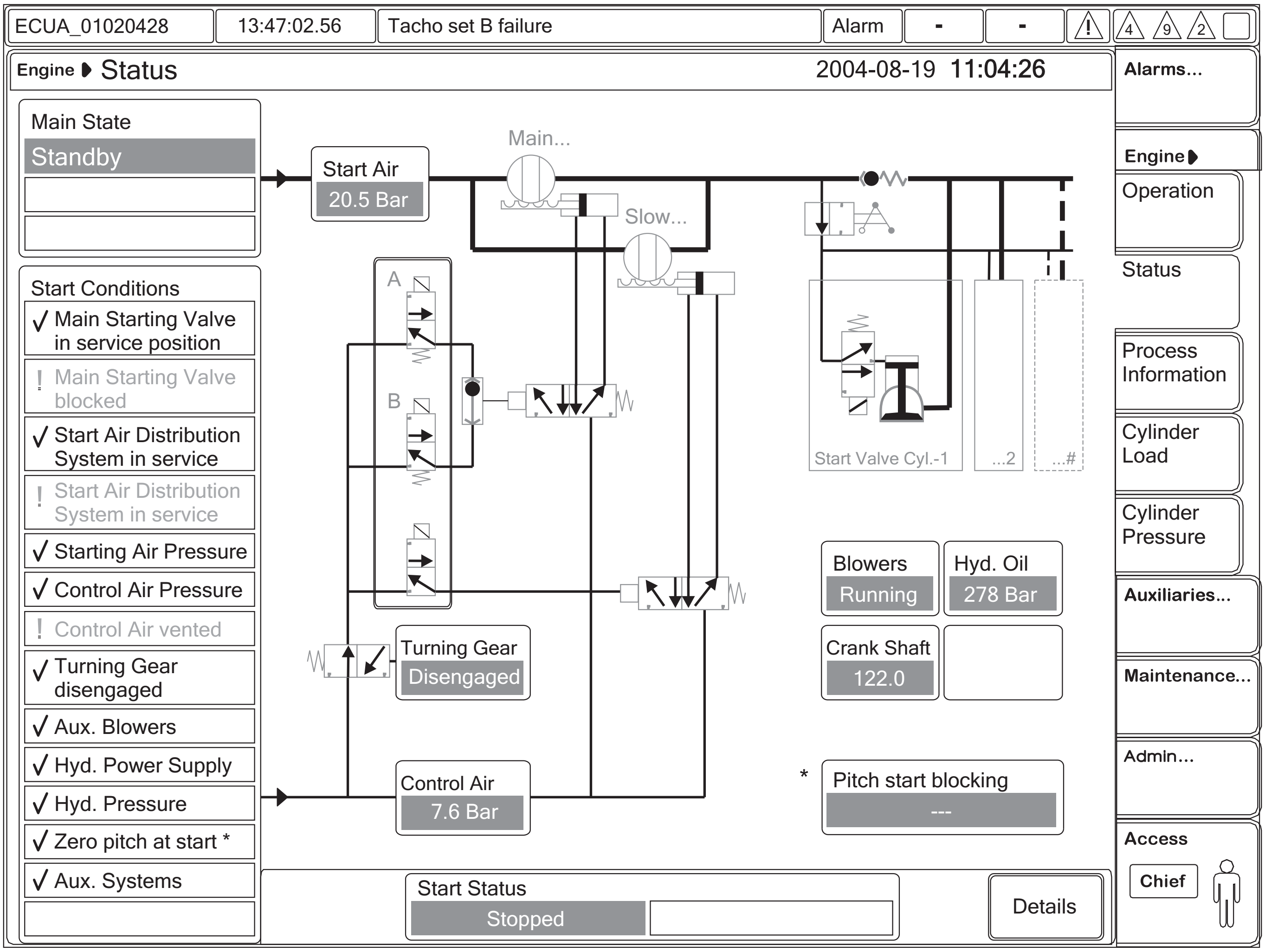


CPP = Controlable Pitch Propeller

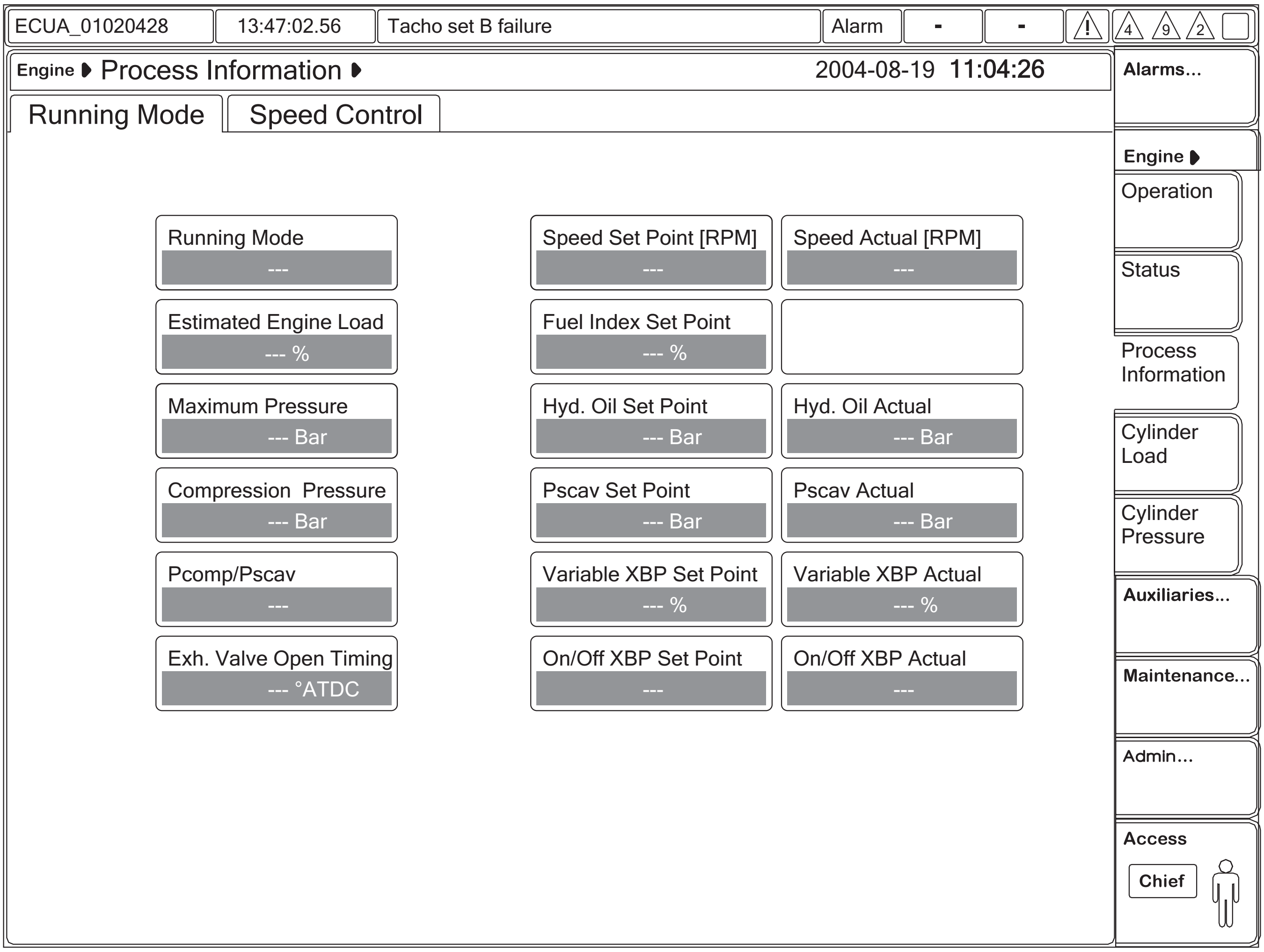


* Barred Speed Range may vary depending on engine setup





* If CPP is present.



ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
-
-
4
9
2
Engine
Process Information
2004-08-19 11:04:26
Running Mode
Speed Control
Running Mode

Estimated Engine Load
--- %
Maximum Pressure
--- Bar
Compression Pressure
--- Bar
Pcomp/Pscav

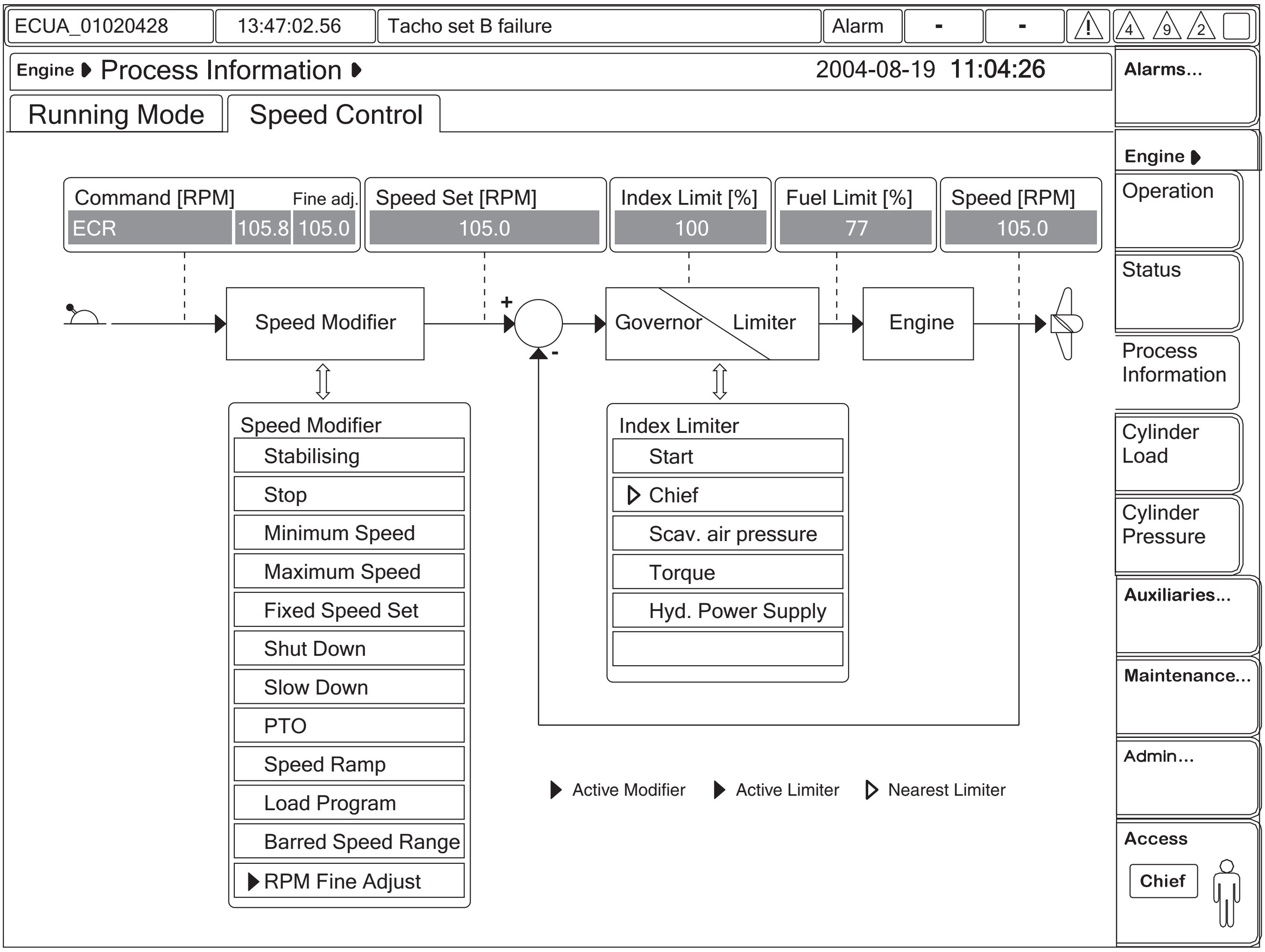
Exh. Valve Open Timing
--- °ATDC
Speed Set Point [RPM]

Speed Actual [RPM]

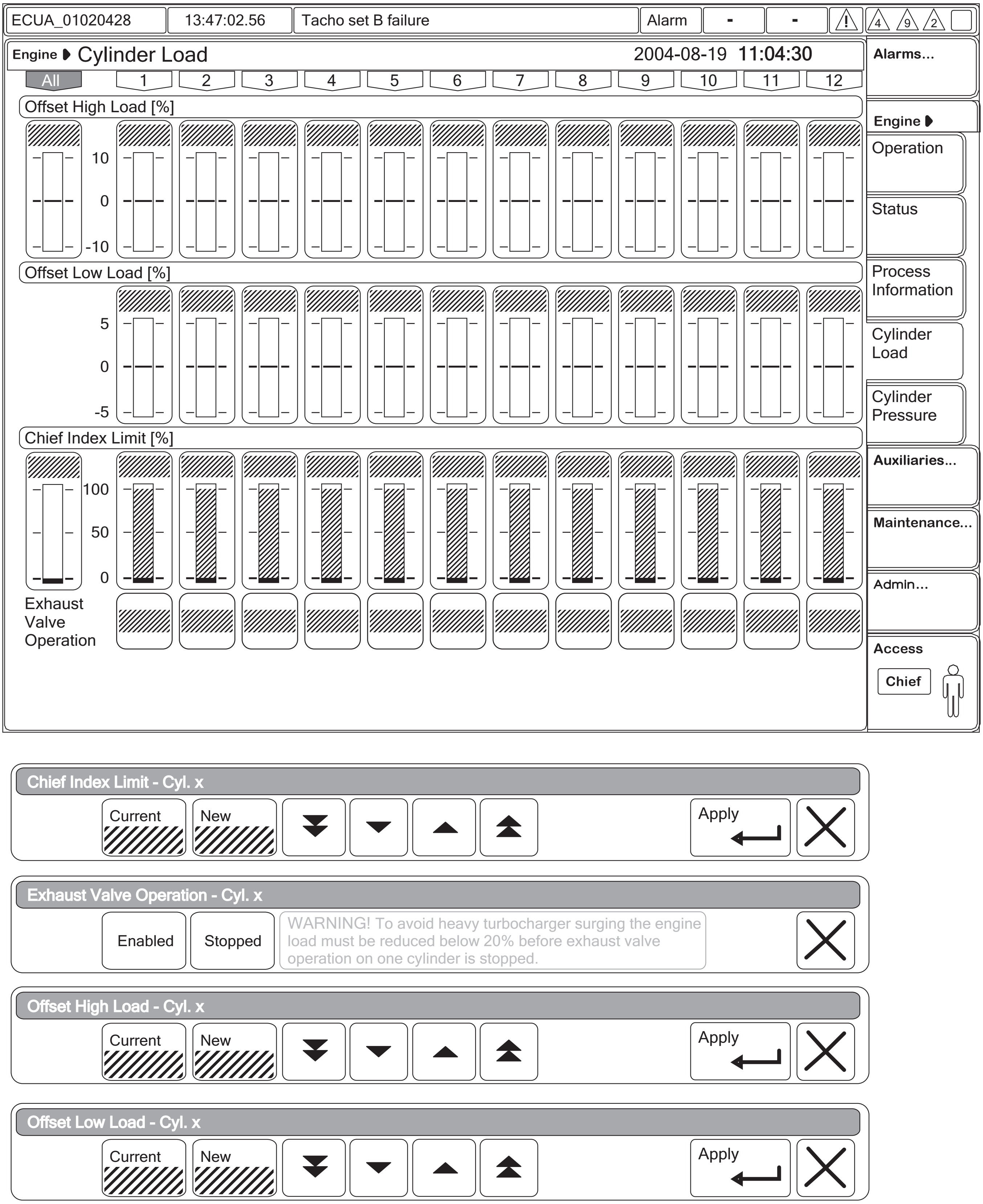
Fuel Index Set Point
--- %
Hyd. Oil Set Point
--- Bar
Hyd. Oil Actual
--- Bar
Pscav Set Point
--- Bar
Pscav Actual
--- Bar
Variable XBP Set Point
--- %
Variable XBP Actual
--- %
On/Off XBP Set Point

On/Off XBP Actual

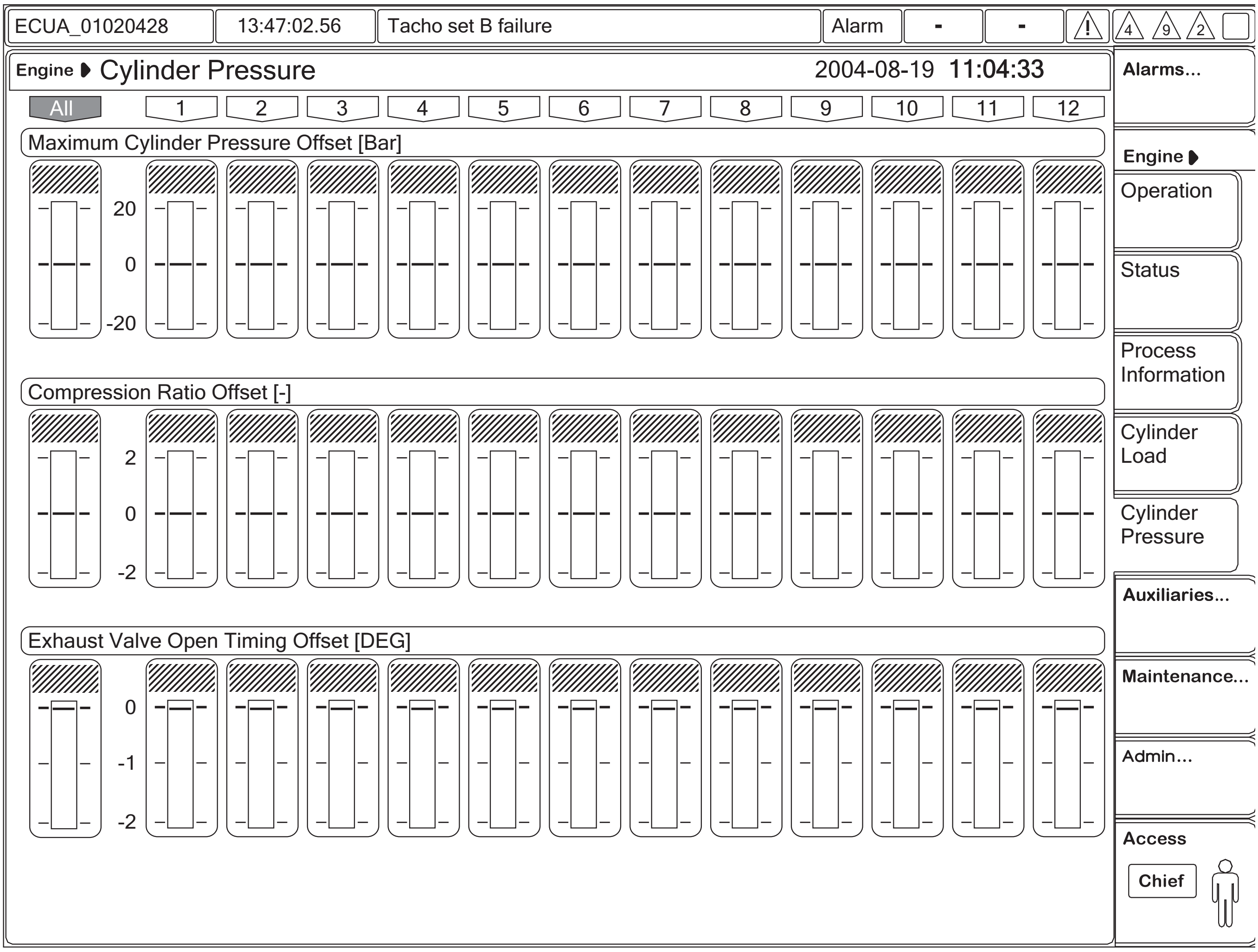
Alarms...
Engine
Operation
Status
Process Information
Cylinder Load
Cylinder Pressure
Auxiliaries...
Maintenance...
Admin...
Access
Chief

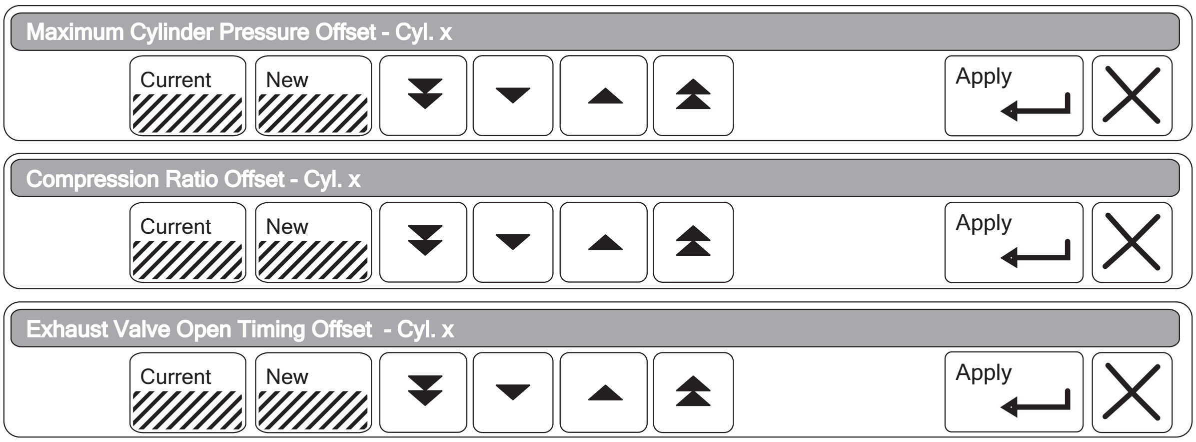

ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
-
-
Engine Process Information
2004-08-19 11:04:26
Alarms...
Running Mode
Speed Control
Engine
Operation
Status
Process Information
Cylinder Load
Cylinder Pressure
Auxiliaries...
Maintenance...
Admin...
Access
Chief
Command [RPM]
Fine adj.
ECR
105.8
105.0
Speed Set [RPM]
105.0
Index Limit [%]
100
Fuel Limit [%]
77
Speed [RPM]
105.0
Speed Modifier
+
-
Governor
Limiter
Engine
Speed Modifier
Stabilising
Stop
Minimum Speed
Maximum Speed
Fixed Speed Set
Shut Down
Slow Down
PTO
Speed Ramp
Load Program
Barred Speed Range
RPM Fine Adjust
Index Limiter
Start
Chief
Scav. air pressure
Torque
Hyd. Power Supply
Active Modifier
Active Limiter
Nearest Limiter

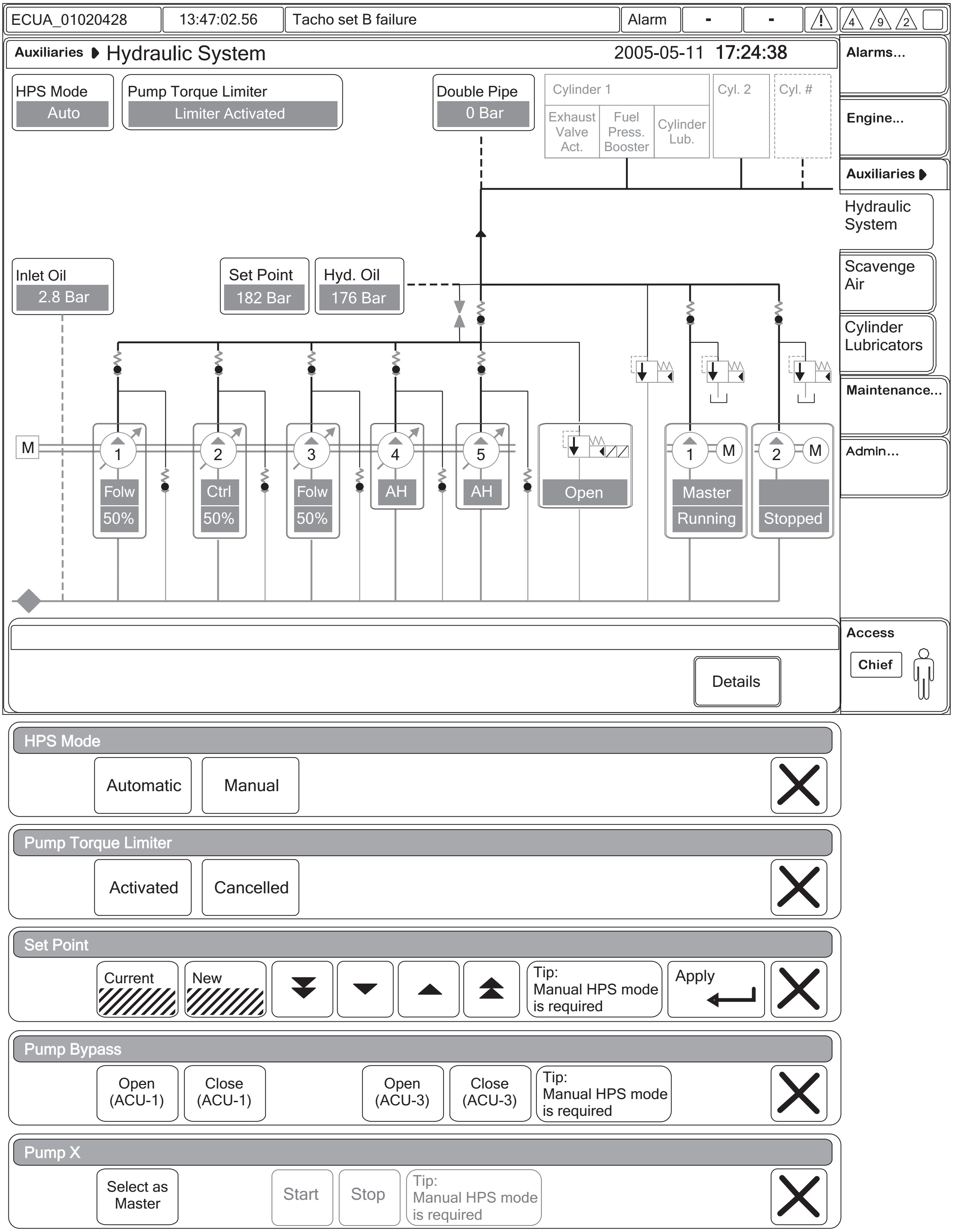
MOP Cylinder Load



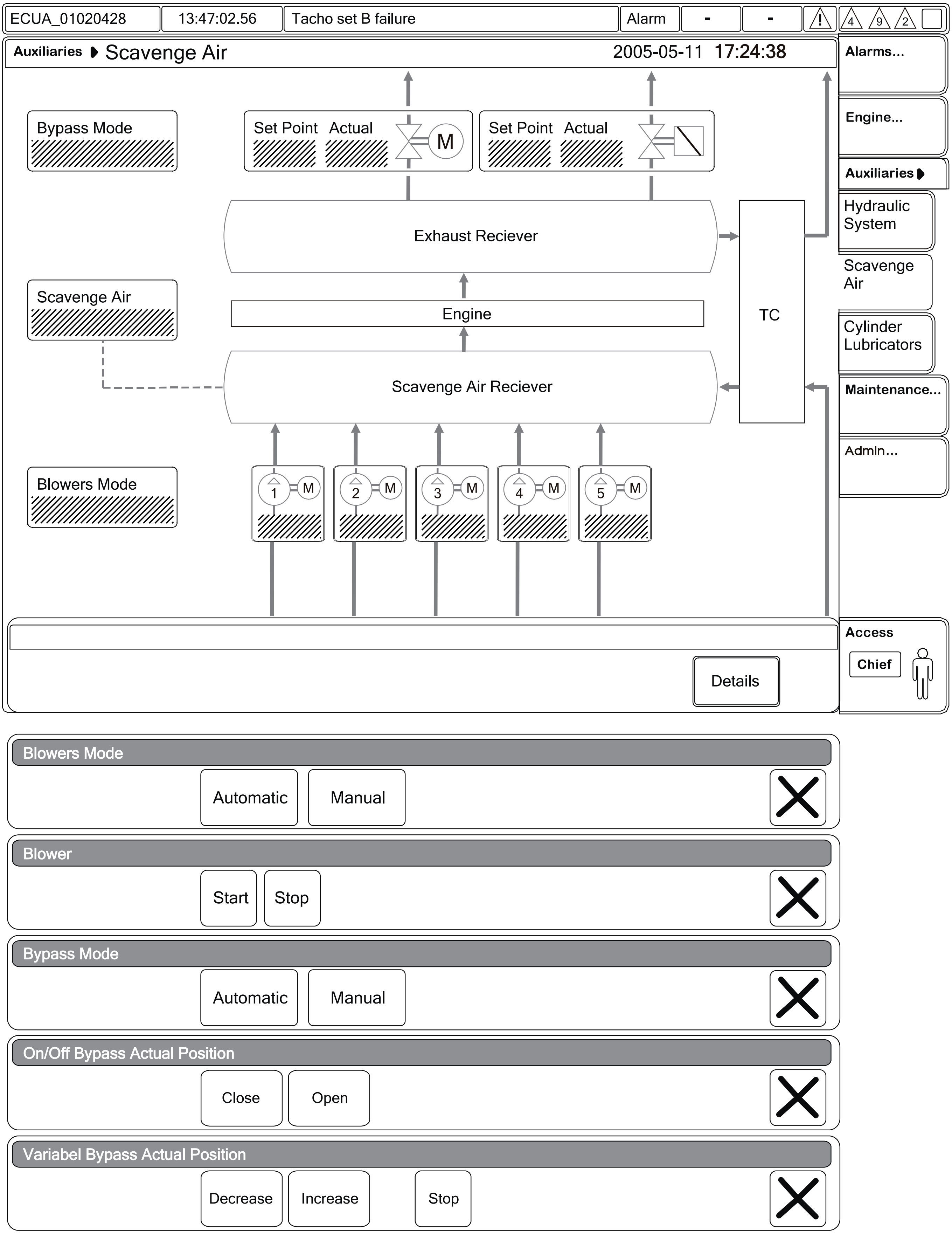
MOP Cylinder Pressure



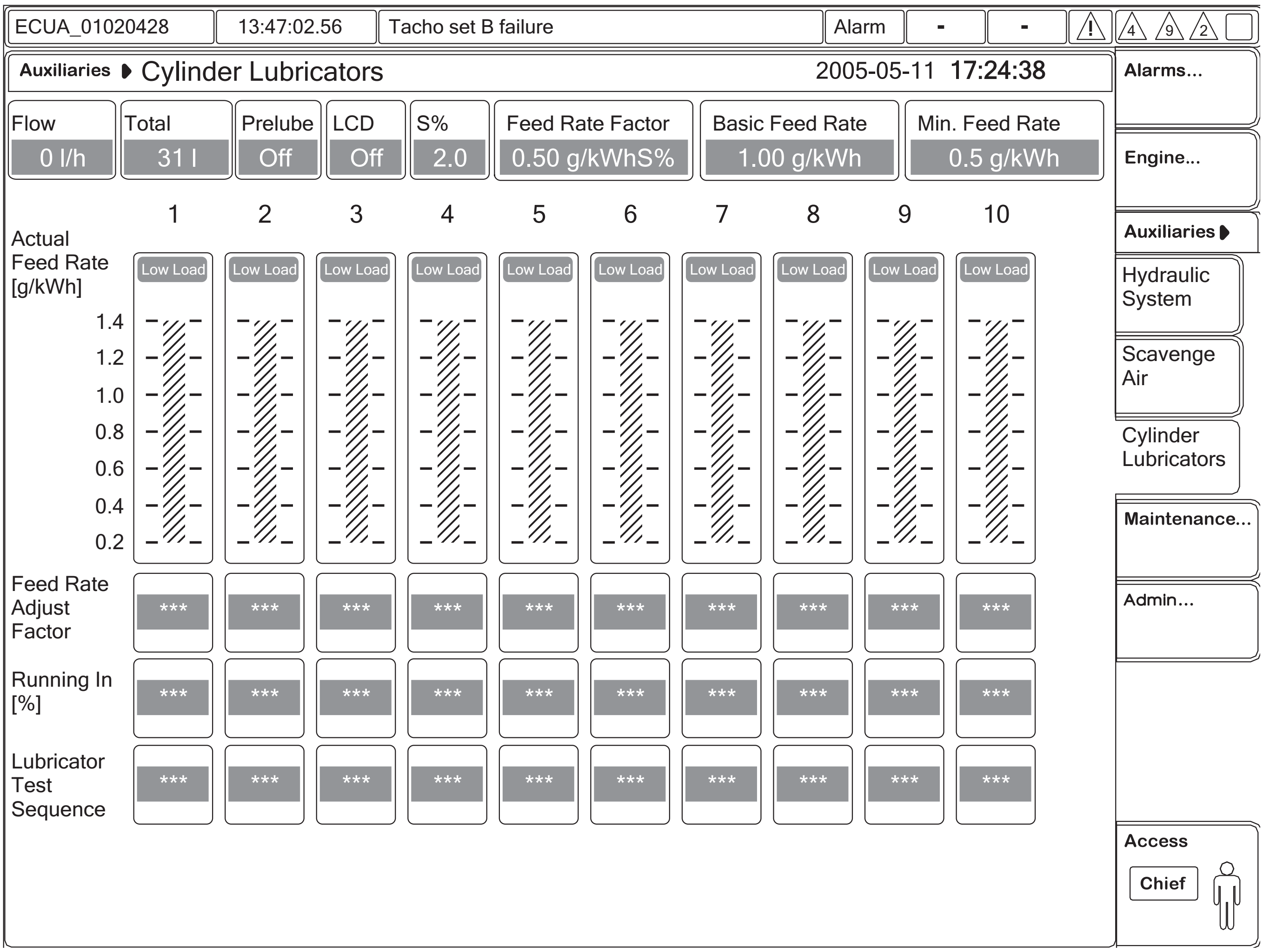




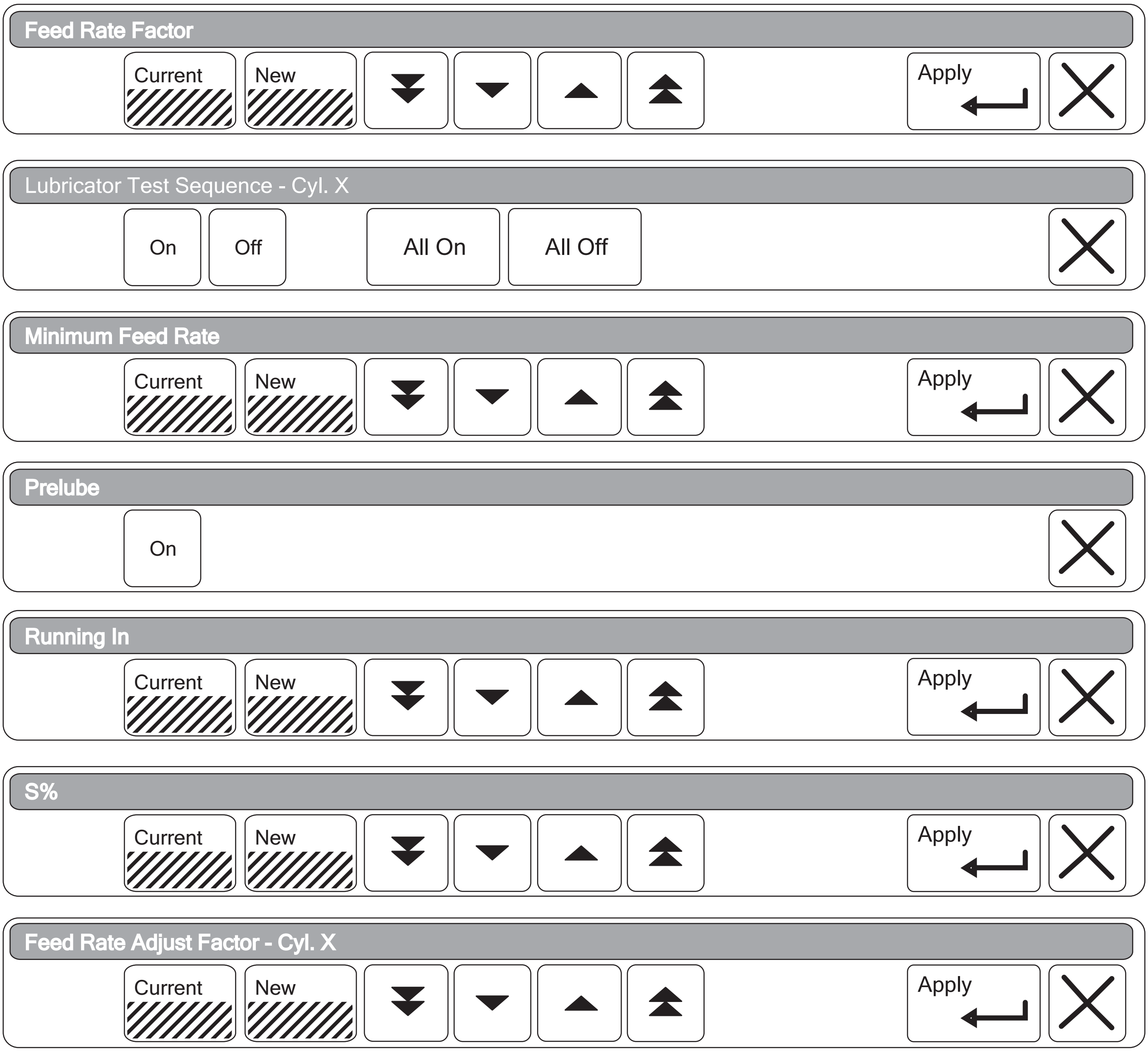
ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
4
9
2
Auxiliaries
Hydraulic System
2005-05-11
17:24:38
Alarms...
HPS Mode
Auto
Pump Torque Limiter
Limiter Activated
Double Pipe
0 Bar
Cylinder 1
Exhaust Valve Act.
Fuel Press. Booster
Cylinder Lub.
Cyl. 2
Cyl. #
Engine...
Auxiliaries
Hydraulic System
Inlet Oil
2.8 Bar
Set Point
182 Bar
Hyd. Oil
176 Bar
Scavenge Air
Cylinder Lubricators
Maintenance...
Admin...
M
1
Folw
50%
2
Ctrl
50%
3
Folw
50%
4
AH
5
AH
Open
1
M
Master
Running
2
M
Stopped
Details
Access
Chief
HPS Mode
Automatic
Manual
Pump Torque Limiter
Activated
Cancelled
Set Point
Current
New
Tip: Manual HPS mode is required
Apply
Pump Bypass
Open (ACU-1)
Close (ACU-1)
Open (ACU-3)
Close (ACU-3)
Tip: Manual HPS mode is required
Pump X
Select as Master
Start
Stop
Tip: Manual HPS mode is required

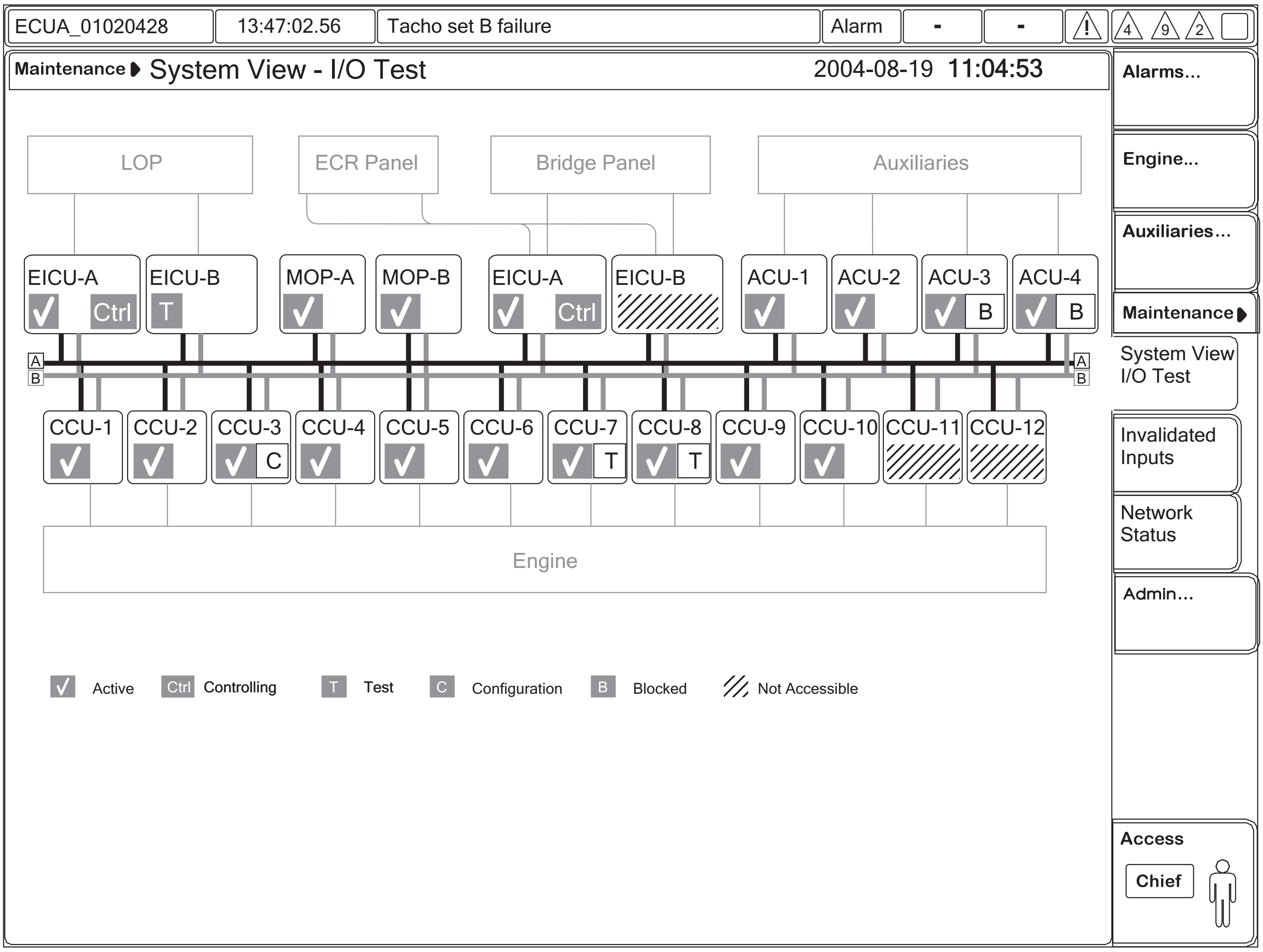


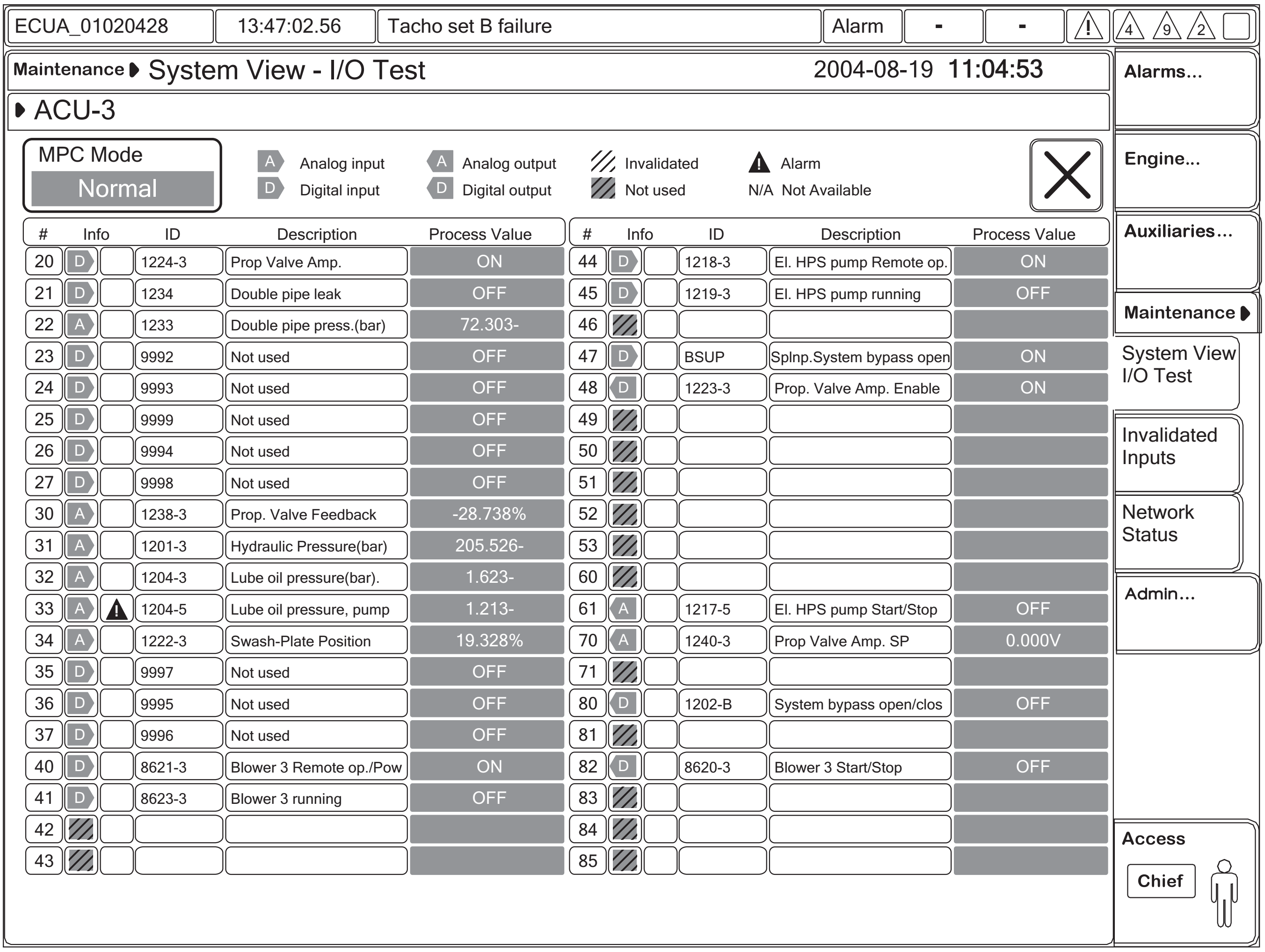
ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
-
-
4
9
2
Auxiliaries
Scavenge Air
2005-05-11
17:24:38
Alarms...
Engine...
Auxiliaries
Hydraulic System
Scavenge Air
Cylinder Lubricators
Maintenance...
Admin...
Bypass Mode
Set Point
Actual
M
Set Point
Actual
Exhaust Reciever
TC
Scavenge Air
Engine
Scavenge Air Reciever
Blowers Mode
1
M
2
M
3
M
4
M
5
M
Details
Access
Chief
Blowers Mode
Automatic
Manual
Blower
Start
Stop
Bypass Mode
Automatic
Manual
On/Off Bypass Actual Position
Close
Open
Variabel Bypass Actual Position
Decrease
Increase
Stop



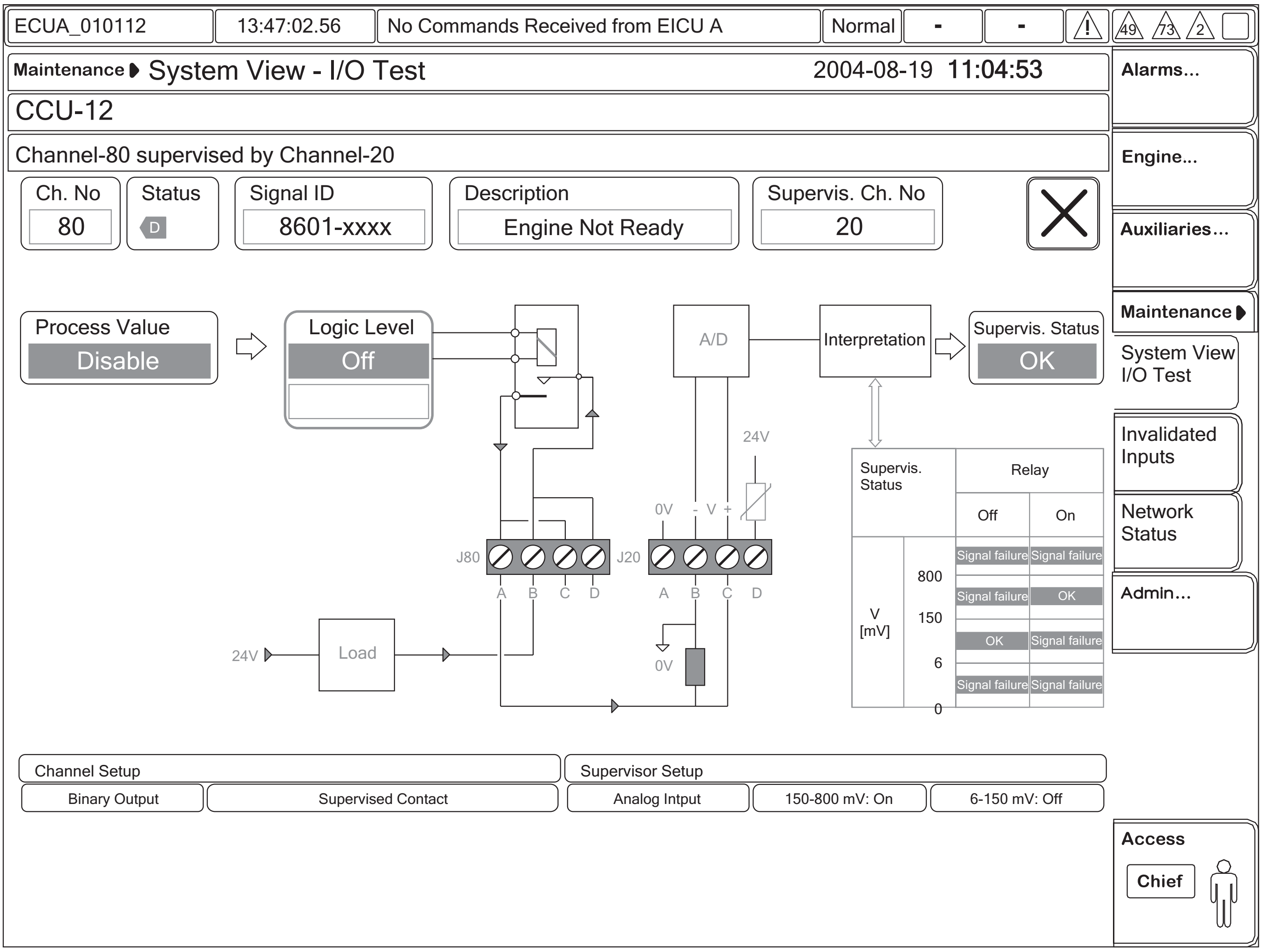
ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
-
-
4
9
2
Auxiliaries
Cylinder Lubricators
2005-05-11 17:24:38
Alarms...
Engine...
Auxiliaries
Hydraulic System
Scavenge Air
Cylinder Lubricators
Maintenance...
Admin...
Access
Chief
Flow
0 l/h
Total
31 l
Prelube
Off
LCD
Off
S%
2.0
Feed Rate Factor
0.50 g/kWhS%
Basic Feed Rate
1.00 g/kWh
Min. Feed Rate
0.5 g/kWh
1 2 3 4 5 6 7 8 9 10
Actual Feed Rate [g/kWh]
Low Load
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Feed Rate Adjust Factor
***
Running In [%]
***
Lubricator Test Sequence
***

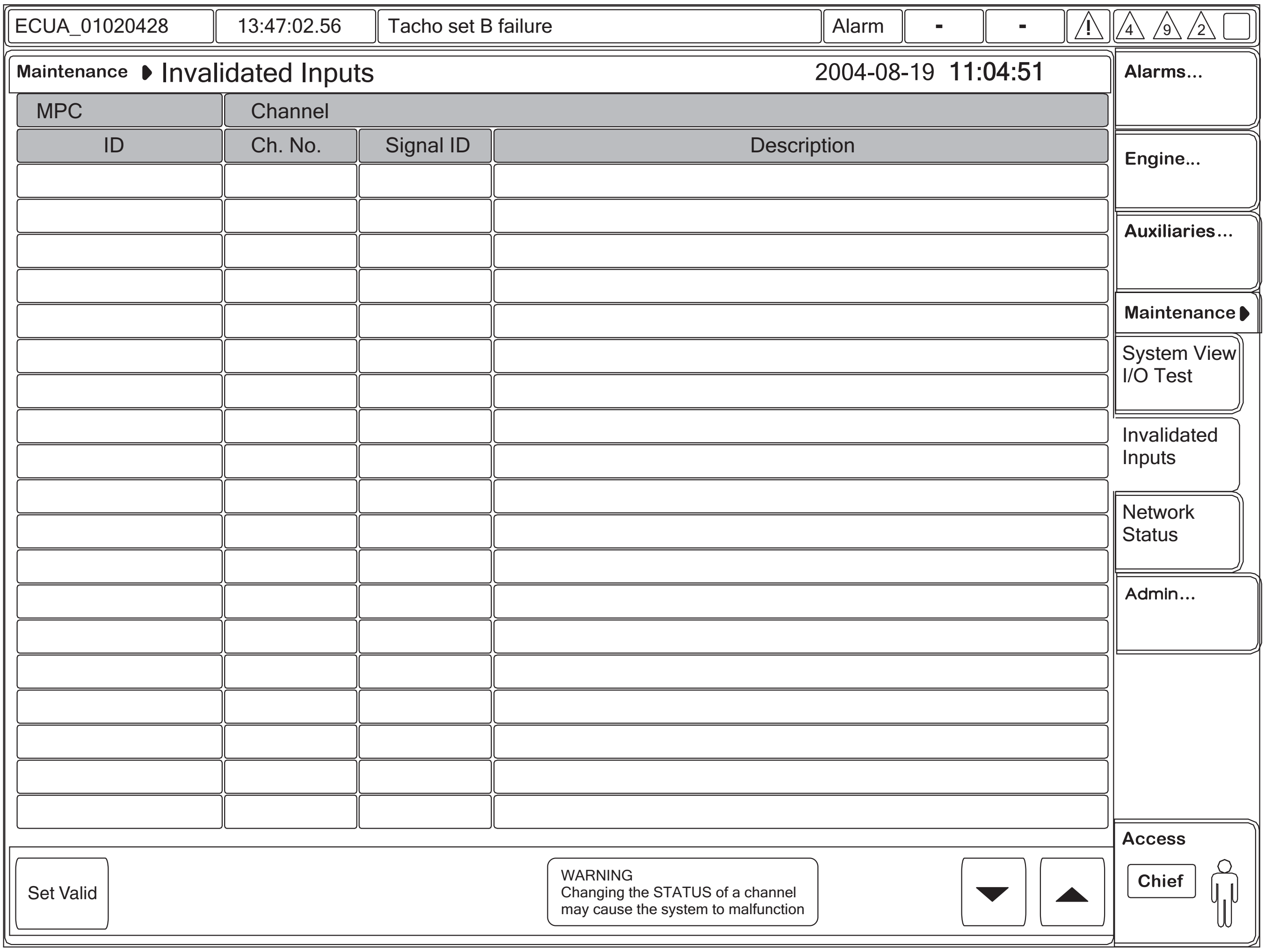

Feed Rate Factor
Current
New
Apply
Lubricator Test Sequence - Cyl. X
On
Off
All On
All Off
Minimum Feed Rate
Current
New
Apply
Prelube
On
Running In
Current
New
Apply
S%
Current
New
Apply
Feed Rate Adjust Factor - Cyl. X
Current
New
Apply

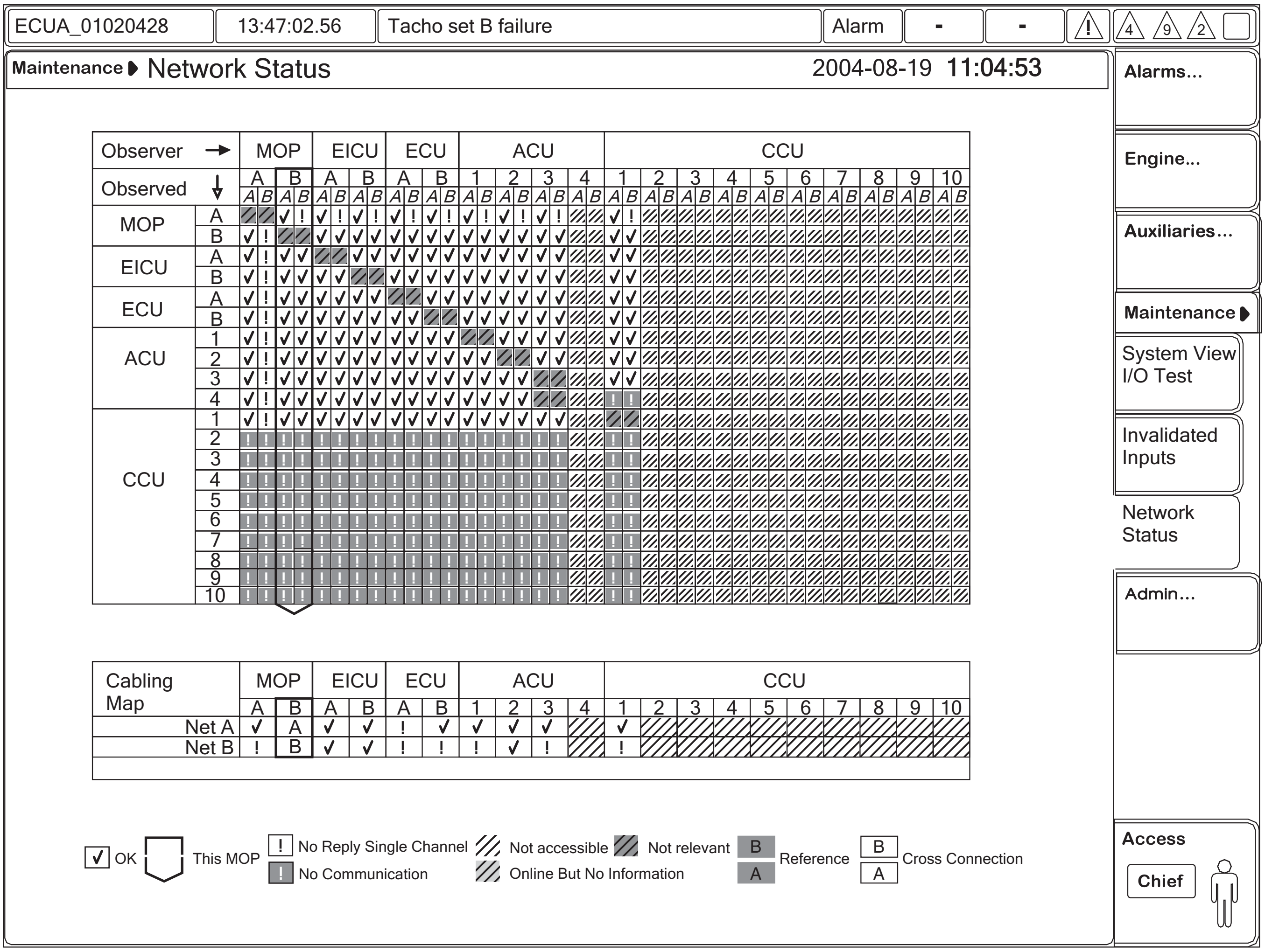

ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
Maintenance
System View - I/O Test
2004-08-19 11:04:53
Alarms...
Engine...
Auxiliaries...
Maintenance
System View I/O Test
Invalidated Inputs
Network Status
Admin...
LOP
ECR Panel
Bridge Panel
Auxiliaries
EICU-A
EICU-B
MOP-A
MOP-B
ACU-1
ACU-2
ACU-3
ACU-4
Ctrl
T
B
A
CCU-1
CCU-2
CCU-3
CCU-4
CCU-5
CCU-6
CCU-7
CCU-8
CCU-9
CCU-10
CCU-11
CCU-12
C
Engine
Active
Controlling
Test
Configuration
Blocked
Not Accessible
Access
Chief



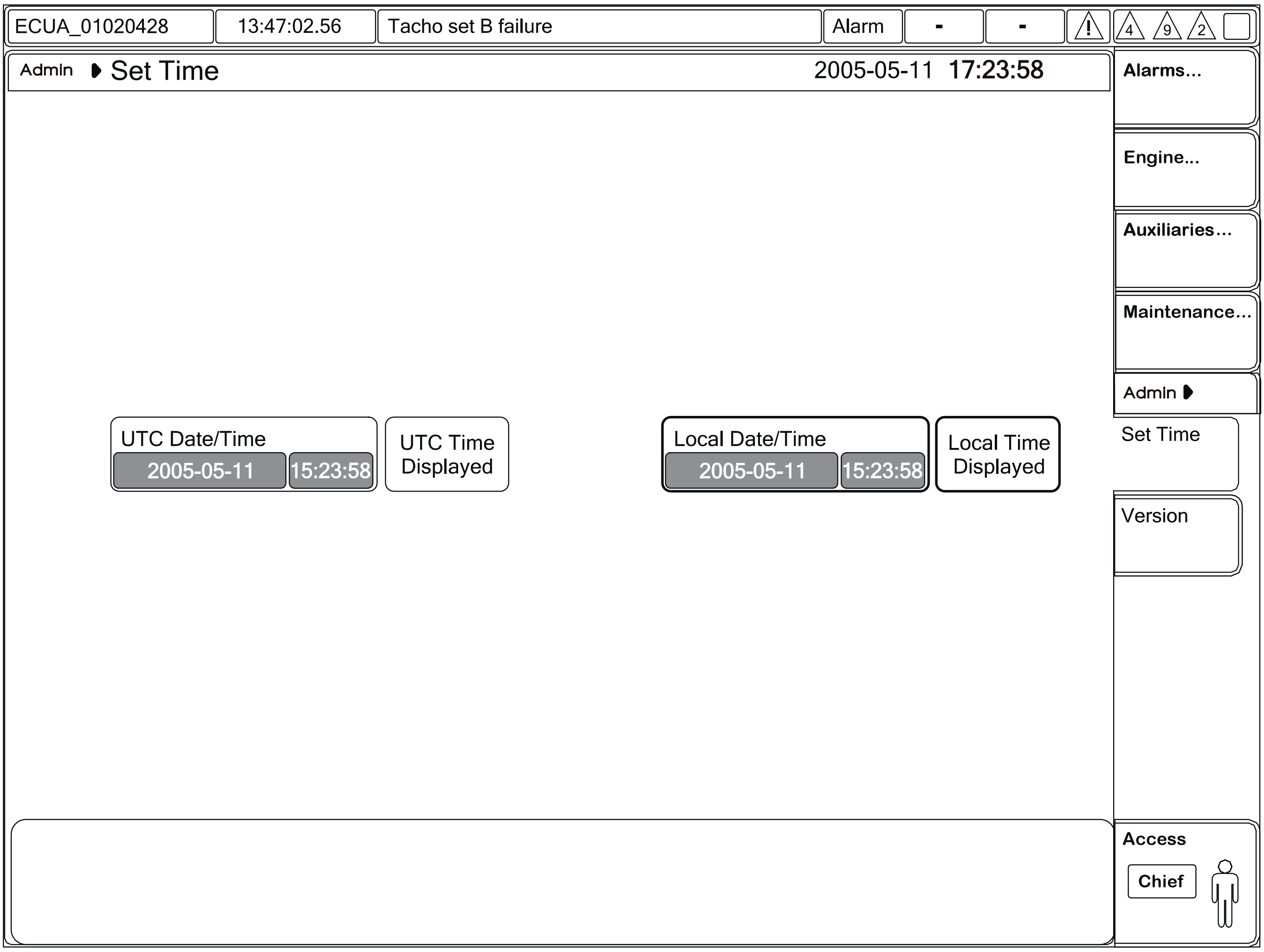
ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
-
-
4
9
2
Maintenance
System View - I/O Test
2004-08-19 11:04:53
ACU-3
MPC Mode
Normal
Analog input
Digital input
Analog output
Digital output
Invalidated
Not used
Alarm
N/A Not Available
Info ID Description Process Value
20 D 1224-3 Prop Valve Amp. ON
21 D 1234 Double pipe leak OFF
22 A 1233 Double pipe press.(bar) 72.303-
23 D 9992 Not used OFF
24 D 9993 Not used OFF
25 D 9999 Not used OFF
26 D 9994 Not used OFF
27 D 9998 Not used OFF
30 A 1238-3 Prop. Valve Feedback -28.738%
31 A 1201-3 Hydraulic Pressure(bar) 205.526-
32 A 1204-3 Lube oil pressure(bar). 1.623-
33 A 1204-5 Lube oil pressure, pump 1.213-
34 A 1222-3 Swash-Plate Position 19.328%
35 D 9997 Not used OFF
36 D 9995 Not used OFF
37 D 9996 Not used OFF
40 D 8621-3 Blower 3 Remote op./Pow ON
41 D 8623-3 Blower 3 running OFF
42
43
Info ID Description Process Value
44 D 1218-3 El. HPS pump Remote op. ON
45 D 1219-3 El. HPS pump running OFF
46
47 D BSUP Splnp.System bypass open ON
48 D 1223-3 Prop. Valve Amp. Enable ON
49
50
51
52
53
60
61 A 1217-5 El. HPS pump Start/Stop OFF
70 A 1240-3 Prop Valve Amp. SP 0.000V
71
80 D 1202-B System bypass open/clos OFF
81
82 D 8620-3 Blower 3 Start/Stop OFF
83
84
85
Alarms...
Engine...
Auxiliaries...
Maintenance
System View
I/O Test
Invalidated
Inputs
Network
Status
Admin...
Access
Chief


ECUA_010112
13:47:02.56
No Commands Received from EICU A
Normal
49
73
2
Maintenance
System View - I/O Test
2004-08-19 11:04:53
Alarms...
CCU-12
Engine...
Channel-80 supervised by Channel-20
Ch. No
80
Status
D
Signal ID
8601-xxxx
Description
Engine Not Ready
Supervis. Ch. No
20
Auxiliaries...
Maintenance
Process Value
Disable
Logic Level
Off
A/D
Interpretation
Supervis. Status
OK
System View
I/O Test
Invalidated
Inputs
Network
Status
Admin...
24V
0V
V
J80
J20
A
B
C
D
24V
Load
0V
Supervis.
Status
Relay
Off
On
800
150
6
0
V
[mV]
Signal failure
OK
Channel Setup
Binary Output
Supervised Contact
Supervisor Setup
Analog Intput
150-800 mV: On
6-150 mV: Off
Access
Chief

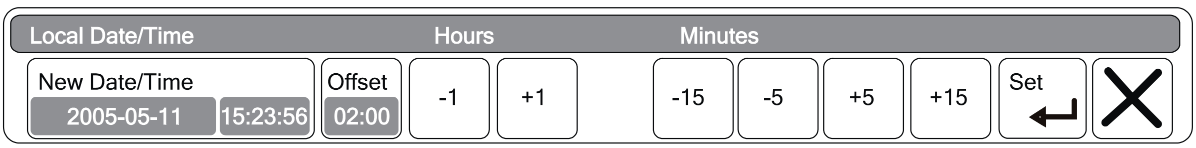

ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
-
-
4
9
2
Maintenance
Invalidated Inputs
2004-08-19 11:04:51
MPC
Channel
ID
Ch. No.
Signal ID
Description
Alarms...
Engine...
Auxiliaries...
Maintenance
System View I/O Test
Invalidated Inputs
Network Status
Admin...
Access
Chief
Set Valid
WARNING
Changing the STATUS of a channel
may cause the system to malfunction



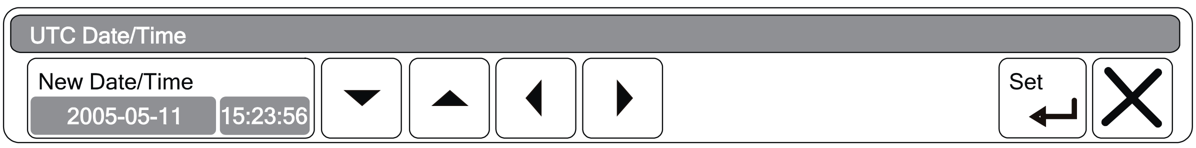
ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
Maintenance
Network Status
2004-08-19 11:04:53
Alarms...
Engine...
Auxiliaries...
Maintenance
System View I/O Test
Invalidated Inputs
Network Status
Admin...
Access
Chief
Observer
Observed
MOP
EICU
ECU
ACU
CCU
Cabling Map
Net A
Net B
OK
This MOP
No Reply Single Channel
No Communication
Not accessible
Online But No Information
Not relevant
Reference
Cross Connection



ECUA_01020428
13:47:02.56
Tacho set B failure
Alarm
4 9 2
Admin
Set Time
2005-05-11 17:23:58
Alarms...
Engine...
Auxiliaries...
Maintenance...
Admin
Set Time
Version
UTC Date/Time
2005-05-11 15:23:58
UTC Time Displayed
Local Date/Time
2005-05-11 15:23:58
Local Time Displayed
Access
Chief



Local Date/Time
Hours
Minutes
New Date/Time
2005-05-11 15:23:56
Offset
02:00
-1
+1
-15
-5
+5
+15
Set



UTC Date/Time
New Date/Time
2005-05-11 15:23:56
Set

ECUA_01020428 | 13:47:02.56 | Tacho set B failure | Alarm | - | -

Admin ▶ Version 2005-05-11 17:24:38

Type	Version	BES Vers.	Engine Group No.	IMO No.	Engine Builder	Eng. No.
---	---	---	---	---	---	---

Controller Unit			Parameter Check Sums					
ID	Addr.	Type	User	Chief	Service	Design	IMO Design	IMO Chief
EICU-A	---	EICU	---	---	---	---	---	---
EICU-B	---	EICU	---	---	---	---	---	---
ECU-A	---	ECU	---	---	---	---	---	---
ECU-B	---	ECU	---	---	---	---	---	---
ACU-1	---	ACU	---	---	---	---	---	---
ACU-2	---	ACU	---	---	---	---	---	---
ACU-3	---	ACU	---	---	---	---	---	---
CCU-1	---	CCU	---	---	---	---	---	---
CCU-2	---	CCU	---	---	---	---	---	---
CCU-3	---	CCU	---	---	---	---	---	---
CCU-4	---	CCU	---	---	---	---	---	---
CCU-5	---	CCU	---	---	---	---	---	---
CCU-6	---	CCU	---	---	---	---	---	---
CCU-7	---	CCU	---	---	---	---	---	---
CCU-8	---	CCU	---	---	---	---	---	---
CCU-9	---	CCU	---	---	---	---	---	---
CCU-10	---	CCU	---	---	---	---	---	---

Alarms...

Engine...

Auxiliaries...

Maintenance...

Admin ▶

Set Time

Version

Access

Chief

Refresh | Print | Printer Status --- | WARNING! Inconsistent controller information.

Export

Print | Printer Status --- | Clear Print | Save | Destination ---

Table of Contents

Table of Contents

PLATES

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, if very combustible material is found here, serious damage can be done to the piston rod and the scavenge air box walls, the latter possibly causing a reduction in 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, owing to a 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, and the back pressure after the turbocharger must not exceed 350 mm WC.

2. Warnings of Fire

WARNING!

If the auxiliary blowers do not start during low-load running (due to faults) 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 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.

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.

If the engine stops on shut-down or if the operator commands a safety stop, the auxiliary blowers are stopped independently of the operating mode (automatic or manual).

A fire in the scavenge box manifests itself 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.

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 respective scavenge box drain cock is opened – therefore keep clear of the line of ejection.

Monitoring devices, see *Section 701-02,* in the scavenge air space give alarm and slow-down at abnormal temperature increase.

For CPP-plants with engaged shaft generator, an auxiliary engine will be started automatically and coupled to the grid before the shaft generator is disengaged and the engine speed reduced.

3. Measures to be taken

Owing to the possible risk of a crankcase explosion, do not stand near the relief valves – flames can suddenly be violently 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. *See Plate 70405.* To prevent the fire from spreading to the next cylinder(s), the ball valve of the neighbouring cylinder(s) should be opened in case of fire in one cylinder.

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.

6. Remove dry deposits and sludge from all the scavenge air boxes. *See also Section 701-01.*
7. Clean the respective piston rods and cylinder liners, and inspect their surface condition, alignment, and whether distorted. If in order, coat with oil.

   Repeat the 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 *Section 703-02.*

   If heating of the scavenge air box walls has been considerable, the staybolts should be retightened at the first opportunity.

   Before retightening, normal temperature of all engine parts must be reestablished.

4. Scavenge Air Drain Pipes *Plate 70402*

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 during running**
- **Cleaning of drain pipes at regular intervals**

4.1 Daily checks during 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.
   Use this procedure to locate any blocking.

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**.*

Does **air** or **oil** blow-out from the individual test-cock?	
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 towards 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 blocking-up 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.

! *If leaking valves are suspected, dismantle and clean the main drain pipe manually.*

If hot water or steam is used, consider the risk of corrosion on the piston rods, 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 leads 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 being flung around everywhere.

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" on the heated surfaces can occur. The "hot spots" will cause the oil 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 full of oil mist, the consequential explosion has blown off the crankcase doors and set 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.*

NB: Similar explosions can also occur in the gear box and scavenge air box.

Every precaution should therefore be taken to:

A) avoid "hot spots"
B) detect the oil mist in time.

A. "Hot Spots" in Crankcase

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 Chapter 708),*
- 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 arranged to give an alarm in cases of low circulating oil pressure and/or high temperature of thrust bearing segments. Keep this equipment in tip-top condition. *(See Section 701-02).*

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 Section 703-03).*

Section 702-01, is 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.*

B. Oil Mist in Crankcase

In order to ensure a reliable, and quick warning of oil mist formation in the crankcase, constant monitoring is obtained with an “Oil Mist Detector”, which samples air from each crankcase compartment.

The detector will give alarm and slow-down, *see Section 701-02,* at a mist concentration which is only a fraction of the lower explosion limit, LEL, to gain time to stop the engine before ignition of the oil mist can take place.

See also the special instructions from the supplier of the oil mist detector.

For CPP-plants with engaged shaft generator, an auxiliary engine will be started automatically and coupled to the grid, before the shaft generator is disengaged and the engine speed reduced.

2. Measures to be taken when Oil Mist has occurred

WARNING!

Do not *stand near crankcase doors or relief valves – nor 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 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 Section 701-02), see above.*
2. Ask 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 casing 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 also point 14.

    Look for 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 Section 708-01 and Section 701-01.*

    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 and thrust bearing *(Section 702-01)*.

    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 Section 703-03.*

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 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 'shots' of surging will often occur, e.g. at crash stop or other abrupt manoeuvrings. This sporadic surging is normally harmless, provided the turbocharger bearings are in a good service condition.

However, continuous surging must be avoided, as there is a risk of damaging the rotor, especially the compressor blading.

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.

However, for convenience, the points in the "check lists" below are grouped according to specific engine systems. *See also Plate 70404.*

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
- 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.Ch.
- Pressure pulsations after T.Ch.
- Pressure pulsations in exhaust receiver
- Damaged compensator before T.Ch.

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:
  - a. when running on high load
  - b. during manoeuvring
  - c. at shut downs/slow downs
  - d. when running ASTERN.
  - e. 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 Chapter 701.*

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 Chapter.

   ***Note** that the exhaust temperatures can sometimes be high 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 *Chapter 701. 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 a reduction of the engine revolutions, until the exhaust temperatures are in accordance with the values stated in *Chapter 701.*

   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” under point 1 above*.

4. When cylinders are out of operation, hunting may occur. When this happens, the load limit must be limited by operating the limiter 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, this speed must be further reduced.

Because the engine is no longer in balance, increased stresses occur in crankshaft. However, if abnormal vibrations do not 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 immediately be 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 *Plate 70401*

See MOP Description.

The following points **(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.

NB 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 *Plate 70401*.

The items stated on Plates 70406 and 70407 are described below:

Component list S50ME-C *Plates 70406 and 70407*

215: Check valve – cartridge (accumulators)

304: Check valve – cartridge (pump pressure side)

305: Check valve – cartridge (ACC-bloc inlet from start-up pumps)

309: Check valve – cartridge (high pressure depart ACC-bloc)

310: Pressure relief valve (out pipe)

311: Pressure relief valve (inner pipe)

315: Plug valve. Drain valve from inner pipe

316: Plug valve. Connection from inner to outer pipe

320: Pressure transducer (3 pcs.). System pressure suveillance

330: Pressure transducer. Double wall suveillance

335: Hydraulic accumulator

339: Mini-mess (pressure outer pipe)

340: Mini-mess (pressure inner pipe)

345: Directional valve. Drain from double wall pipe

350: Orifice part of 345

355: Leak indicator double wall suveillance

405: Plug valve. From T-side (return oil)

420: Plug valve. Inlet valve high pressure supply

421: Plug valve. Drain valve from high pressure supply line

425: Mini-mess (high pressure supply line)

430: Plug valve. Leak detection valve from double wall pipe

431: Plug valve. Drain valve from double wall pipe

435: Mini-mess. Pressure between double wall pipes

450: Hydraulic accumulator. The nitrogen pre-charged accumulators are during operation partly full of high-pressure oil, ensuring a stable supply, without fluctuations to the cylinder units.

455: Mini-mess. Oil pressure supply at ELFI inlet

456: Mini-mess. Oil pressure supply at ELVA inlet

465: Mini-mess. T-side (return oil)

540: Mini-mess. Push rod oil pressure

545: Mini-mess. Oil pressure in ELVA actuator

550: Mini-mess. Oil pressure in ELFI pump

560: Plug valve. Oil supply to cylinder lubricator (currently blanked)

A. Combustion cut out. Piston and exhaust actuator (ELVA) still working Compression on

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 pump. *(See MOP Description).*

! *Piston cooling oil and cylinder cooling water must not be cut off. See also Item 4.*

B. Combustion and compression cut out. Piston still working in cylinder

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 D or E. *See also Item 3.*

Procedure:

1. Cut out the fuel pump. *See MOP Description.*
2. Put the exhaust valve out of action and lock it in **open** position.
   See Vol. II, Procedure 906-28 (Special Running).

   Shut-off the air supply to the exhaust valve, and stop the lube oil pumps. Restart the lube oil pumps.
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 also 'Note' below.*

! *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.

C. Combustion cut out. Exhaust valve closed. Piston still working in cylinder.

Reasons:
This measure may be used if, for instance, the exhaust valve or the actuator is defective. *See also Item 4.*

Procedure:
1. Cut out the fuel pump. *(See MOP Description).*
2. Put the exhaust valve out of action *(See MOP Description)* so that the valve remains **closed** (stop the oil supply and remove the hydraulic pipe).

! *The cylinder cooling water and piston cooling oil must not be cut out.*

D. Piston, piston rod, and crosshead suspended in the engine. Connecting rod out

Reasons:
For instance, serious defects in piston, piston rod, connecting rod, cylinder cover, cylinder liner and crosshead. *See also Item 3.*

Procedure:
1. Cut out the fuel pump. *(See MOP Description).*
2. Put the exhaust valve out of action *(See MOP Description)* so that the valve remains closed.
3. Dismantle the starting air pipe
   Blank off the main pipe and the control air pipe for the pertaining cylinder.

   ! *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 take the connecting rod out of the crankcase, in accordance with the directions in *Volume II, Chapter 904.*

5. Blank off the oil inlet to the crosshead.
6. Set the cylinder lubricator for the pertaining cylinder, to “zero” delivery.

E. Piston, piston rod, crosshead, connecting rod, and telescopic pipe out

Reasons:
This method is only used if lack of spare parts makes it necessary to repair the defective parts during the voyage. *See also Item 3.*

Procedure:
1. Cut out the fuel pump. *(See MOP Description).*
2. Put the exhaust valve out of action *(See MOP Description)* so that the valve remains closed.
3. Dismantle the starting air pipe, and blank off the main pipe and the control air pipe for the pertaining cylinder.
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.

Note Only valid for misfiring, i.e. Item 2, cases A and C. *See also Plate 70401.*

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.

<u>Running limitations in Cases B, D and E</u>
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 also 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:

A. If the ship must be instantly manoeuvrable:

Reduce the load until the vibrations cease.

B. If the ship must be instantly manoeuvrable, but the damaged turbocharger cannot run even at reduced load:

! *This mode of operation is only recommendable if no time is available for carrying out the procedures described in Item '**C**', '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 '**B**', before the bearings will be damaged.

<u>Engines with **one** turbocharger:</u>

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 Plate 70403.*

<u>Engines with **two or more** turbochargers:</u>

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 Plate 70403.*

! *The load limit can be increased considerably if an orifice plate is also inserted in the turbine inlet, as described in Item **C**, 'Engines with **two or more** Turbochargers'.*

C. Running for an extended period with a turbocharger out of operation

<u>Engines with **one** turbocharger:</u>

- Engines <u>with</u> exhaust by-pass (Option).

! *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 Plate 70403.*

- 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 Plate 70403.*

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 Plate 70403.*

D. Repair to be carried out during voyage.

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 Plate 70403.*

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 '**C**', '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 also Vol. III, 'Components Descriptions', Chapter 910.*

If a crack in a cylinder cover stud/ staybolt occurs, replacement should preferably be carried out immediately.

If this is not possible, the engine can still be operated at reduced speed according to the guidelines specified below.

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. Gasleaks will cause burnings on the joint surfaces of the cylinder cover and liner.

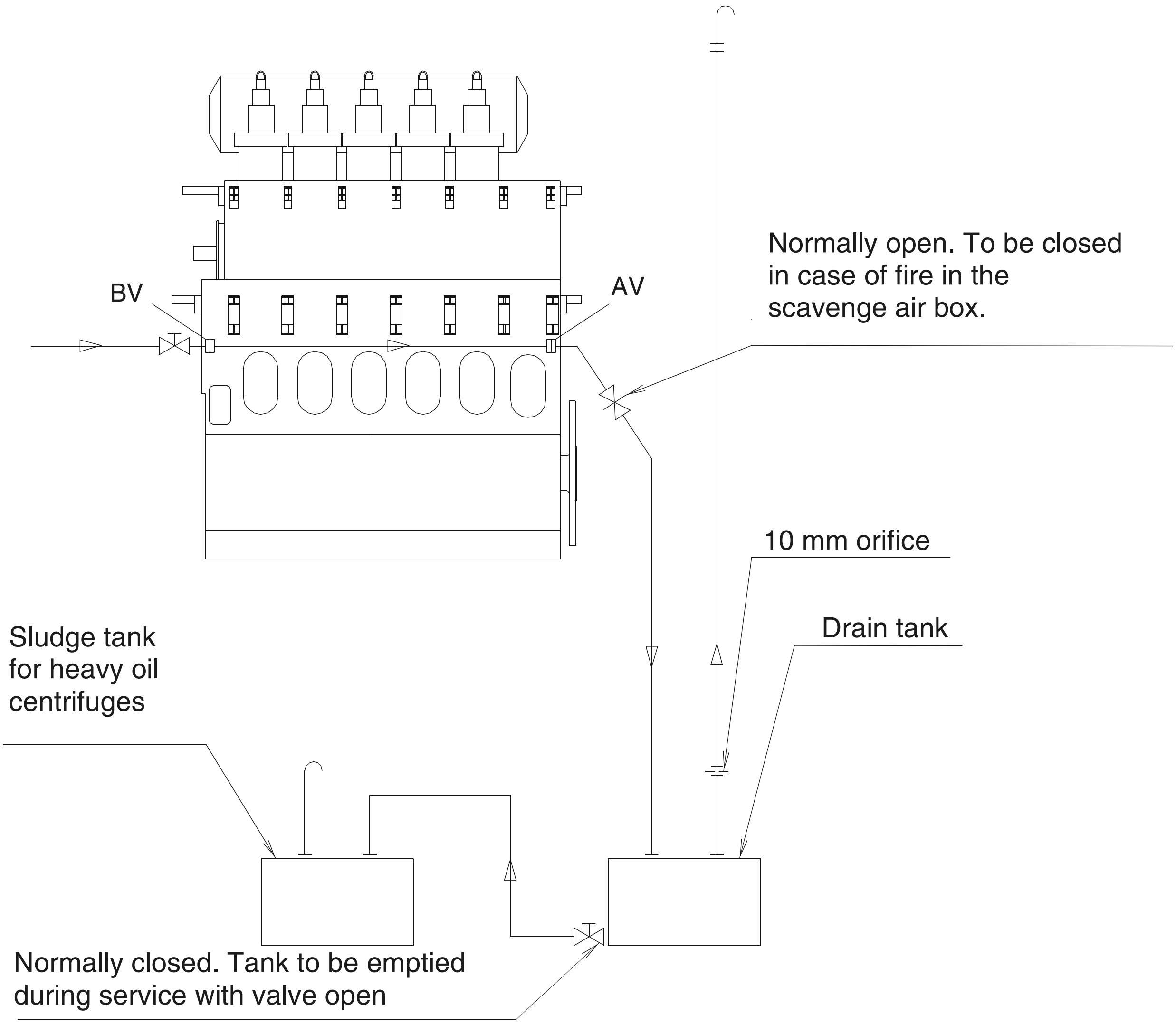
2. Staybolts, Mono and Twin Staybolts

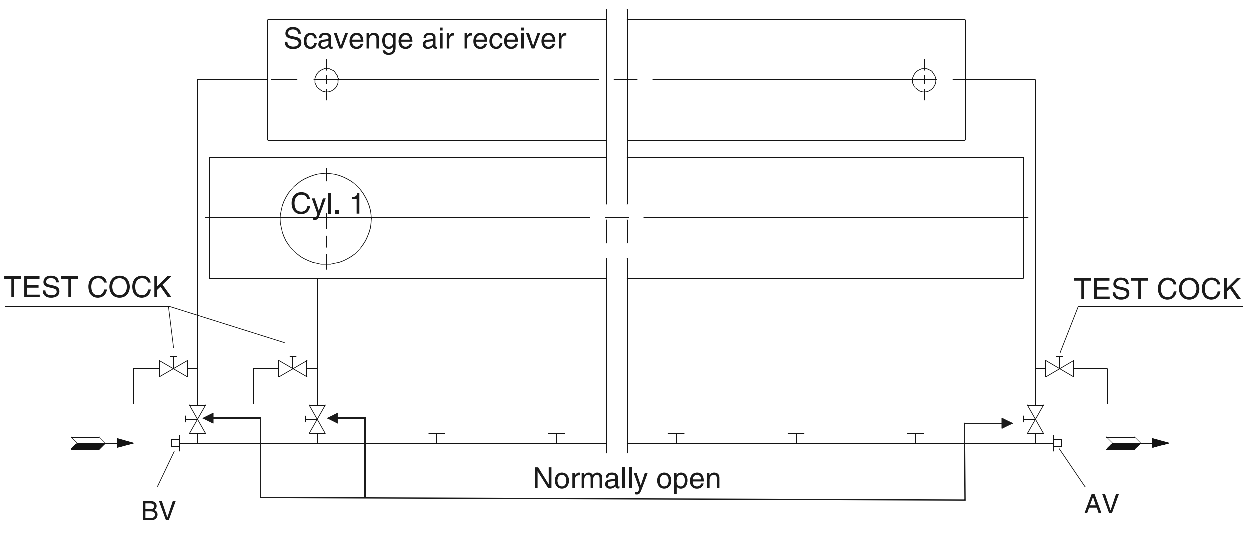
- Engine end staybolts; one bolt cracked (located ahead of cylinder No. 1 or the aft cylinder), reduce the cylinder pressure in the nearest cylinder to 75 % of p_{max}.
- Staybolts in between cylinder No. 1 and the aftmost cylinder, including the bolts located by the chain drive at the centre; reduce the cylinder pressure in the both adjacent cylinders to 80 % of p_{max} (by the centre chain drive, only the nearest cylinder is affected).

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.

In all other situations (than the above-mentioned) involving cracked cylinder cover studs or staybolts, MAN Diesel or the engine builder must be contacted.

	Case A	Case B	Case C	Case D	Case E
Nature of the action	Combustion to be stopped	Compression and combustion to be stopped	Combustion to be stopped (due to faulty exhaust valve)	All reciprocating parts suspended or out	All reciprocating parts out
Some reasons for the action	Blow-by at piston rings or exhaust valve. Reduction of load on bearings. Faulty injection equipment.	Leaking cylinder cover or liner	Exhaust valve, or exhaust valve actuator, malfunction	Quickest and safest measure in the event of faults in large moving parts, or cylinder cover or cylinder liner	Only of interest if spare parts are not available
ELFI (fuel pump)	Cut out	Cut out	Cut out	Cut out	Cut out
Exhaust valve	Working	Held open	Closed	Closed	Closed
Air for air spring	Open	Closed	Open	Open	Open
ELVA (exhaust actuator)	Working	Cut out	Cut out	Cut out	Cut out
Starting valve	Working	Blanked	Working	Blanked	Blanked
Piston with rod	Moving	Moving	Moving	Suspended	Out
Crosshead	Moving	Moving	Moving	Suspended	Out
Connecting rod	Moving	Moving	Moving	Out	Out
Crankpin bearing	Moving	Moving	Moving	Out	Out
Oil inlet to crosshead	Open	Open	Open	Blanked	Blanked
Cooling oil outlet from crosshead	Open	Open	Open		
Cylinder lubricators	Working	Working	Working	Stopped	Stopped


Normally open. To be closed in case of fire in the scavenge air box.
BV
AV
10 mm orifice
Drain tank
Sludge tank for heavy oil centrifuges
Normally closed. Tank to be emptied during service with valve open


Scavenge air receiver
Cyl. 1
TEST COCK
TEST COCK
Normally open
BV
AV

Component	Case B		Case C [1]			Case D
	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
Turbine inlet					Orifice plate	Blanking plates
Turbine 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]	15/(53) [3]	–	–
1 T/C of 2	–	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]	15/(53) [4]	10/(46) [3]	10/(46) [3]	[8]	[8]
1 Aux.bl. of 3 [7]	–	15/(53) [4]	–	–	[8]	[8]
1 Aux.bl. of 4 [7]	–	15/(53) [4]	–	–	[8]	[8]

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**, however, exceed the value(s) stated in Chapter 701. See also the Note in Item 1, 'General'.

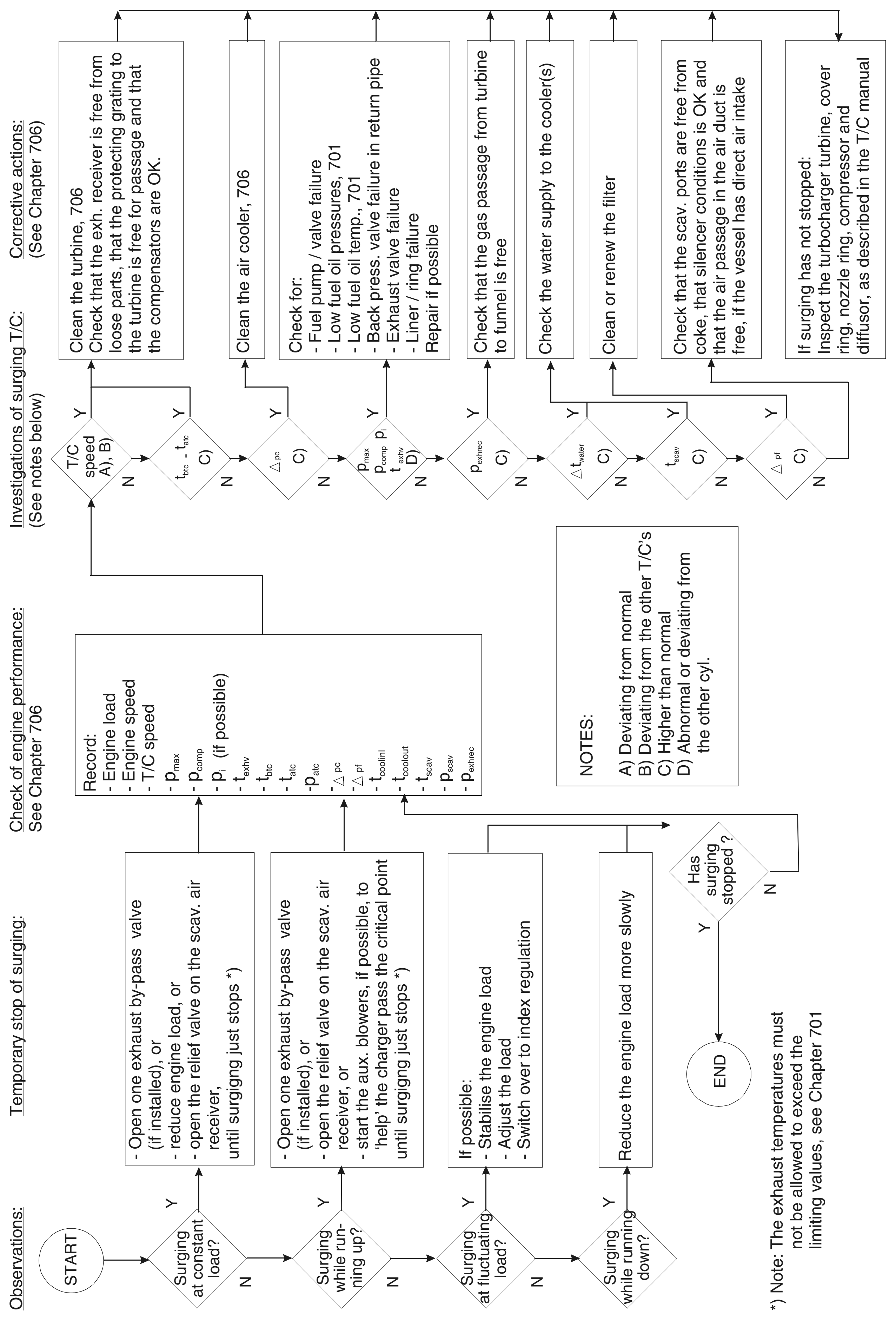
4) The exhaust temperature must **not** exceed 430°C.

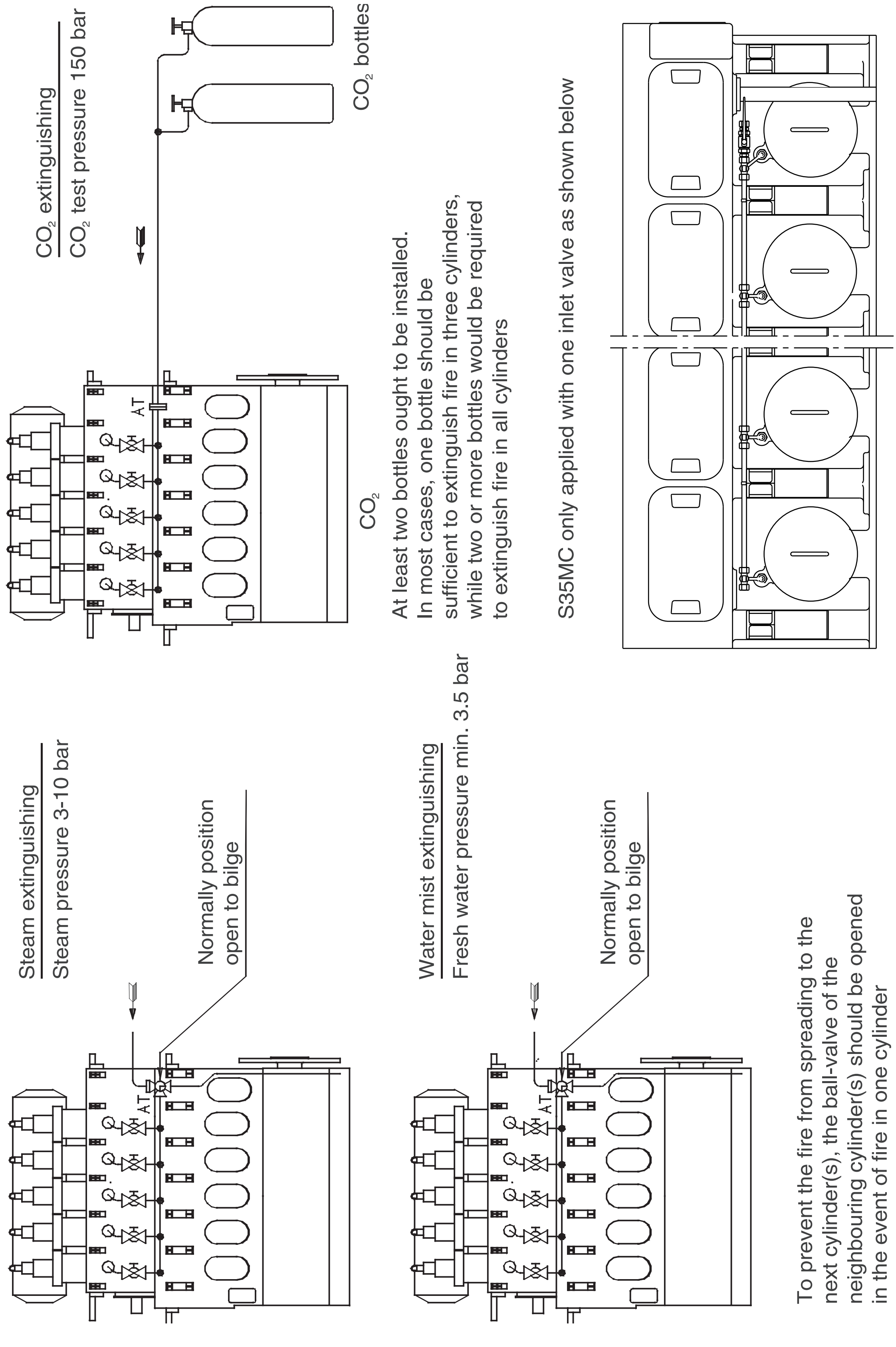
5) This is due to the loss of exhaust gas through the damaged turbocharger.

6) The mentioned exhaust temperature limit is an average value for the whole load range.

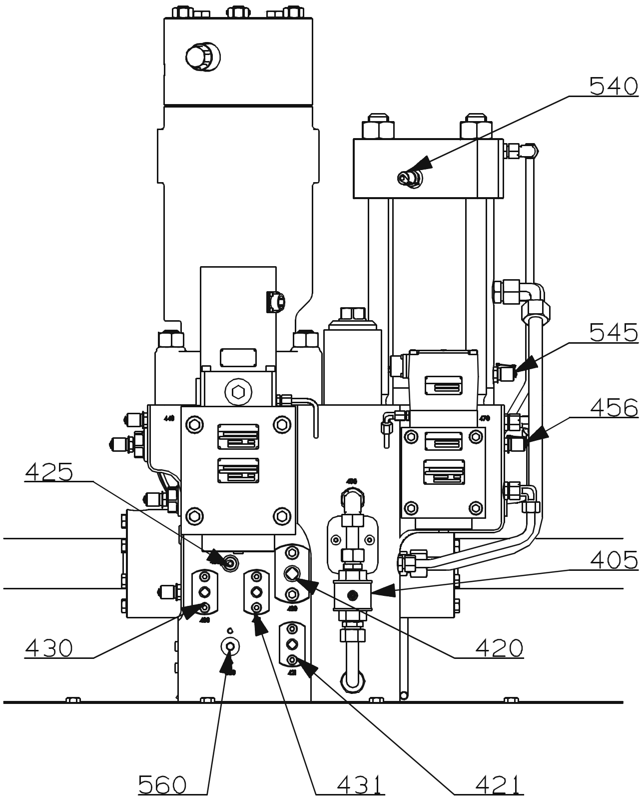
7) Simultaneous with 1 T/C out of operation. There are no load restrictions with 1 aux. blower out of operation and all T/C's in operation.

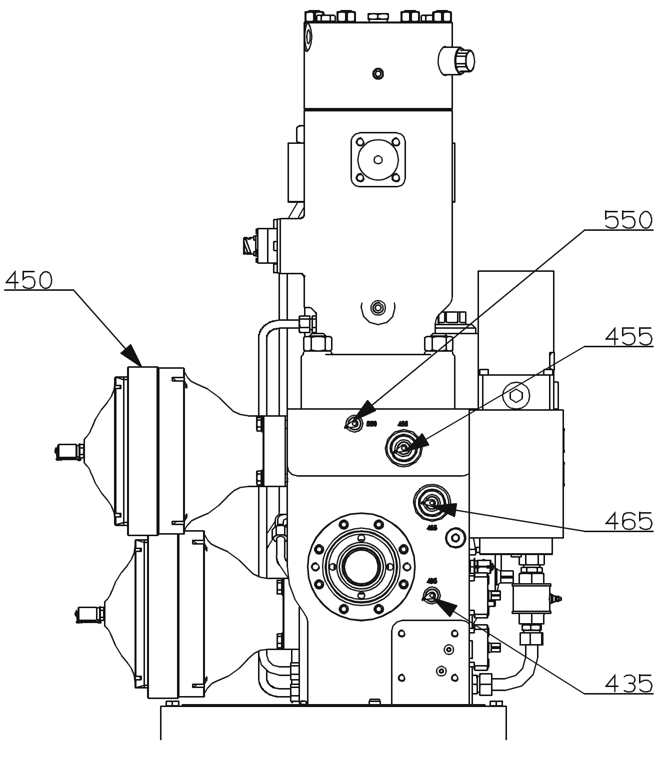
8) See the limits given under '1 T/C of 2', '1 T/C of 3', and '1 T/C of 4', above.

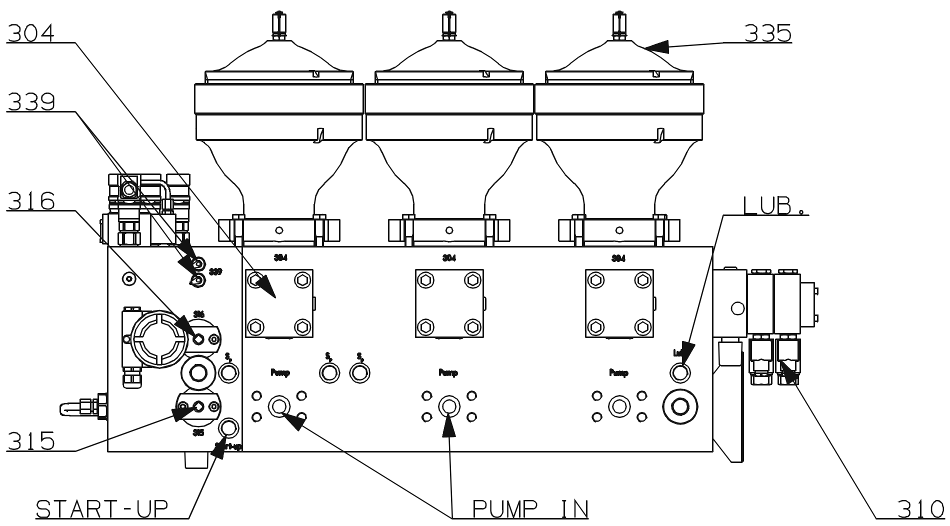

Observations:
START
Surging at constant load?
Surging while running up?
Surging at fluctuating load?
Surging while running down?
Y
N
Temporary stop of surging:
- Open one exhaust by-pass valve (if installed), or
- reduce engine load, or
- open the relief valve on the scav. air receiver,
until surgigng just stops *)
- Open one exhaust by-pass valve (if installed), or
- open the relief valve on the scav. air receiver, or
- start the aux. blowers, if possible, to 'help' the charger pass the critical point
until surgigng just stops *)
If possible:
- Stabilise the engine load
- Adjust the load
- Switch over to index regulation
Reduce the engine load more slowly
Has surging stopped ?
END
Check of engine performance:
See Chapter 706
Record:
- Engine load
- Engine speed
- T/C speed
- p_{max}
- p_{comp}
- p_i (if possible)
- t_{exhv}
- t_{btc}
- t_{atc}
-p_{atc}
- Δpc
- Δpf
- $t_{coolinl}$
- $t_{coolout}$
- t_{scav}
- p_{scav}
- p_{exhrec}
NOTES:
A) Deviating from normal
B) Deviating from the other T/C's
C) Higher than normal
D) Abnormal or deviating from the other cyl.
Investigations of surging T/C:
(See notes below)
T/C speed A), B)
t_{btc} - t_{atc} C)
Δpc C)
p_{max} p_{comp} p_i t_{exhv} D)
p_{exhrec} C)
Δt_{water} C)
t_{scav} C)
Δpf C)
Corrective actions:
(See Chapter 706)
Clean the turbine, 706
Check that the exh. receiver is free from loose parts, that the protecting grating to the turbine is free for passage and that the compensators are OK.
Clean the air cooler, 706
Check for:
- Fuel pump / valve failure
- Low fuel oil pressures, 701
- Low fuel oil temp., 701
- Back press. valve failure in return pipe
- Exhaust valve failure
- Liner / ring failure
Repair if possible
Check that the gas passage from turbine to funnel is free
Check the water supply to the cooler(s)
Clean or renew the filter
Check that the scav. ports are free from coke, that silencer conditions is OK and that the air passage in the air duct is free, if the vessel has direct air intake
If surging has not stopped:
Inspect the turbocharger turbine, cover ring, nozzle ring, compressor and diffusor, as described in the T/C manual
*) Note: The exhaust temperatures must not be allowed to exceed the limiting values, see Chapter 701

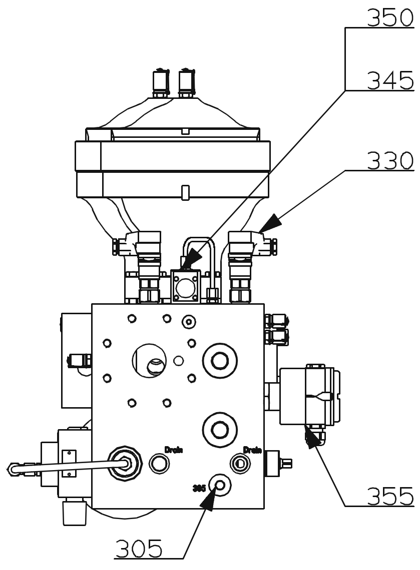


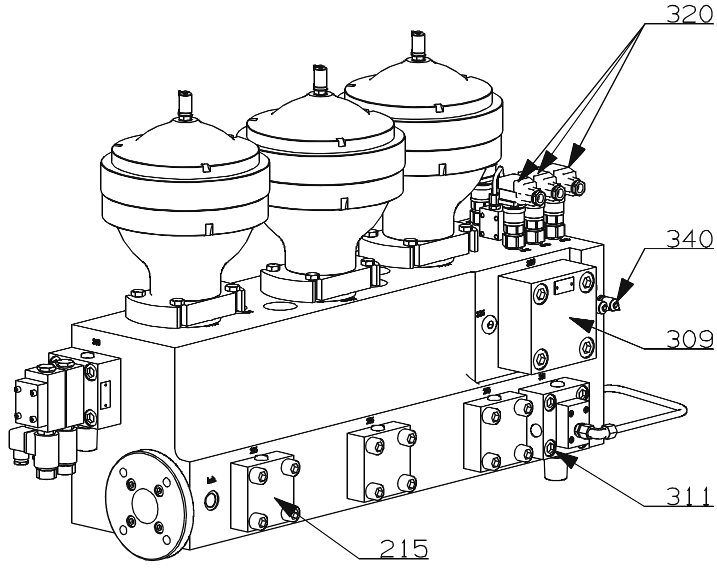
CO$_2$ extinguishing
CO$_2$ test pressure 150 bar
CO$_2$ bottles
AT
CO$_2$
At least two bottles ought to be installed.
In most cases, one bottle should be
sufficient to extinguish fire in three cylinders,
while two or more bottles would be required
to extinguish fire in all cylinders
S35MC only applied with one inlet valve as shown below
Steam extinguishing
Steam pressure 3-10 bar
Normally position
open to bilge
AT
Water mist extinguishing
Fresh water pressure min. 3.5 bar
Normally position
open to bilge
AT
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


540
545
456
425
405
430
420
560
431
421


550
450
455
465
435


304
339
316
315
START-UP
PUMP IN
335
LUB.
310


350
345
330
355
305


320
340
309
311
215

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PLATES

1. Diesel Oil

Diesel oil 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 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 RMH 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 Plate 70501.

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 Section 705-03.

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 further on in this Chapter.

3. Fuel 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 Specifications

Based on our general service experience we have, as a supplement to the abovementioned 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 two-stroke low speed diesel engines, as well as MAN Diesel auxiliary engines.

Guiding specification (maximum values)	Unit	Fuel Oil
Density at 15°C	kg/m3	991[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
Aluminium + Silicon	mg/kg	60
Equal to ISO 8217 RMH 700/CIMAC H700		

1) 1010 provided automatic modern centrifuges are installed.

Note!
The Heavy Fuel 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:

Viscosity	450 cSt / 50 °C
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 *(Plates 70502, 70503)*

The system is normally arranged such that both diesel oil and heavy fuel oil can be used as fuel.

Plate 70502 shows the UNI-Concept common for plant engines.

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 Section 705-03). 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, which deliver the oil, under a pressure of about 4 bar (possibly through a meter), to the low pressure side of the fuel oil system.

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 50 μm (0.050 mm). The absolute fineness corresponds to a nominal fineness of approximately 30 μm at a retaining rate of 90%.

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 also Plate 70903.*

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, *see Vol. III, Section 909.*

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 Section 705-03.*

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:

- either changing to diesel oil in due time before the engine is stopped, *see Section 705-03, 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 Section 705-03.*

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. <u>Supply Pumps:</u> 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. <u>Circulating Pumps:</u> 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 by-pass 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 also Chapter 701.*

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.

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 Plate 70505.*

The centrifuge should operate for 24 hours a day except during necessary cleaning.

Re b.
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 Plate 70504

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 oportunity 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 Plate 70505 can be used as a guidance.

1.3 High Density Fuels

To cope with the trend towards fuels with density exceeding 991 kg/m^3 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/m^3 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 Plate 70506, 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 Plate 70502.

4.2 Change-over between heavy fuel oil and distillate fuel (DFO)

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.

4.2.1 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 heat-up 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

4.2.2 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.

4.3 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.

4.3.1 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

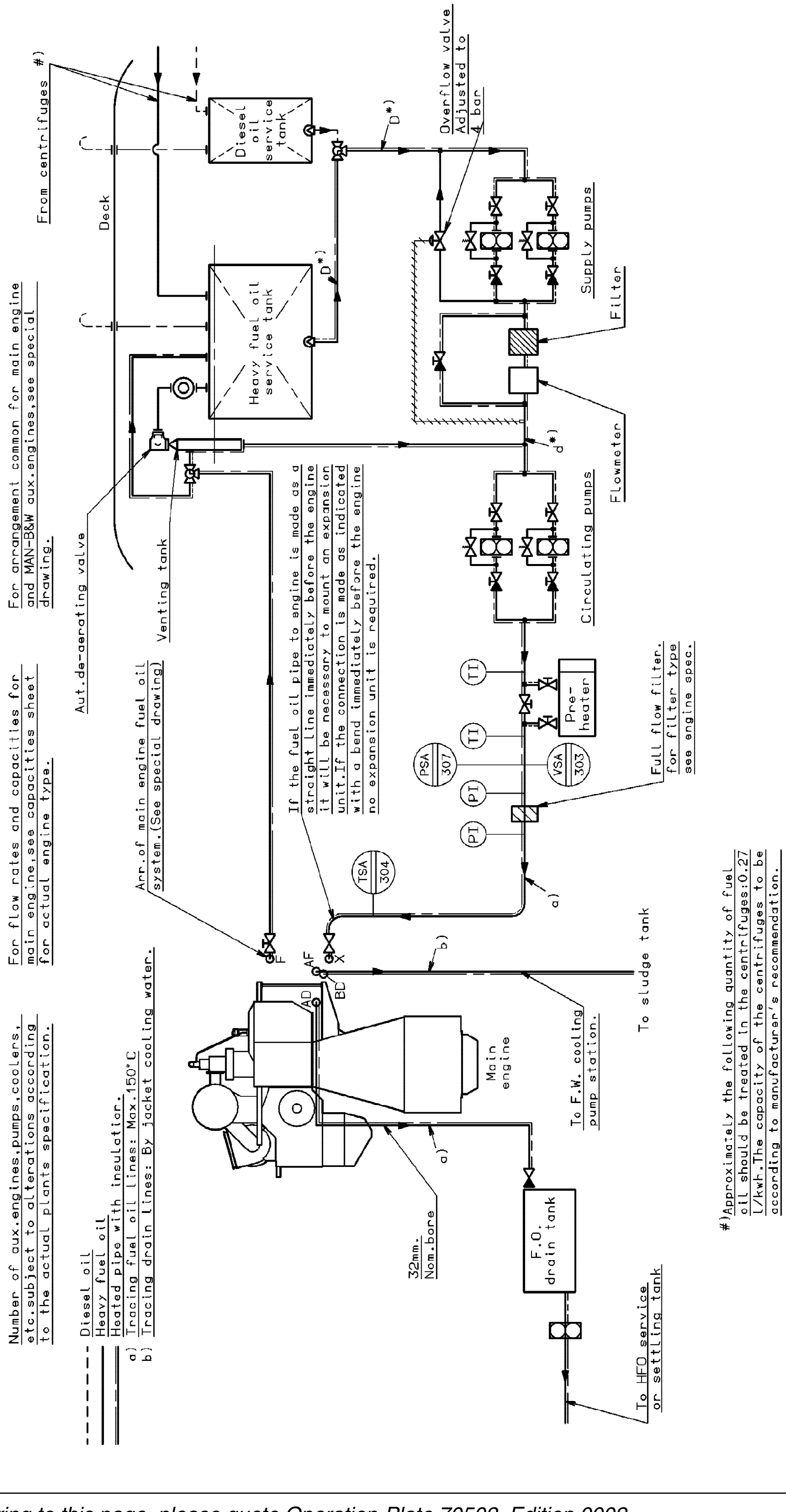
- Change position of the change-over valve at the fuel tanks, so that DFO is led to the supply pumps
- When the HFO is replaced with DFO, turn the change-over valve at the venting pipe back to its normal position. The HFO in the venting pipe is now mixed with DFO
- Stop the circulating pumps
- Stop the supply pumps.
- 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.

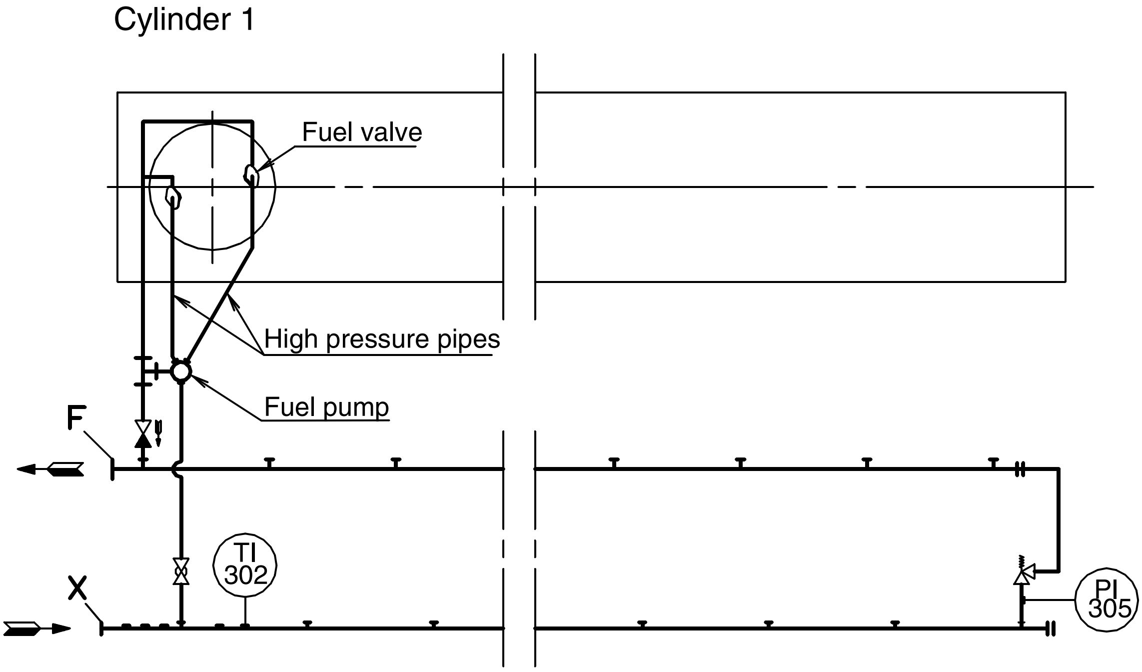
Recommendations for residual fuels for diesel engines (as received)

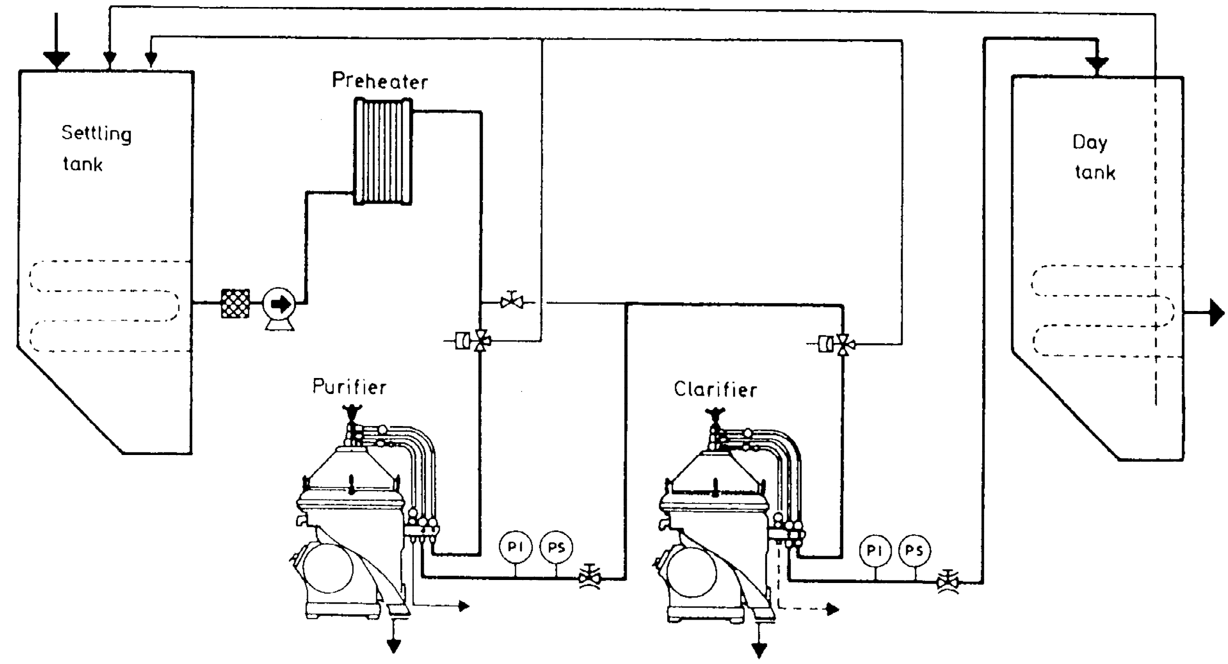
Note: This table is derived from CIMAC official document no. 21

Characteristics[1]	Unit	Limit	CIMAC A 30	CIMAC B 30	CIMAC D 80	CIMAC E 180	CIMAC F 180	CIMAC G 380	CIMAC H 380	CIMAC K 380	CIMAC H 700	CIMAC K 700	Test method reference
Density at 15 °C,	kg/m³	max.	960,0	975,0	980,0	991,0		991,0		1010,0	991,0	1010,0	ISO 3675 or ISO 12185 (see also 6.1)
Kinematic viscosity at 50 °C	mm²/s [2]	max.	30,0		80,0	180,0		380,0			700,0		ISO 3104
		min. [3]	22,0		-	-		-			-		ISO 3104
Flash point	°C	min.	60		60	60		60			60		ISO 2719 (see also 6.2)
Pour point (upper)	°C												
- winter quality		max.	0	24	30	30		30			30		ISO 3016
- summer quality		max.	6	24	30	30		30			30		ISO 3016
Carbon residue	% (m/m)	max.	10		14	15	20	18	22		22		ISO 10370
Ash	% (m/m)	max.	0,10		0,10	0,10	0,15	0,15			0,15		ISO 6245
Water	% (V/V)	max.	0,5		0,5	0,5		0,5			0,5		ISO 3733
Sulfur [4]	% (m/m)	max.	3,50		4,00	4,50		4,50			4,50		ISO 14596 or ISO 8754 (see also 6.3)
Vanadium	mg/kg	max.	150		350	200	500	300	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		ISO 10307-2 (see also 6.6)
Aluminium plus silicon [5]	mg/kg	max.	80		80	80		80			80		ISO 10478
Used lubricating oil (ULO)			The fuel shall be free of ULO. A fuel shall be considered to be free of ULO if one or more of the elements Zinc, Phosphorus and Calcium are below or at the specified limits. All three elements must exceed the same limits before a fuel shall be deemed to contain ULO.										
Zinc	mg/kg	-	15										IP 501 or IP 470
Phosphorus	mg/kg	-	15										IP 501 or IP 500
Calcium	mg/kg	-	30										IP 501 or IP 470 (see also 6.7)

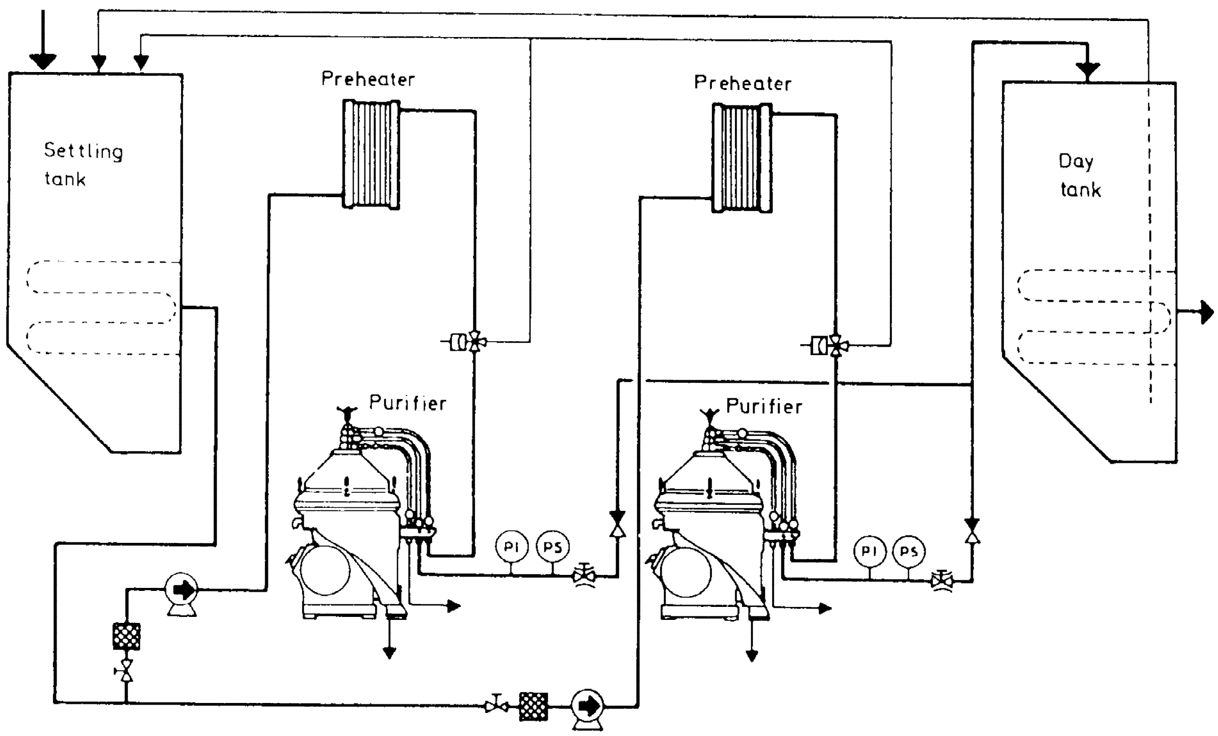
1) See General Recommendations paragraph 3 for additional characteristics not included in this table
2) 1 mm²/s = 1 cSt
3) Fuels with density close to the *maximum*, but with very low viscosity, may exhibit poor ignition quality. See Annex 6.
4) A sulphur limit of 1.5% m/m will apply in SOx Emission Control Areas designated by the IMO, when its relevant Protocol comes into force. There may be local variations.
5) See Annex 3.


From centrifuges #)
Deck
Diesel oil service tank
Heavy fuel oil service tank
D*)
Overflow valve Adjusted to 4 bar
Supply pumps
Filter
Flowmeter
d*)
Circulating pumps
For arrangement common for main engine and MAN-B&W aux.engines,see special drawing.
Aut.de-aerating valve
Venting tank
For flow rates and capacities for main engine,see capacities sheet for actual engine type.
Arr.of main engine fuel oil system.(See special drawing)
If the fuel oil pipe to engine is made as a straight line immediately before the engine it will be necessary to mount an expansion unit.If the connection is made as indicated with a bend immediately before the engine no expansion unit is required.
TI
TI
Pre-heater
PSA 307
VSA 303
PI
PI
Full flow filter. for filter type see engine spec.
TSA 304
a)
b)
F
X
AF
AD
BD
To sludge tank
To F.W. cooling pump station.
Main engine
a)
32mm. Nom.bore
F.O. drain tank
To HFO service or settling tank
Number of aux.engines,pumps,coolers, etc.subject to alterations according to the actual plants specification.
Diesel oil
Heavy fuel oil
Heated pipe with insulation.
a) Tracing fuel oil lines: Max.150°C
b) Tracing drain lines: By jacket cooling water.
#)Approximately the following quantity of fuel oil should be treated in the centrifuges:0.27 l/kwh.The capacity of the centrifuges to be according to manufacturer's recommendation.
*)D to have min.50% bigger passage area than d


Cylinder 1
Fuel valve
High pressure pipes
Fuel pump
F
X
TI
302
PI
305



In Series Fig. 1

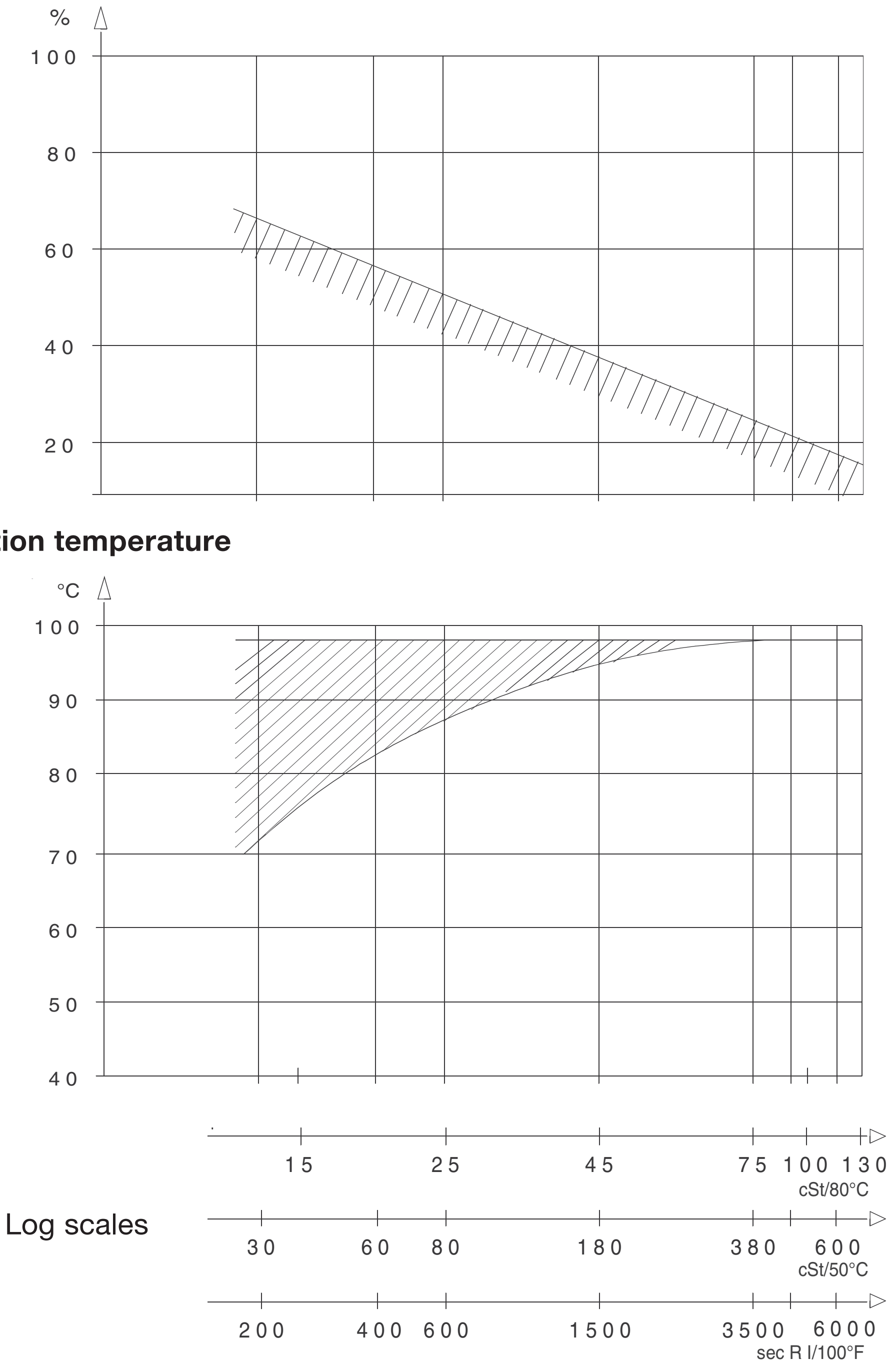


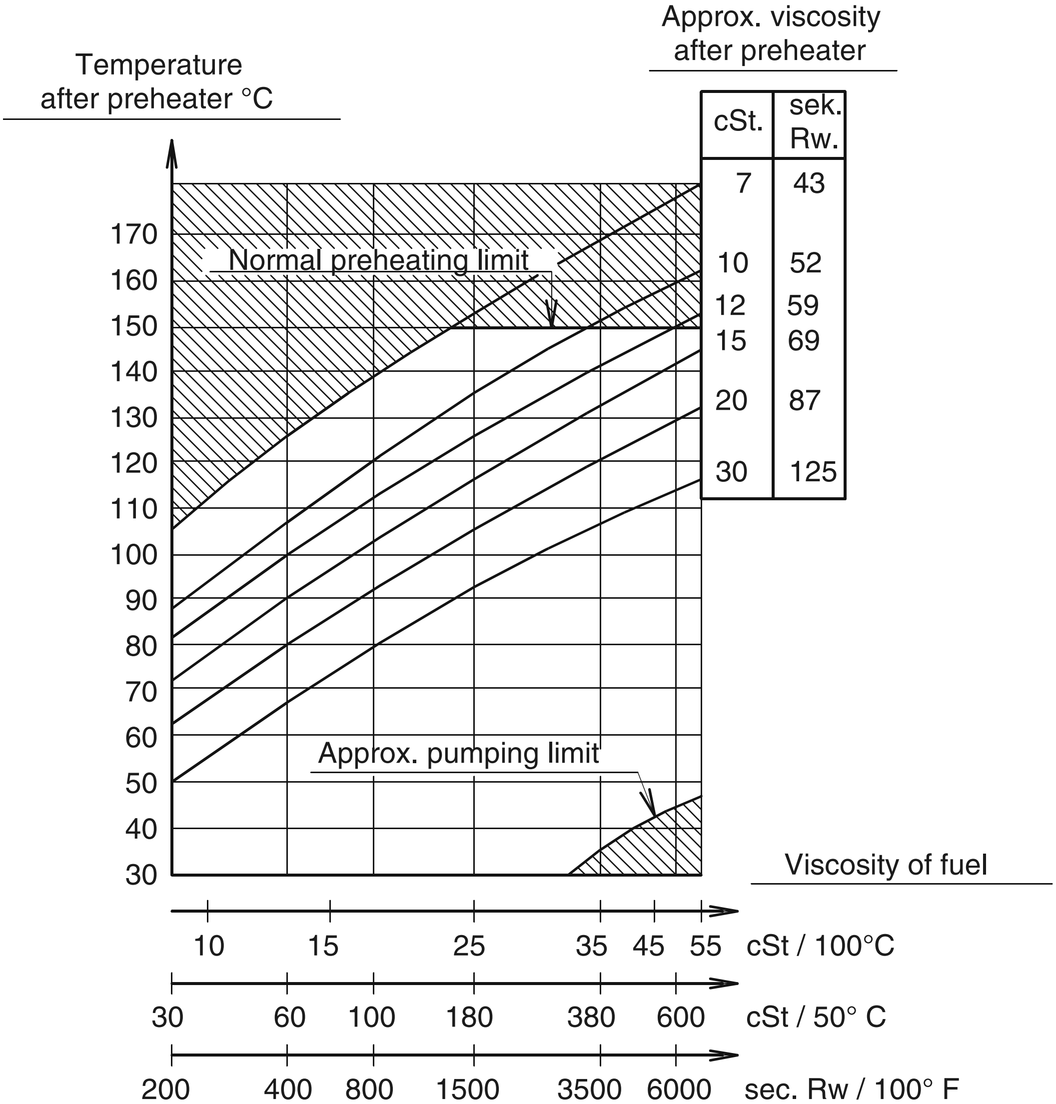
In Parallel Fig. 2

By courtesy of Alfa-Laval

Rate of Flow - related to rated capacity of centrifuge

Separation temperature





This cart 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.

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PLATES

1. Symbols and Units

The following designations are used:

Parameter	Symbol	Unit 1	Unit 2
Effective engine power	P_e	bhp	kW
Engine speed	**speed**	speed	speed
Indicated engine power	p_i	ihp	ikW
Fuel pump index	**Index**	No.	%
Specific fuel oil consumption	**SFOC**	g/bhph	g/kWh
Fuel oil lower calorific value	**LCV**	kcal/kg	kJ/kg
Turbocharger speed	**T/C speed**	speed	speed
Barometric pressure	p_{baro}	mmHg	mbar
Pressure drop across T/C air filters	Δp_f	mmWC	mbar
Pressure drop across air cooler	Δp_c	mmWC	mbar
Scavenge air pressure	p_{scav}	mmHg	bar ★)
Mean indicated pressure	p_i	bar ★)	bar ★)
Mean effective pressure	p_e	bar ★)	bar ★)
Compression pressure	p_{comp}	bar ★)	bar ★)
Maximum combustion pressure	p_{max}	bar ★)	bar ★)
Exhaust receiver pressure	p_{exhrec}	mmHg	bar ★)
Pressure after turbine	p_{atc}	mmWC	mbar
Air temperature before T/C filters	t_{inl}	°C	°C
Air temperature before cooler	t_{bcoo}	°C	°C
Cooling water inlet temp., air cooler	$t_{coolinl}$	°C	°C
Cooling water outlet temp., air cooler	$t_{coolout}$	°C	°C
Scavenge air temperature	t_{scav}	°C	°C
Temperature after exhaust valve	t_{exhv}	°C	°C
Temperature before turbine	t_{btc}	°C	°C
Temperature after turbine	t_{atc}	°C	°C

Conversion factors:

1 bar= 1.02 kp/cm^2 = 0.1 MPa = 10^5 Pa = $10^5 \frac{N}{m^2}$

1 kg/cm^2 = 0.9807 bar

1 kW = 1.3596 hp

1 mbar = 10.2 mmWC = 0.75 mm

π = 3.14159

! ★) *Pressure stated in **bar** is the measured value, i.e. read from an ordinary pressure gauge. Note: the official designation of **bar** 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, *Plate 70601.*
- For propulsion and main engine driven generator, *Plate 70602.*

Specific engine calculations (load diagrams) can be ordered by contacting MAN B&W Diesel A/S.

2.2 Definitions

The load diagram, in logarithmic scales *(Plates 70601 and/or 70602)* defines the power and speed limits for continuous as well as overload operation of an installed engine having a specified MCR (Maximum Continous 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 Plate 70601*, and for main engine driven shaft generator, if installed, *see Plate 70602.*

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.

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 *Plates 70603 (two pages), 70604*

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

- Ships 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
- Δ p air filter (if pressure gauge installed)
- Δ p 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 measurring equipment
- Eventually the engine diagnosis system CoCos-EDS

It is important to check the measuring instruments for correct functioning.

Regarding check of thermometers and pressure gauges, see Section 706-04.

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 *Section 701-02.*

Daily: Fill-in the Performance Observation record, *Plate 70603.*

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 Chapter 701, 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 Section 706-02.

1. General

Record the performance observations as described in the previous *Section 706-01.*

Use the *synopsis diagrams* to obtain the best and most simple method of plotting and evaluating the parameters:

Engine:	Plates 70605, 70606, 70607
Turbocharger:	Plates 70608, 70609
Air cooler:	Plate 70610

Plates 70605, 70606 and 70607 are sufficient to give a general impression of the overall engine condition.

The plates comprise:

Model curve: shows the parameter as a function of the parameter on which it is most dependent (based on the testbed/sea trial 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 B&W CAPA-system. (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 6L60MC has been used in these examples.

2.1 Parameters related to the Mean Indicated Pressure (p_i)

Plates 70605 and 70606 (engine synopsis diagrams) show model curves for engine parameters which are dependent upon the mean indicated pressure (p_i).

! *Plate 70605 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 Section 706-05.*

2.1.A Mean Draught

The mean draught is depicted here because, for any particular engine speed, it wil have an influence on the engine load.

2.1.B 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.

! *The load balance **must not** be adjusted on the basis of the exhaust gas temperatures after each exhaust valve.*

The fuel index must be steady. Unbalances in the load distribution may cause the governor to be unstable.

2.1.C 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 Section 706-01,* 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 Section 706-01*, and from that judge the necessity of making alterations on the engine, or to the propeller.

2.1.D 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.

! *For correction to reference conditions, see Section 706-06.*

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_{comp}-p_{max} must not exceed the specified limit, i.e. 45 bar.

2.1.E 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:

a. 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.

b. 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.

c. 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 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)

Plate 70607 shows model curves for engine parameters which are dependent on the effective power (P_e).

Regarding the calculation of effective engine power, *see Section 706-05.*

Because the ME engine is without indicator drive, the estimated effective engine power is found by using the fuel index and T/C revolutions as parameters, *see Section 706-08.*

It is recommended to apply PMI-system for easy access to P-V-diagrams (work diagrams) and thereby the effective engine power.

2.2.A 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).

! *For correction to ISO reference ambient conditions, see Section 706-06.*

Regarding maximum exhaust temperatures, *see also Section 706-06.*

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 • Indicator and draw diagrams *See Section 706-05.* Check the fuel valves: • visually • by pressure testing.
b. Cylinder condition: – Blow-by, piston rings *See also Chapter 703, Item '4.1, Running Difficulties', point 7.* – Leaking exhaust valves *See also Chapter 703, Item '4.1, Running Difficulties', point 6.*	These faults occur in individual cylinders. • Compare the compression pressures from the indicator and draw diagrams. *See Section 706-05.* • During engine standstill: Carry out scavenge port inspection. *See Section 707-01.* Check the exhaust valves.
c. Air coolers: – Fouled air side – Fouled water side	Check the cooling capability. *See Section 706-02.*
d. Climatic conditions: – Extreme conditions	Check cooling water and engine room temperatures. Correct T_{exhv} to reference conditions. *See Section 706-06.*
e. Turbocharger: – Fouling of turbine side – Fouling of compressor side	Use the turbocharger synopsis methods for diagnosing. *See Section 706-02.*
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.B 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.

For correction to reference conditions, see Section 706-06.

Deviation from the model curve can be due to:

a. a scavenge air pressure reduction,

b. – 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 ‘a’ and ‘b’, and investigate how large a part of a possible compression reduction is due to ‘a’ or ‘b’.

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.

<u>Example:</u>

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

$$\frac{p_{comp\ abs}}{p_{scav\ abs}} = \frac{116}{3.25} = 35.7$$

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:

$p_{comp\ abs} = 35.7 \times (2.0 + 1.02) = 107.8$ bar

i.e. $p_{comp} = 107.8 - 1.02 = 106.8$ 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_{comp}-p_{max},
see Item 2.1.D, 'Maximum Combustion Pressure ($p_{max} - p_i$)'.

Mechanical Defects which can influence the Compression Pressure

Possible Causes	Diagnosis / Remedy
a. Piston rings: – Leaking	Diagnosis: *See Table Increased Exhaust Temperature Level – Fault Diagnosing* *Remedy: See Section 703-04.*
b. Piston crown: – Burnt	Check the piston crown by means of the template. *See Vol. II, Procedure 902-3.*
c. Cylinder liner: – Worn	Check the liner by means of the measuring tool. *See Vol. II, Procedure 903-2.*
d. Exhaust valve: – Leaking – The exhaust temperature rises. – A hissing sound can possibly be heard at reduced load. – Timing	Remedy: *See Section 703-04.* Check: – 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: Overhaul the stuffing box, see Vol. II, Chapter 902.*

3. Turbocharger Synopsis

Plates 70608 and 70609
(Turbocharger synopsis diagrams)

! *Plates 70608 and 70609 should be filled out in a number of copies which corresponds to the number of turbochargers.*

Regarding cleaning of the turbochargers, *see Section 706-03.*

3.0.A 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 Sections 706-05 and 706-08 regarding the effective engine power.

! *For correction to ISO reference ambient conditions, see Section 706-06.*

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.

3.0.B Turbocharger Speed (T/C speed – p_{scav})

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 B&W) / cover ring (BBC / 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.

3.0.C Pressure Drop across Turbocharger Air Filter (Δp_f – p_{scav})

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.

3.0.D Turbocharger Efficiency (ηT/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 *Section 706-07.*

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 *Plate 70610 (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 Section 706-03.*

4.0.A Temperature Difference between Air Outlet and Water Inlet ($\Delta\ t_{(air\text{-}water)} - p_{scav}$)

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’.

4.0.B 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.

4.0.C 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’.

4.1 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:

a. Fouling of the air side
b. Fouling of the water side

a. 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 also Section 706-03.*

b. Fouling of the water side: Normally *involves a reduction of the coding 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 salt-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 *Plate 70611*

Calculation of the specific fuel oil consumption (g/kWh, g/bhph) requires that engine power, and the consumed fuel oil amount (kg), are known for a certain period of time.

The method of determining the engine power is illustrated in *Section 706-05*. For engines without indicator drive, *see Section 706-08.*

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 calm weather 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 bunker specifications.

Normally, in bunker specifications, the specific gravity is indicated at 15°C/60°F.

The actual density (g/cm^3) at the measuring point is determined by using the curve on *Plate 70611*, 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 (corresponding to 10,200 kcal/kg). If no other instructions have been given by the shipowner, it is recommended to convert to this value.

Usually, the lower calorific value of a bunker oil is not specified by the oil companies. However, by means of the graph, *Plate 70611*, 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 either:

$\frac{LCV_1}{42{,}707}$ LCV_1 = the specific lower calorific value, in kJ/kg, of the bunker oil concerned

or

$\frac{LCV_2}{10{,}200}$ LCV2 = the specific lower calorific value, in kcal/kg, of the bunker oil concerned

Example: (6L60MC)

Effective Engine Power, P_e	:	15,600 bhp
Consumption, Co	:	7.125 m^3 over 3 hours
Measuring point temperature	:	119°C
Fuel data	:	Specific gravity: 0.9364 g/cm^3 at 15°C, 3% sulphur

Density at 119°C *(see Plate 70611)*, ρ 119: 0.9364 – 0.068 = 0.8684 g/cm^3.

Specific consumption:

$$\frac{Co \times \rho\ 119 \times 10^6}{h \times P_e}\ (g / bhph)$$

where:
Co = Fuel oil consumption over the period, m^3
ρ 119 = Corrected gravity, g/cm^3
h = Measuring period, hours
P_e = Brake horse power, bhp

$$\frac{7.125 \times 0.8684 \times 10^6}{3 \times 15{,}600} = 132.2 \text{ g/bhph}$$

Correction to ISO reference conditions
regarding the specific lower calorific value:

LCV_1 = 40,700 kJ/kg, derived from *Plate 70611.*
Consumption corrected for calorific value:

$$\frac{132.2 \times 40{,}700}{42{,}707} = 126.0 \text{ g/bhph}$$

or
LCV_2 = 9723 kcal/kg derived from *Plate 70611.*

Consumption corrected for calorific value:

$$\frac{132.2 \times 9723}{10{,}200} = 126.0 \text{ g/bhph}$$

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.

! *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	Vibrations occur after cleaning	THEN	Clean again
	Vibrations occur after repeated cleaning		*See Section 704-04.* 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.A Dry Cleaning *(Plate 70612)*

Intervals between cleaning: 24-50 hours of operation.

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 Plate 70612. See also Vol. II, 'Maintenance', Chapter 910.*

1.2.B Water Cleaning (Not TCA, TCR and MET-Turbochargers) *(Plate 70613)*

Intervals between cleaning: Approx. every 50 to 500 operating hours.

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 Plate 70613.*

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.

! ***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.

! *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 in-service cleaning unnecessary.

Replace and discard the filter gauze, when it becomes dirty.

2. Air Cooler Cleaning System *Plate 70614*

See Section 701-02 regarding the basis for intervals between cleaning.

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 the *‘Maintenance’ instruction book, Chapter 910.*

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 (^{o}C)
- Relative humidity of ambient air (%)
- Scavenge air pressure (Bar abs)
- Scavenge air temperature (^{o}C)

Figures of water vapour in ambient and scavenge air can be seen in full figur on plate 70712.

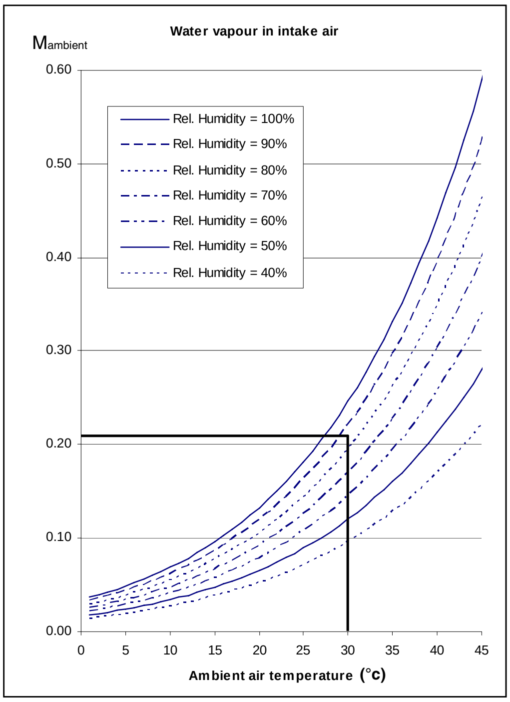


Figure 1

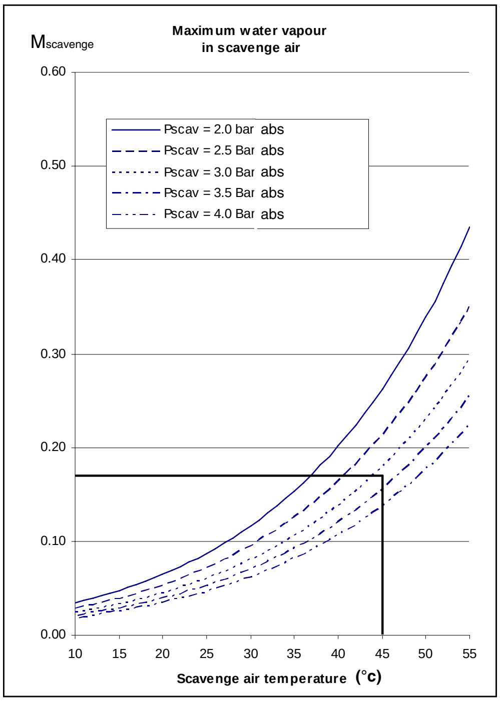


Figure 2

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:

$$M_{Condens} = k \times \text{Engine load} \times (M_{ambient} - M_{scavnege})^{*} \quad [kg/h]$$

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 ± 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 ^{o}C
Relative humidity:	85 %
Scavenge air pressure:	3.25 Bar abs
Scavenge air temperature:	45 ^{o}C

Calculation procedure:

1) $M_{ambient}$ = 0.21 kg/kWh found from figure 1 (as outlined)

2) $M_{scavenge}$ = 0.17 kg/kWh found from figure 2 (as outlined)

3a) k = 1.05 for K80 type engine

3b) $M_{condens}$ = 1.05 x 22700 x (0.21 - 0.17) = 953 kg/h

The condensate amount is estimated to be 950 kg/h (± 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 *Plate 70614*

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 *(Section 701-02)* 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

a. A mixed flow of air and water indicates a correctly working system where condensation takes place.

b. 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.

c. A flow of air is only normal when running under dry ambient conditions

! *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.

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.

This would 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 B&W Diesel'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.

Regarding taking the diagrams, see Section 706-04.

1. Calculation of the Indicated and Effective Engine Power

(For engines without PMI-system, *see Section 706-08)*

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

<u>The mean indicated pressure</u>, p_i

$$p_i = \frac{A}{L \times C_s} \quad \text{(bar)}$$

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.

<u>The mean effective pressure</u>, p_e

$p_e = p_i - k1$ (bar)

where
k1 = 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 : $k_2 = 1{,}30900 \times D^2 \times S$

For power in BHP : $k_2 = 1{,}77968 \times D^2 \times S$

where:
D (m) = cylinder diameter
S (m) = piston stroke

Engine type	For power in kW k_2	For power in BHP k_2
S50ME	0.6250	0.8498
S50ME-C	0.6545	0.8899
L60ME	0.9161	1.2455
S60ME	1.0801	1.4685
S60ME-C	1.1310	1.5377
L70ME	1.4547	1.9779
S70ME	1.7151	2.3319
S70ME-C	1.7959	2.4418
L80ME	2.1715	2.9524
S80ME	2.5602	3.4809
K80ME-C	1.9268	2.6198
L90ME	3.0918	4.2037
K90ME	2.7037	3.6761
K90ME-C	2.4387	3.3157
K98ME-C	3.0172	4.1022
K98ME-C	3.0172	4.1022

The indicated engine power, P_i

$P_i = k_2 \times n \times p_i$ (ikW or ihp)

where
n (rpm) = engine speed.

The effective engine power, P_e

$P_e = k_2 \times n \times p_e$ (kW or bhp)

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 also Section 706-01.*

Making such corrections enables comparison to earlier (corrected) readings or model curves, regardless of deviations of the actual tinl and tcoolinl 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 *Section 706-02*.

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 also Plate 70610, regarding Δt (t_{scav}-$t_{coolinl}$).

See also Section 706-01.

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 Plate 70624, which shows how to use Plates 70620-70623 to determine the correction.

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}.

See Plates 70620, 70621, 70622 and 70623, which show how to use the formulas.

Parameter to be corrected	**F_1**: for air inlet temp.	**F_2**: for cooling water inlet temp.	K
t_{exhv}	-2.446×10^{-3}	-0.59×10^{-3}	273
p_{scav}	$+2.856 \times 10^{-3}$	-2.220×10^{-3}	p_{baro} = 1 bar
p_{comp}	$+2.954 \times 10^{-3}$	-1.530×10^{-3}	p_{baro} = 1 bar
p_{max}	$+2.198 \times 10^{-3}$	-0.810×10^{-3}	p_{baro} = 1 bar

3. Examples of calculations:

See Plate 70624, which states a set of service readings.

1. Correction of t_{exhv} *(Plate 70621).*

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) × (–2.466 × 10^{-3}) × (273 + 425)	=	–29.3°C
Correction for cooling water inlet temperature: (40 – 25) × (–0.59 × 10^{-3}) × (273 + 425)	=	–6.2°C
Corrected t_{exhv} value = 425 – 29.3 – 6.2	=	<u>389.5°C</u>

2. Correction of pscav (Plate 70623):

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) × (2.856 × 10^{-3}) × (1 + 2.0)	=	0.146 bar
Correction for cooling water inlet temp.: (40 – 25) × (–2.220 × 10^{-3}) × (1 + 2.0)	=	–0.10 bar
Corrected pscav value = 2.0 + 0.146 – 0.10	=	<u>2.046 bar</u>

Corrections of p_{comp} *(Plate 70622)* and p_{max} *(Plate 70620)* can be made in a similar manner.

4. Maximum Exhaust Temperature

The engine is designed to allow a limited increase of the thermal loading, i.e. increase of t_{exhv}.

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, *see also Chapter 701, Item* TC 8707	+ 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 also Section 706-02.

For new engines it is not unusual to observe a temperature increase of 50–60°C from the testbed to the commissioning test.

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.

! *The exhaust temperature must not exceed the alarm limit, see Section 701-02.*

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 Plate 70621*:
Air inlet temp. (t_{inl}) = **42°C** corresponding to (42 – 25) = 17°C above the reference value.

Cooling water inlet temp. to the air cooler ($t_{coolinl}$) = **40°C**, corresponding to (40 – 25) = 15°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°C – 375°C = 50°C, is caused by:

- an increase of 33.0°C on account of climatic alterations,
- an increase of 50°C – 33°C = 17°C, due to mechanical conditions and operation on heavy fuel oil.

1. General

To record the turbocharger efficiencies, see Section 706-02.

Plate 70609 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 Section 706-01*:

		Unit	Examples 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 *)
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/g

M_X : Exhaust gas mass flow through turbine: 48.05 kg/g

M_A : Air mass flow through compressor

$M_A = M_X - M_F$

$$\eta_{tot} = 0.9265 \frac{M_A \times T_1 \times (R_1^{0.286} - 1)}{M_X \times T_2 \times (1 - R_2^{0.265})}$$

if MA or MX unknown:

$$\frac{M_A}{M_X} \approx 0,9817$$

	Example of Calculation, η_{tot} *See measurements in Table 1*
$T_1 = t_{inl} + 273,15$	$T_1 = 21 + 273,15 \quad = \quad 294,,15\ K$
$R_1 = \frac{p_{baro} + p_{scav} + \Delta p_c}{p_{baro}}$	$R_1 = \frac{1,022 + 2,533 + 0,017}{1,022} \quad = \quad 3,495$
$T_2 = t_{btc} + 273,15$	$T_2 = 400 + 273,15 \quad = \quad 673,15\ K$
$R_2 = \frac{p_{baro} + p_{atc}}{p_{baro} + p_{exh}}$	$R_2 = \frac{1,022 + 0,026}{1,022 + 2,393} \quad = \quad 0,307$
$(R_1^{0.286}-1)$ H	$(R_1^{0,286}-1) \quad = \quad 0,430$
$(1 - R_2^{0.265})$ H	$(1 - R_1^{0,265}) \quad = \quad 0,269$
$\eta_{tot} = 0.9265 \frac{M_A \times T_1 \times (R_1^{0.286} - 1)}{M_X \times T_2 \times (1 - R_2^{0.265})}$	$M_X \quad = \quad 48,05\ kg/g$
	$M_A = 48,05 - 0,88 \quad = \quad 47,17\ kg/g$
	$\eta = 0,9265 \times \frac{47,17 \times 294,15 \times 0,430}{48,05 \times 673,15 \times 0,269} = \underline{0,64}$

Compressor efficiency:

The compressor efficiency η_{compr} is given by the equation

$$\eta_{compr} = \frac{3628800 \times T_1 (R_1^{0.286} - 1)}{\mu \times U^2}$$

μ = slip factor, *see Plate 70628*

$U^2 = (\pi \times D \times n)^2$

D = Diameter of compressor wheel, *see Plate 70628*

n = is the peripheral speed of the compressor wheel.

The turbocharger used in this example is a MAN B&W, type TCA77.

From Plate 70628 is taken:

D = 0,752 m

μ = 0,745

	Example of Calculation, η_{compr} *See measurements in Table 1*		
$T_1 = t_{inl} + 273{,}15$ °K	21 + 273,15	=	294,15 K
$R_1 = \frac{p_{baro} + p_{scav} + \Delta p_c}{p_{baro}}$	$\frac{1{,}022 + 2{,}533 + 0{,}017}{1{,}022}$	=	3,495
$(R_1^{0.286} - 1)$*		=	0,430
$U^2 = (p \times D \times n)^2$	$(\pi \times 0{,}752 \times 11950)^2$	=	797022356
$\eta_{compr} = \frac{3628800 \times T_1 (R_1^{0.286} - 1)}{\mu \times U^2}$	$\frac{3628800 \times 294 \times 0{,}430}{0{,}745 \times 797022356}$	=	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 Plates 70625 and 70626.

Turbine efficiency:
The turbine efficiency η_{turb} appears from

$$\eta_{total} = \eta_{compr} \times \eta_{turb}$$

$$\text{i.e. } \eta_{turb} = \frac{\eta_{total}}{\eta_{compr}} = \frac{0.64}{0{,}77} = 0.83$$

2.2 Plants with TCS and/or Exhaust By-Pass

The equation $\eta_{total} = 0.9265 \frac{M_A \times T_1 \times (R_1^{0.286} - 1)}{M_X \times T_2 \times (1 - R_2^{0.265})}$ 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:

$$\eta_{tot\ TCS/by\text{-}pass} = \eta_{tot} \times \frac{A_{eff} + a_{eff}}{A_{eff}}$$

where
A_{eff} = Effective area in turbocharger turbine
a_{eff} = Effective area in TCS or exhaust by-pass.

See also ‘Remarks’, below

Turbine Efficiency:

$$\eta_{turb\ TCS/by\text{-}pass} = \eta_{turb} \times \frac{A_{eff} + a_{eff}}{A_{eff}}$$

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 $\frac{A_{eff} + a_{eff}}{A_{eff}}$ 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 $\frac{A_{eff} + a_{eff}}{A_{eff}}$ 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 Plate 70627. 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

See also Plate 70627.

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)

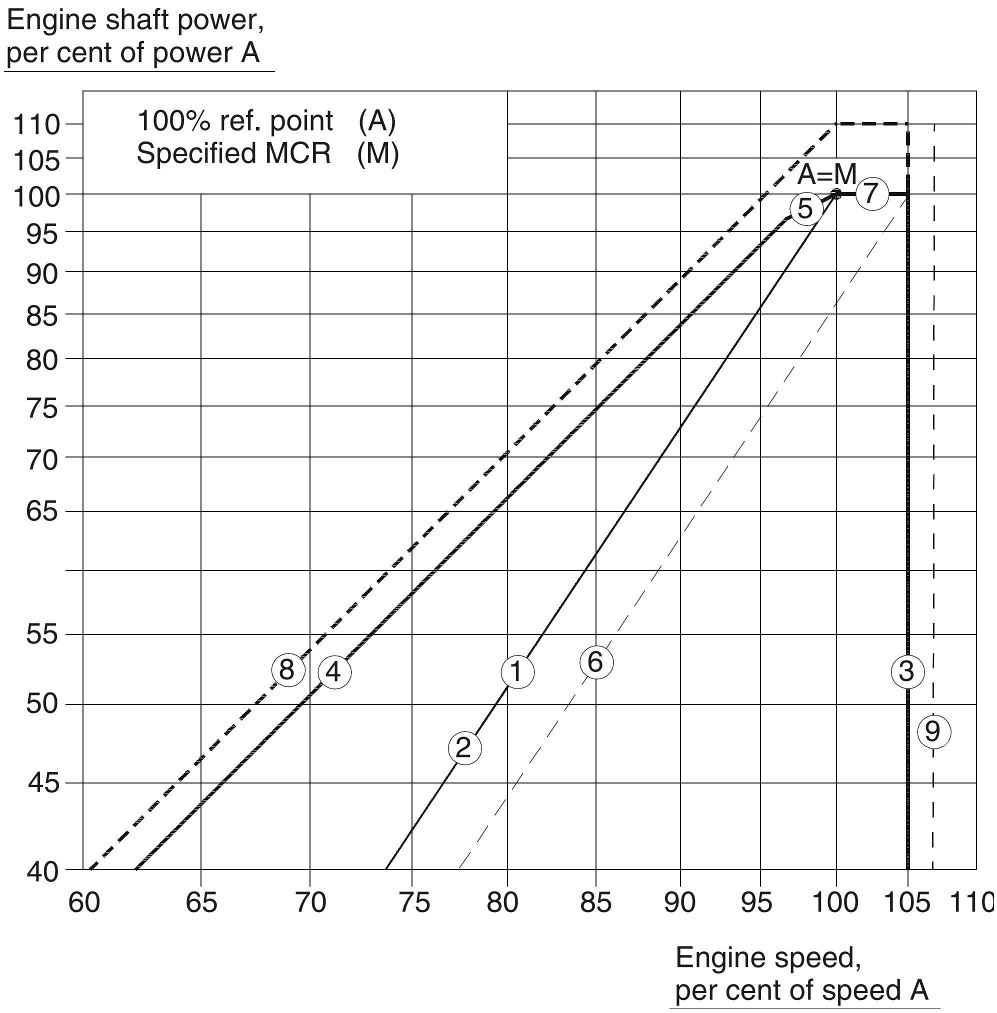
Chart III: Draw a horizontal line from the observed tscav value and an inclined line from the observed turbocharger speed.

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. 11,600 kW.

This method is more reliable, and an accuracy to within ± 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 also Section 706-05.



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

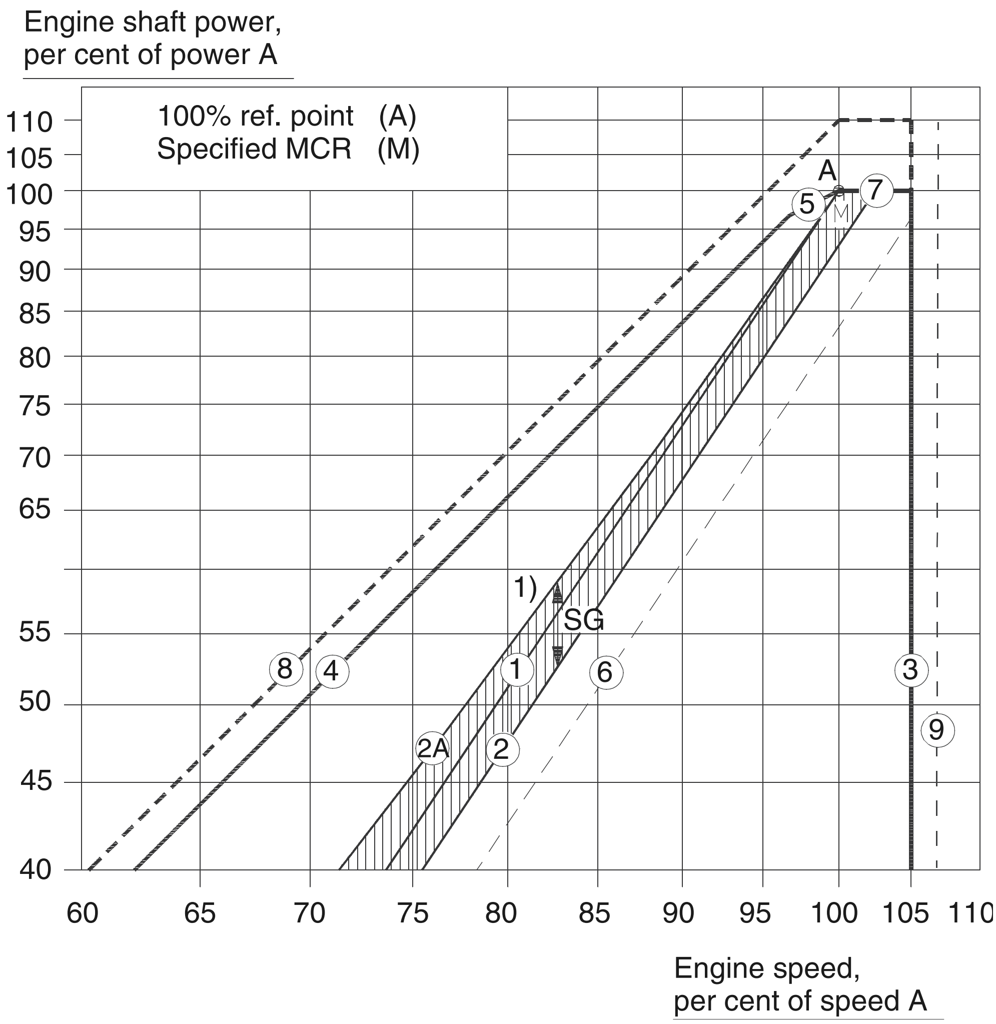
Line 6: Propeller curve – light running (range: 3.0-7.0%) for clean hull and calm weather conditions – for propeller layout

Line 7: Power limit for continuous running

Line 8: Overload limit

Line 9: Speed limit at sea trial.

Plant specific calculations can be prepared by contacting MAN B&W Diesel A/S.



Line 1: Propeller curve through point A – layout curve for engine

Line 2: Propeller curve for propulsion alone – 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 for propulsion alone – light running (range: 3.0 - 7.0%), 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.

1) Note: 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.

Performance Observations

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:	Stroke, m:
Make:	Type:	1		Cylinder Constant, (HP,bar):	Mean Friction. Press., bar:	
Max. RPM:	Max. Temp., °C:	2		Lubrication Oil System (Tick box)		
Compr. Slip Factor:	Compr. Diam., m:	3		☐ Internal	☐ External from M. E. System	☐ External from Gravity Tank
TC specification:		4				

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	Engine RPM	Total Running Hours	Fuel Index ECU %	Speed Setting RPM	VIT Control
								bar

Effective Power BHP	Effective Power kW	Indicated Power kW	Eff. Fuel Consumption g/BHPh	Eff. Fuel Consumption g/kWh	Draft Fore, m	Log Knots	Wind, m/s	Direction, °
					Draft Aft, m	Obs. Knots	Wave Height, m	Direction, °

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 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	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	
		Seaw. Temp.				mmHg			Axial Vibration			mmHg
2	2		2	2	2		2	2		2	2	
									mm			
3	3		3	3	3		3	3		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	Hydraulic Pressure	
Scav. Air Temp. °C	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 Before Pumps	Main Pressure	
	4	4	4	Temperature, °C Inlet Engine	3	3		Swash Plate Position, %	
								1	2
	Ave.	Ave.	Ave.		4	4			
				Thrust Segment				3	4
					Ave.	Ave.			

Remarks:

Performance Observations

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

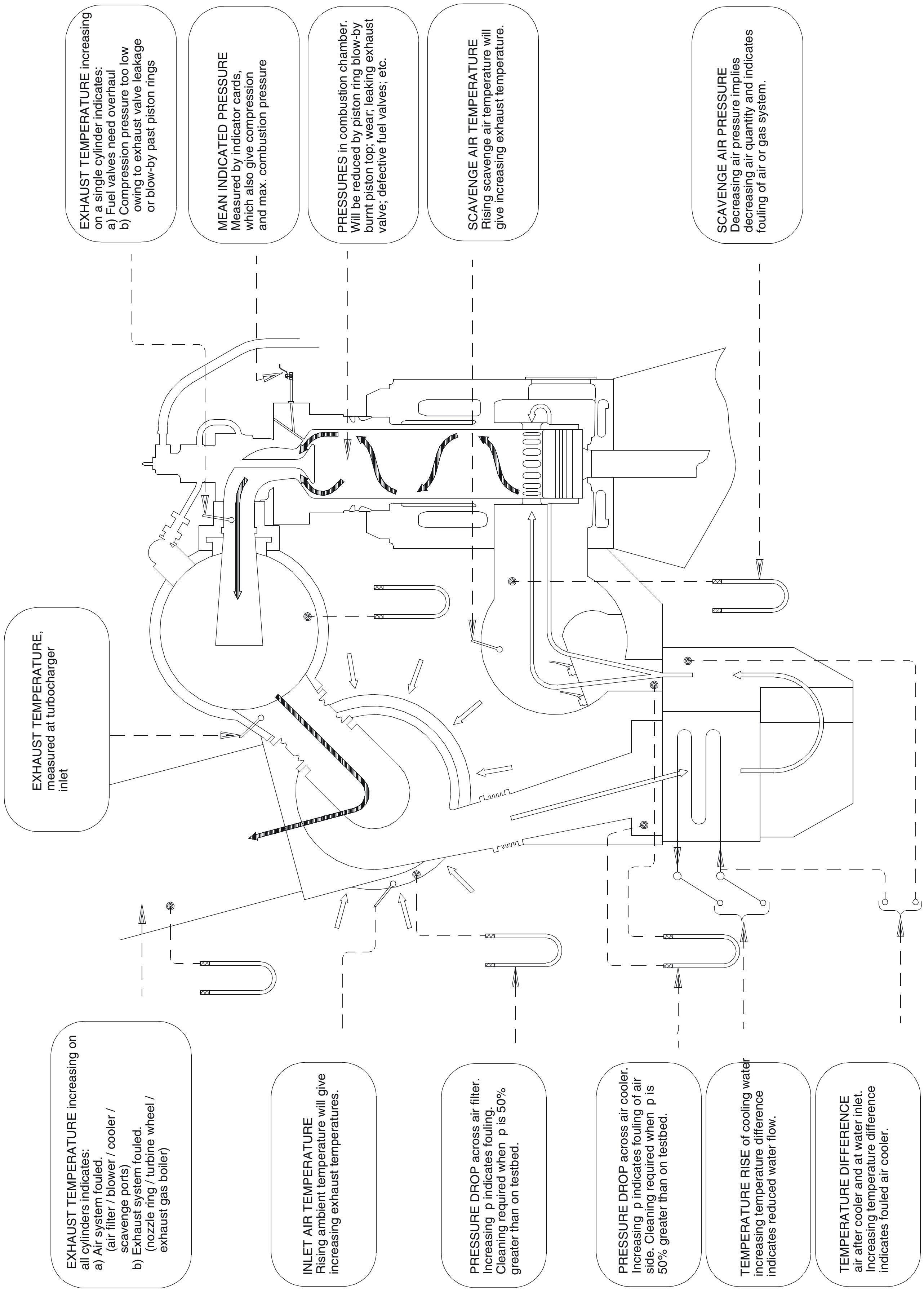
Effective Power BHP	Effective Power kW	Indicated Power kW	Eff. Fuel Consumption g/BHPh	Eff. Fuel Consumption g/kWh	Indicated Fuel Consumption g/IHPh	Indicated Fuel Consumption g/kWh

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.			▲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	
		Seaw. Temp.				mmHg			Axial Vibration			mmHg
2	2		2	2	2		2	2		2	2	
									mm			
3	3		3	3	3		3	3		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 bar
Scav. Air	Inlet Blower	Before Cooler	After Cooler	Pressure, bar	Temperature, °C	Temperature, °C		
	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 Before Pumps
	4	4	4	Turbine Oil	Thrust Segment	3	3	
	Ave.	Ave.	Ave.			4	4	
						Ave.	Ave.	

Remarks:

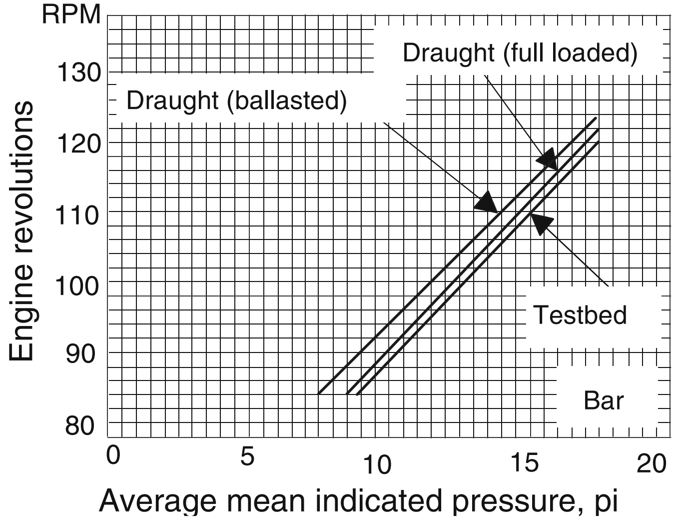

EXHAUST TEMPERATURE increasing on a single cylinder indicates:
a) Fuel valves need overhaul
b) Compression pressure too low owing to exhaust valve leakage or blow-by past piston rings
MEAN INDICATED PRESSURE Measured by indicator cards, which also give compression and max. combustion pressure
PRESSURES in combustion chamber. Will be reduced by piston ring blow-by burnt piston top; wear; leaking exhaust valve; defective fuel valves; etc.
SCAVENGE AIR TEMPERATURE Rising scavenge air temperature will give increasing exhaust temperature.
SCAVENGE AIR PRESSURE Decreasing air pressure implies decreasing air quantity and indicates fouling of air or gas system.
EXHAUST TEMPERATURE, measured at turbocharger inlet
EXHAUST TEMPERATURE increasing on all cylinders indicates:
a) Air system fouled. (air filter / blower / cooler / scavenge ports)
b) Exhaust system fouled. (nozzle ring / turbine wheel / exhaust gas boiler)
INLET AIR TEMPERATURE Rising ambient temperature will give increasing exhaust temperatures.
PRESSURE DROP across air filter. Increasing p indicates fouling. Cleaning required when p is 50% greater than on testbed.
PRESSURE DROP across air cooler. Increasing p indicates fouling of air side. Cleaning required when p is 50% greater than on testbed.
TEMPERATURE RISE of cooling water increasing temperature difference indicates reduced water flow.
TEMPERATURE DIFFERENCE air after cooler and at water inlet. Increasing temperature difference indicates fouled air cooler.

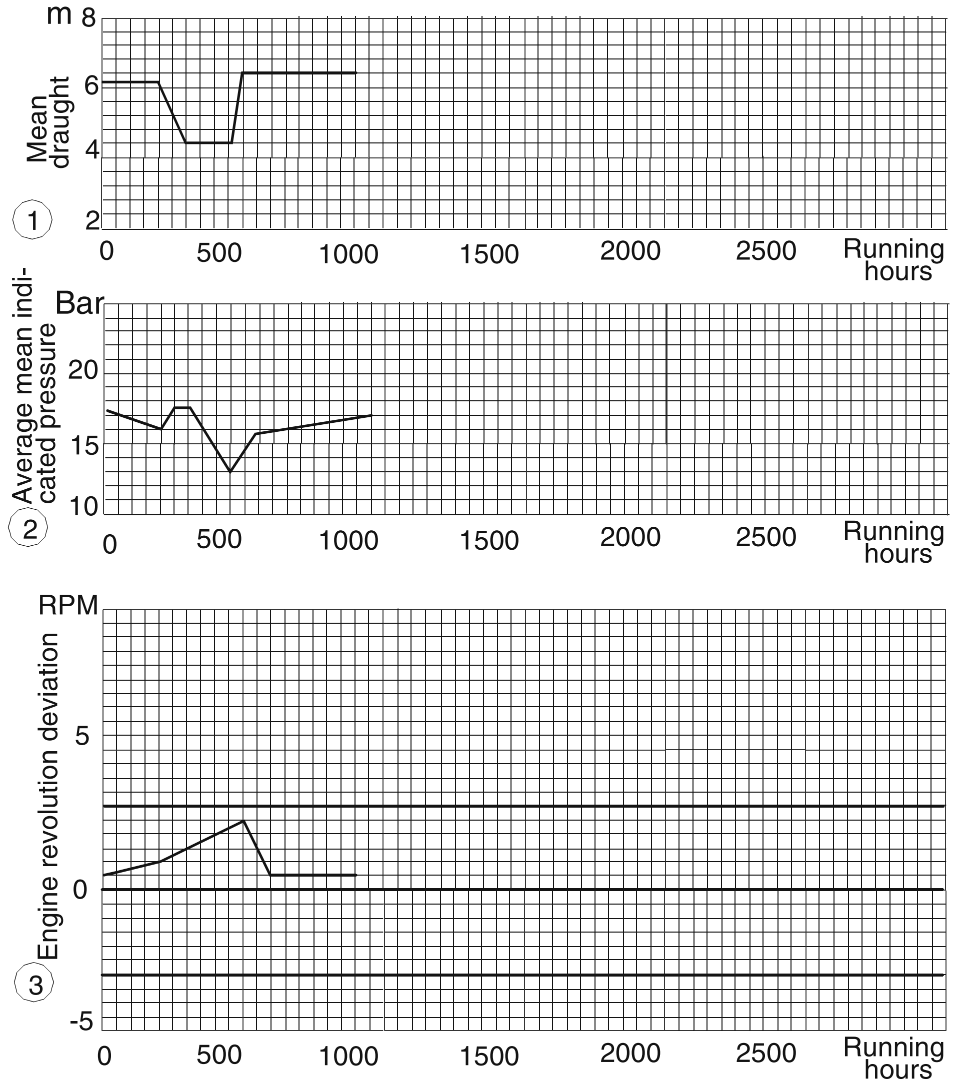
Time based deviation charts for: mean draught and average mean indicated pressure (p_i).
Model curves + time based deviation chart for: r/min as a function of p_i.

M / V	Engine Type		Time based Deviation Charts	Checked by:
Yard	Builder	No.		Date:
	Built year			

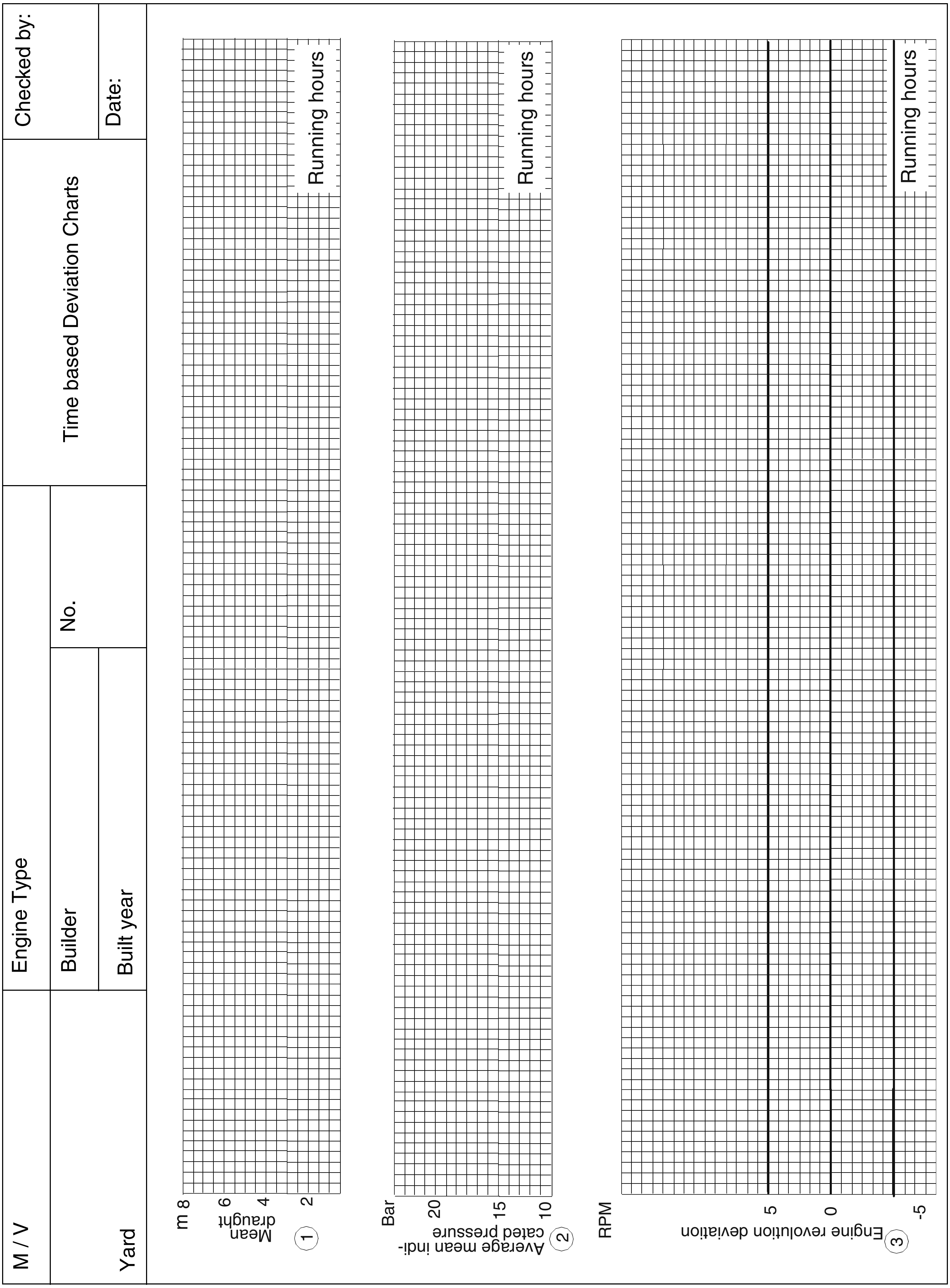
All the model curves are based on test results from shop trial or sea trial.

Directions for use:
Service results are plotted faintly in the Model Curve diagrams. The vertical deviations are transferred to the pertaining Time based Deviation-chart (on the right hand side).





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.



Model curves and time based deviation chart for:
p_{max} and fuel index as a function of p_i

M / V

Yard

Engine Type

Builder

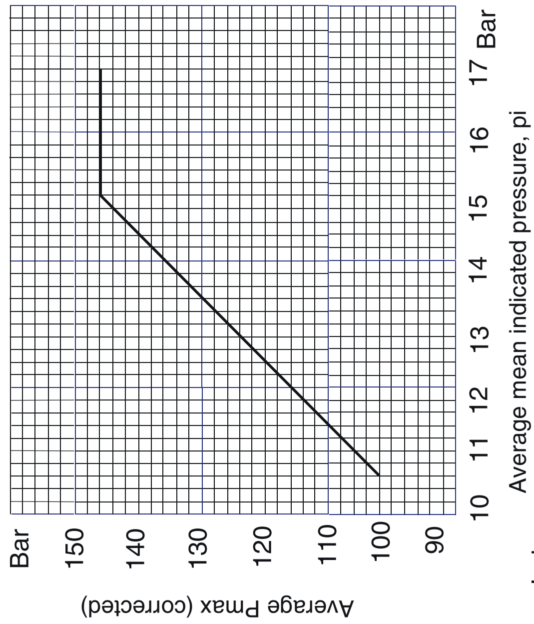
Built year

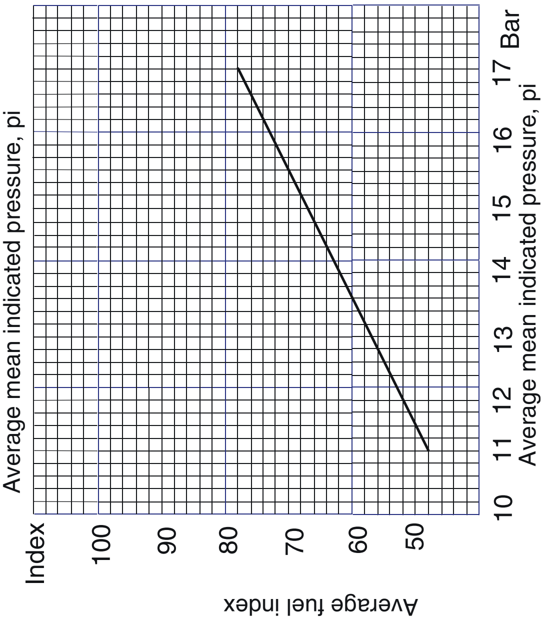
No.

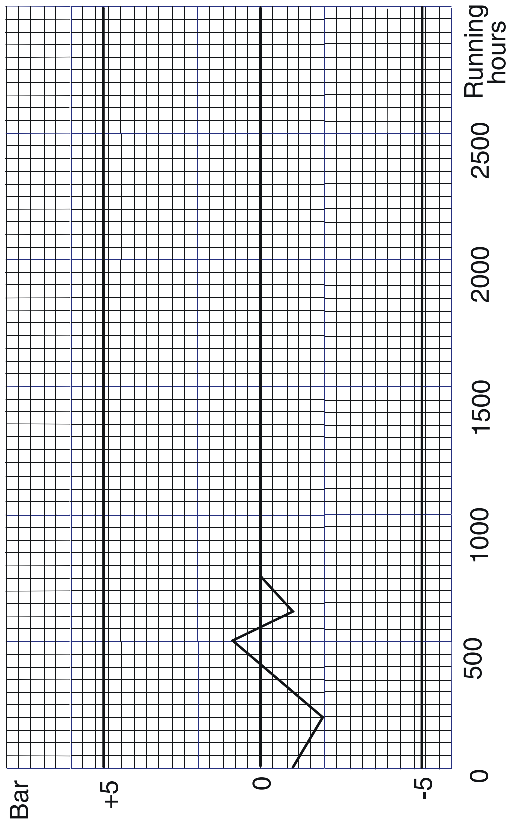
Time based Deviation Charts

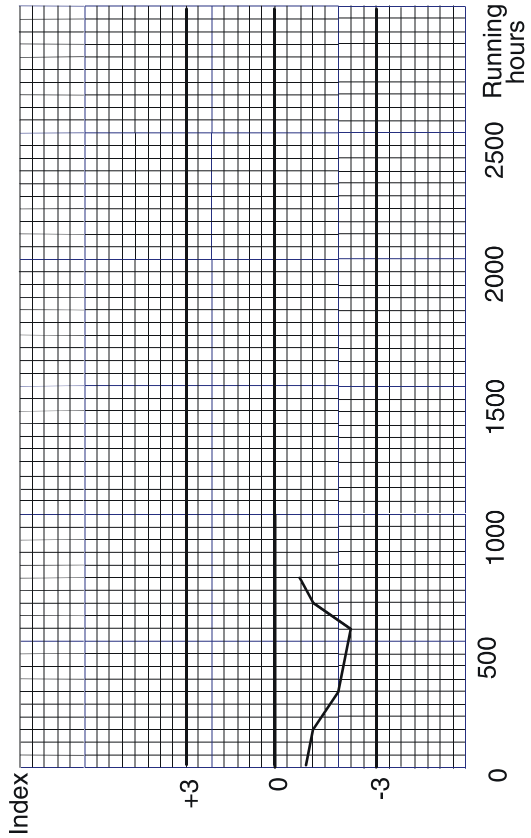
Checked by:

Date:





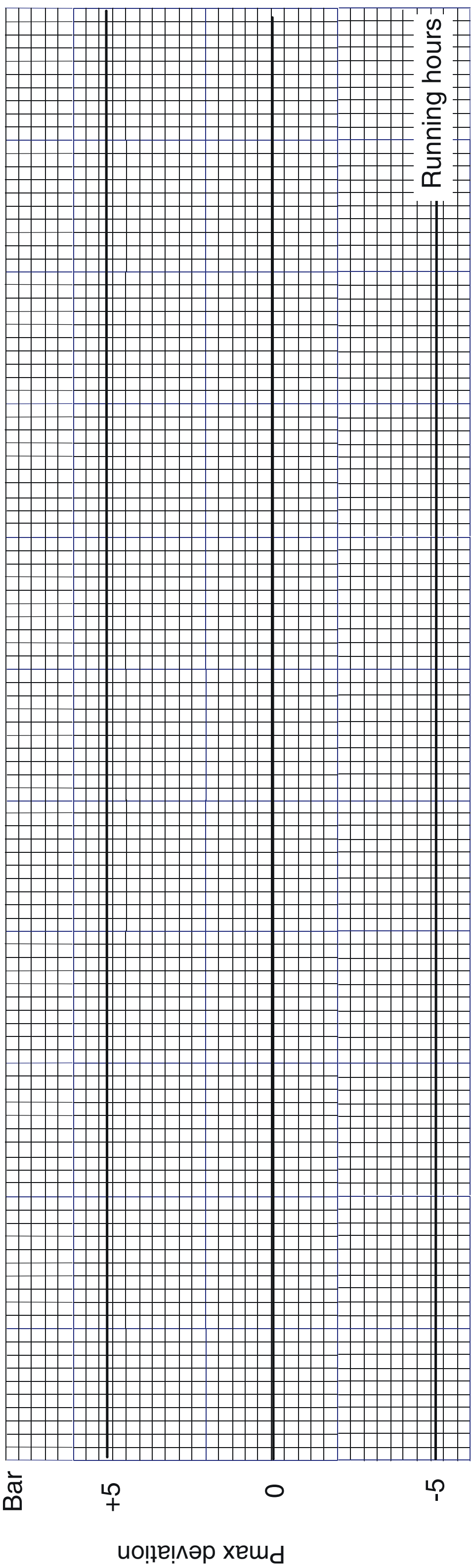


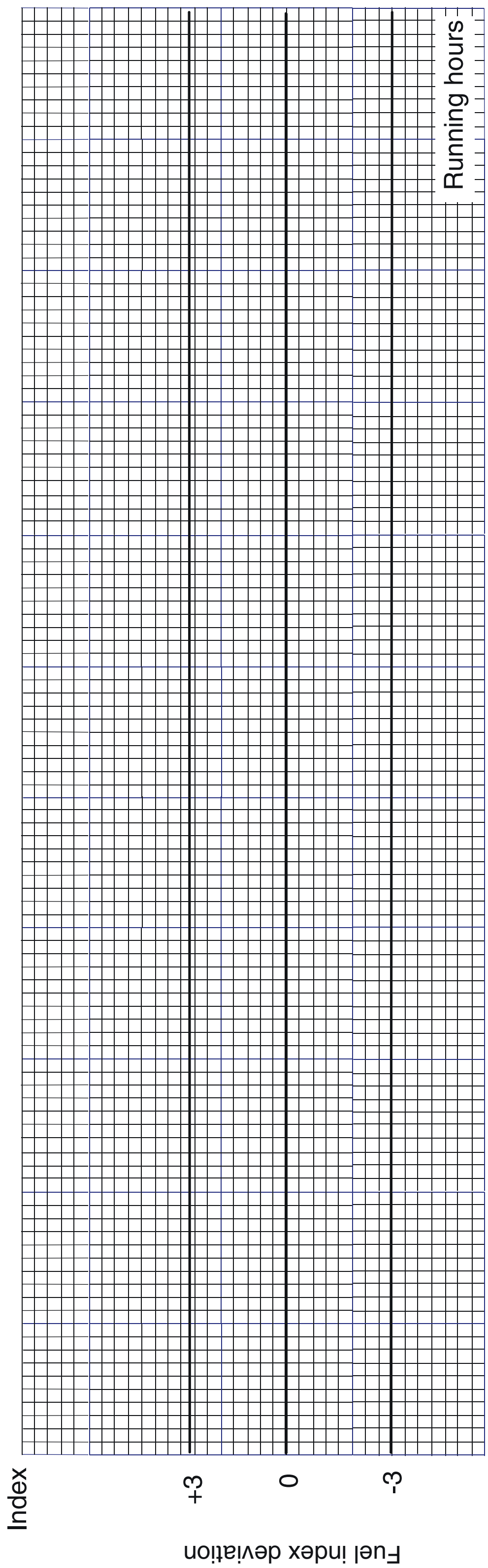


Synopsis Diagrams – for engine

Time based deviation chart for:
p_{max} and fuel index

Checked by:	Date:	
Time based Deviation Charts		
Engine Type	No.	
	Builder	Built year
M / V		Yard





Synopsis Diagrams – for engine

Model curves and time based deviation chart for:
t_{exhv} and p_{comp} as a function of p_e

M / V

Yard

Engine Type

Builder

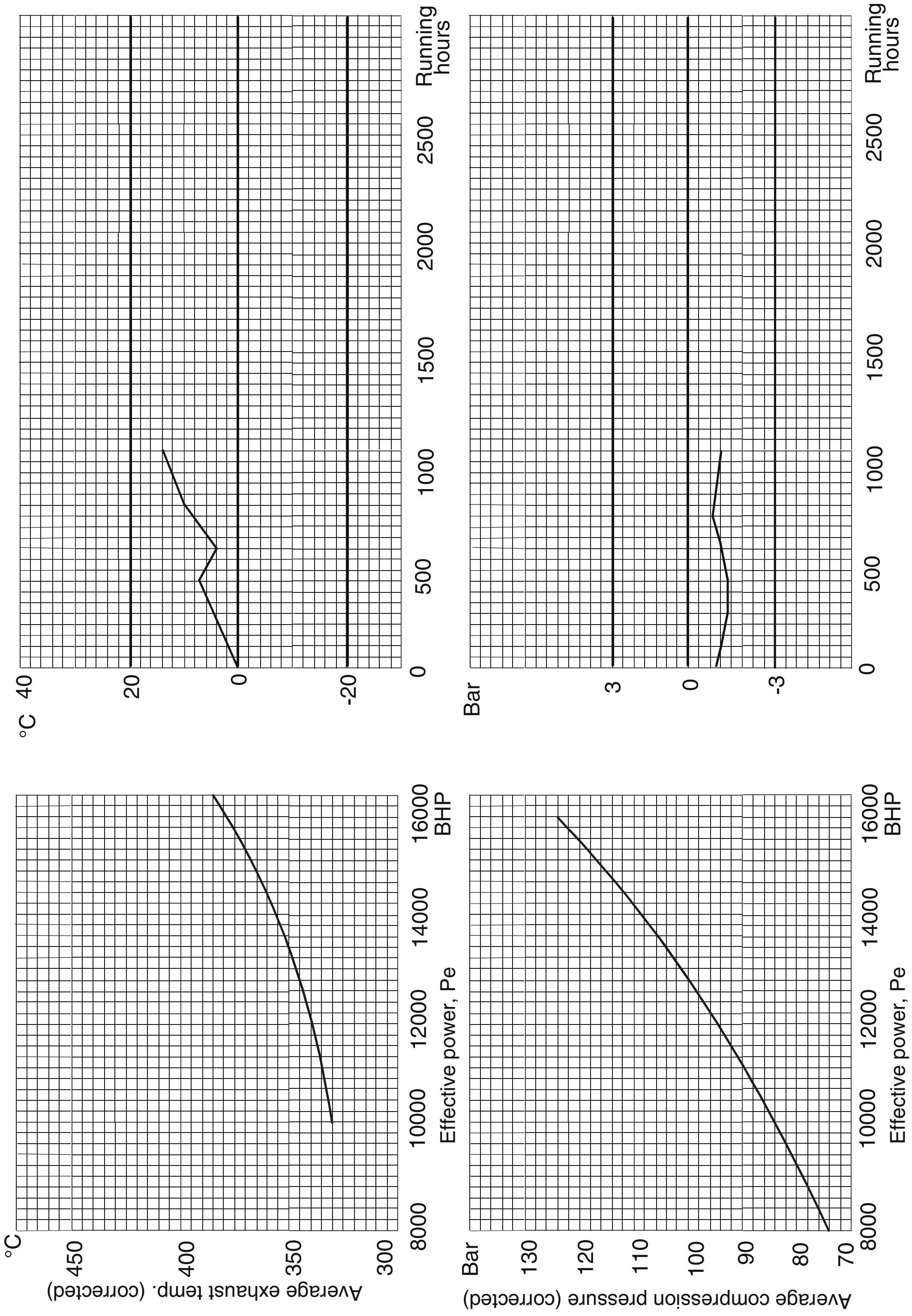
Built year

No.

Time based Deviation Charts

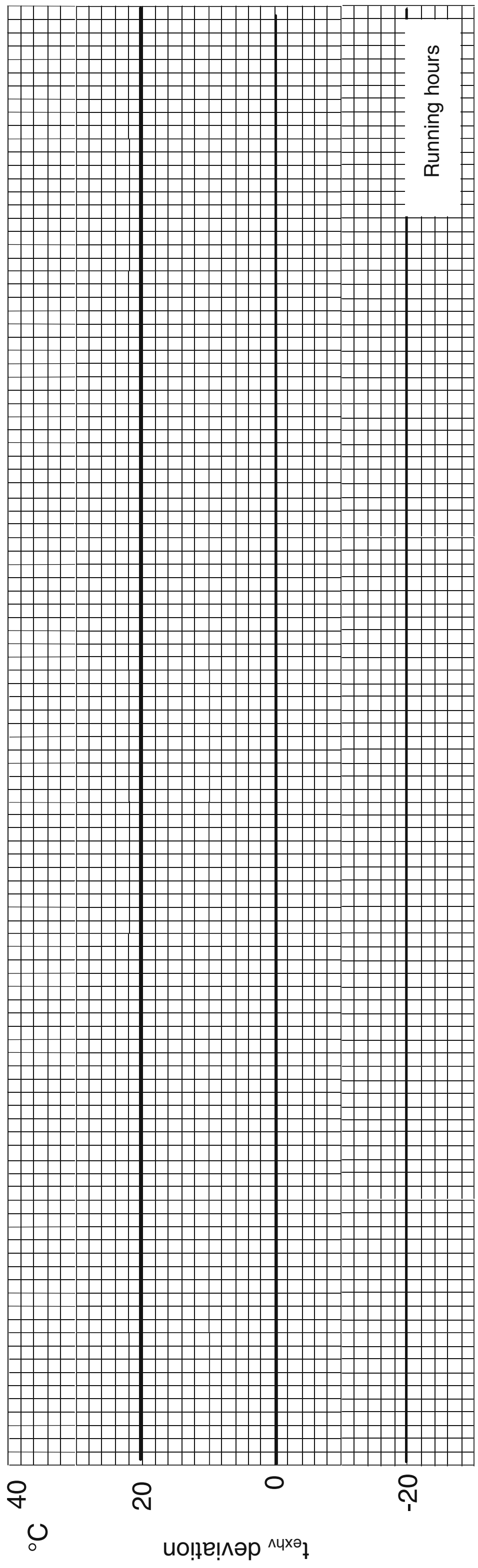
Checked by:

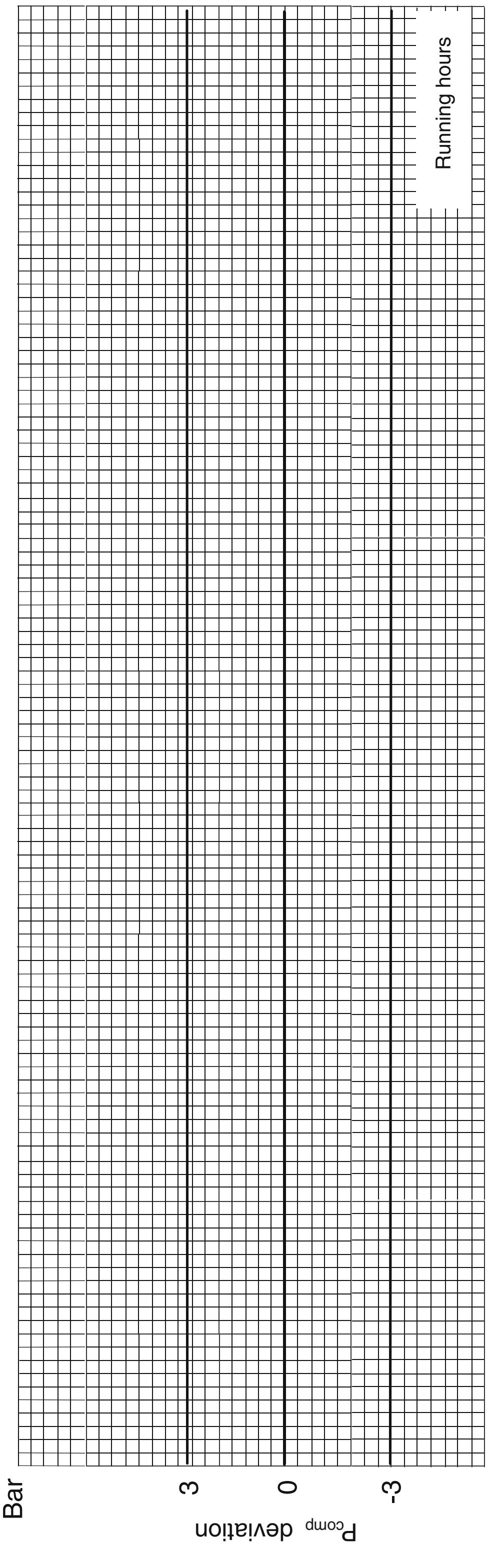
Date:



Time based deviation chart for:
t_{exhv} and p_{comp}

Checked by:
Date:
Time based Deviation Charts
Engine Type
No.
Builder
Built year
M / V
Yard

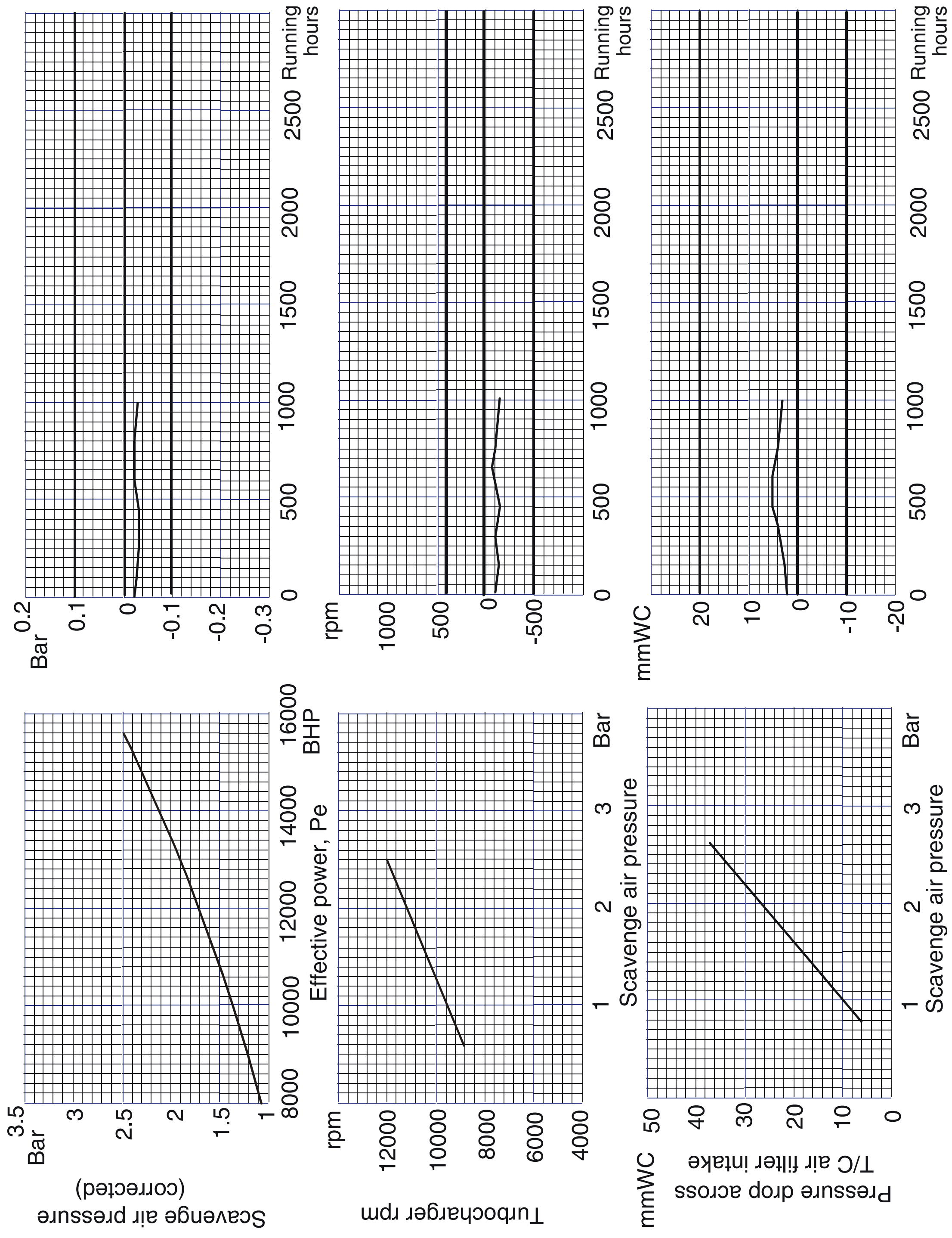




Synopsis Diagrams – for turbocharger

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}

M / V	Engine Type	Checked by:
	Builder	No.
Yard	Built year	Date:
	Time based Deviation Charts	



Time based deviation chart for:
p_{scav} T/C r/min and Δ p_f

Checked by:

Date:

Time based Deviation Charts

Engine Type

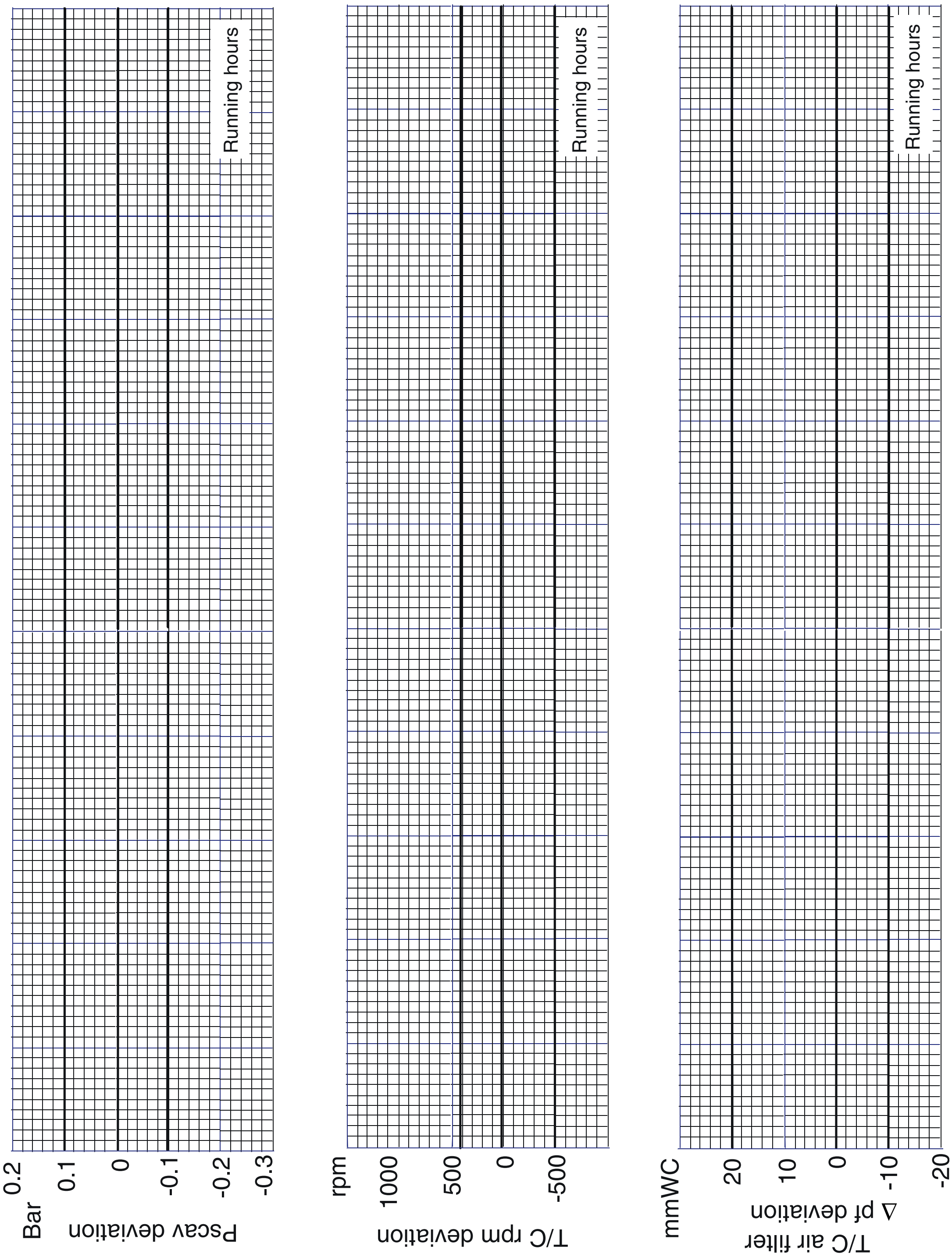
No.

Builder

Built year

M / V

Yard

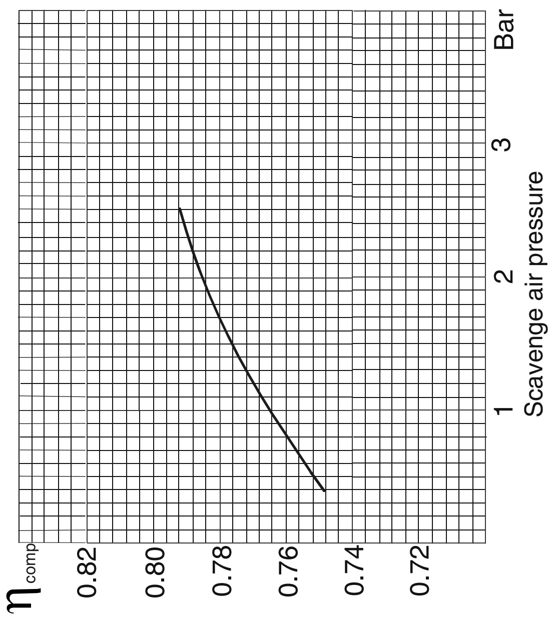


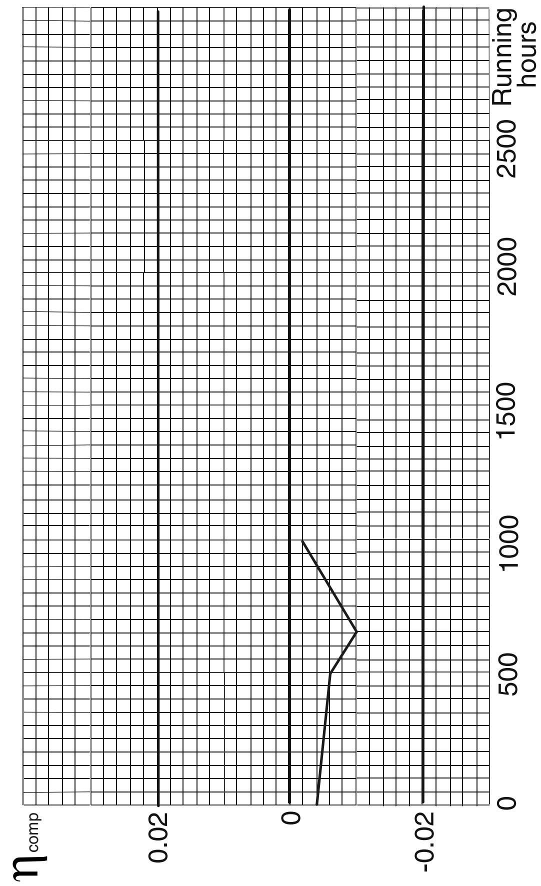
Synopsis Diagrams – for turbocharger

Model curves and time based deviation chart for:
Compressor and turbine efficiencies as a function of p_{scav}

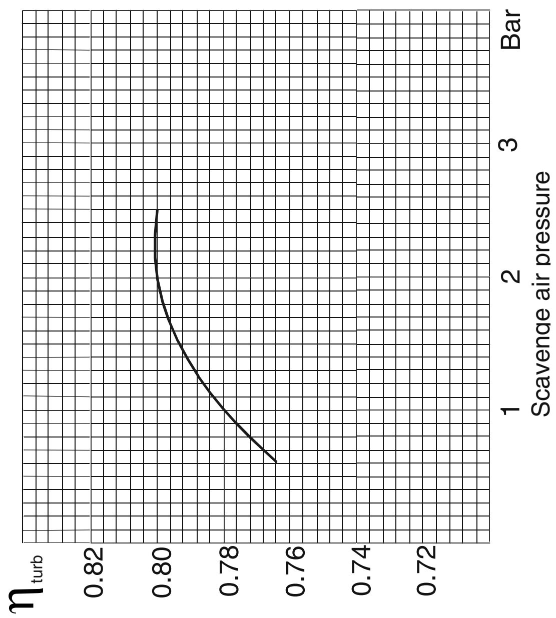
M / V	Engine Type	Time based Deviation Charts	Checked by:
	Builder	No.	
Yard	Built year		Date:

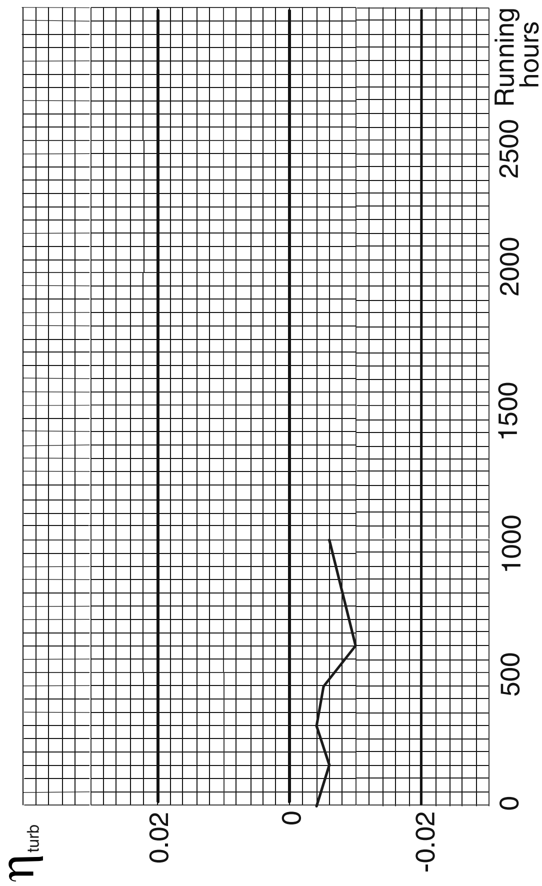
compressor





turbine

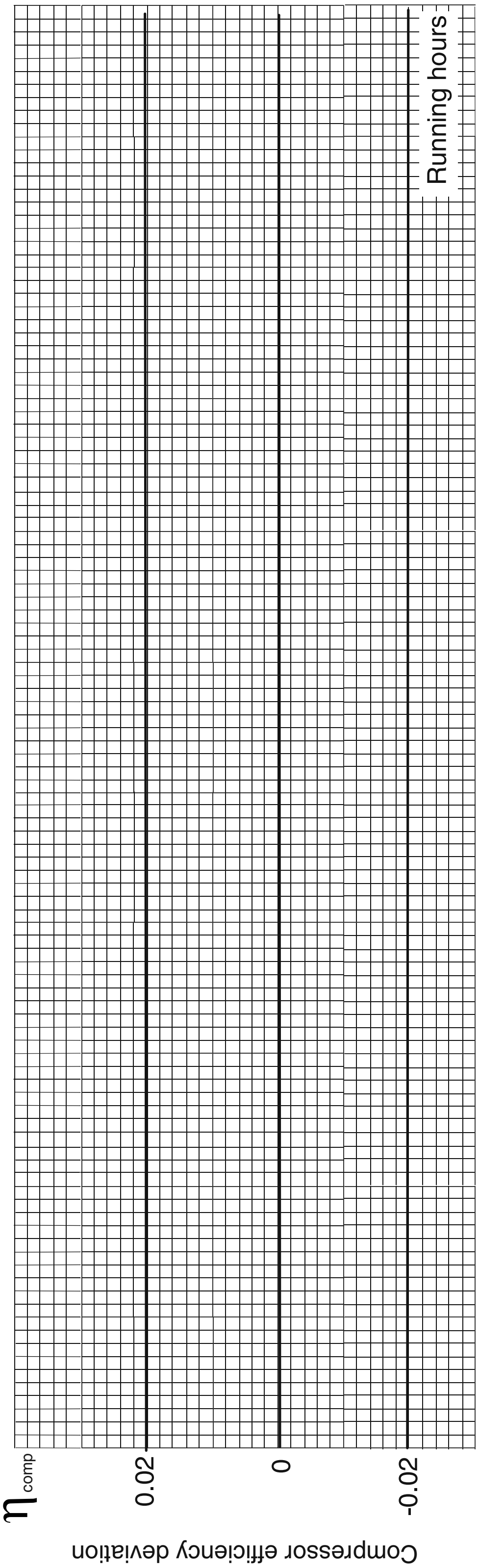


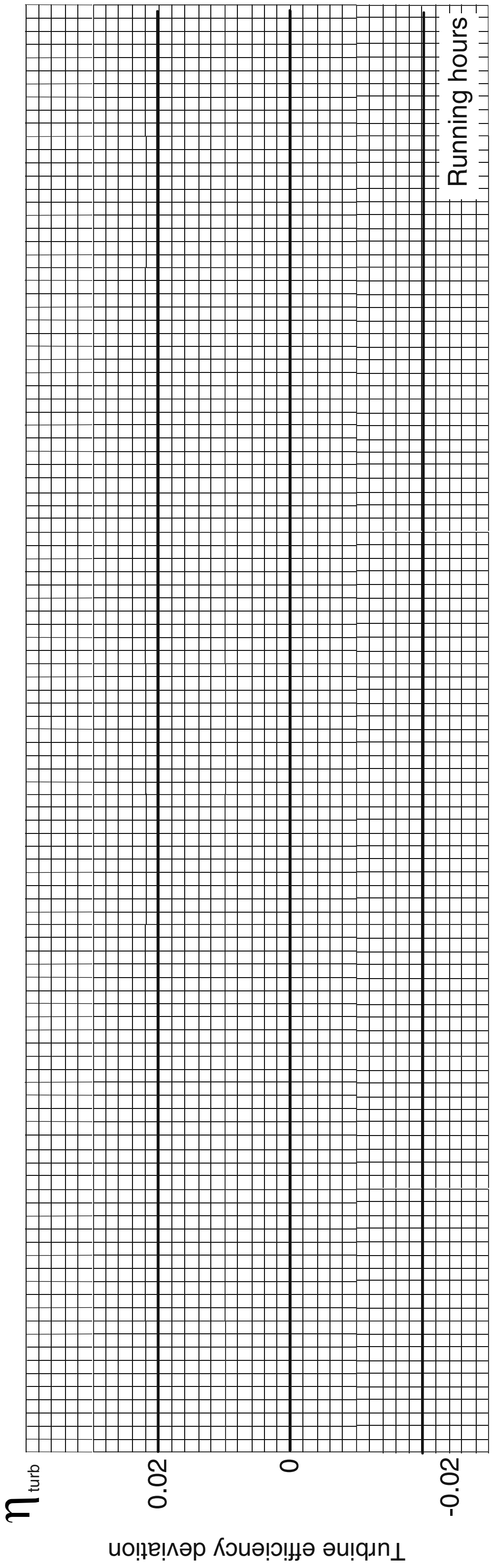


Synopsis Diagrams – for turbocharger

Time based deviation chart for:
compressor and turbine efficiencies

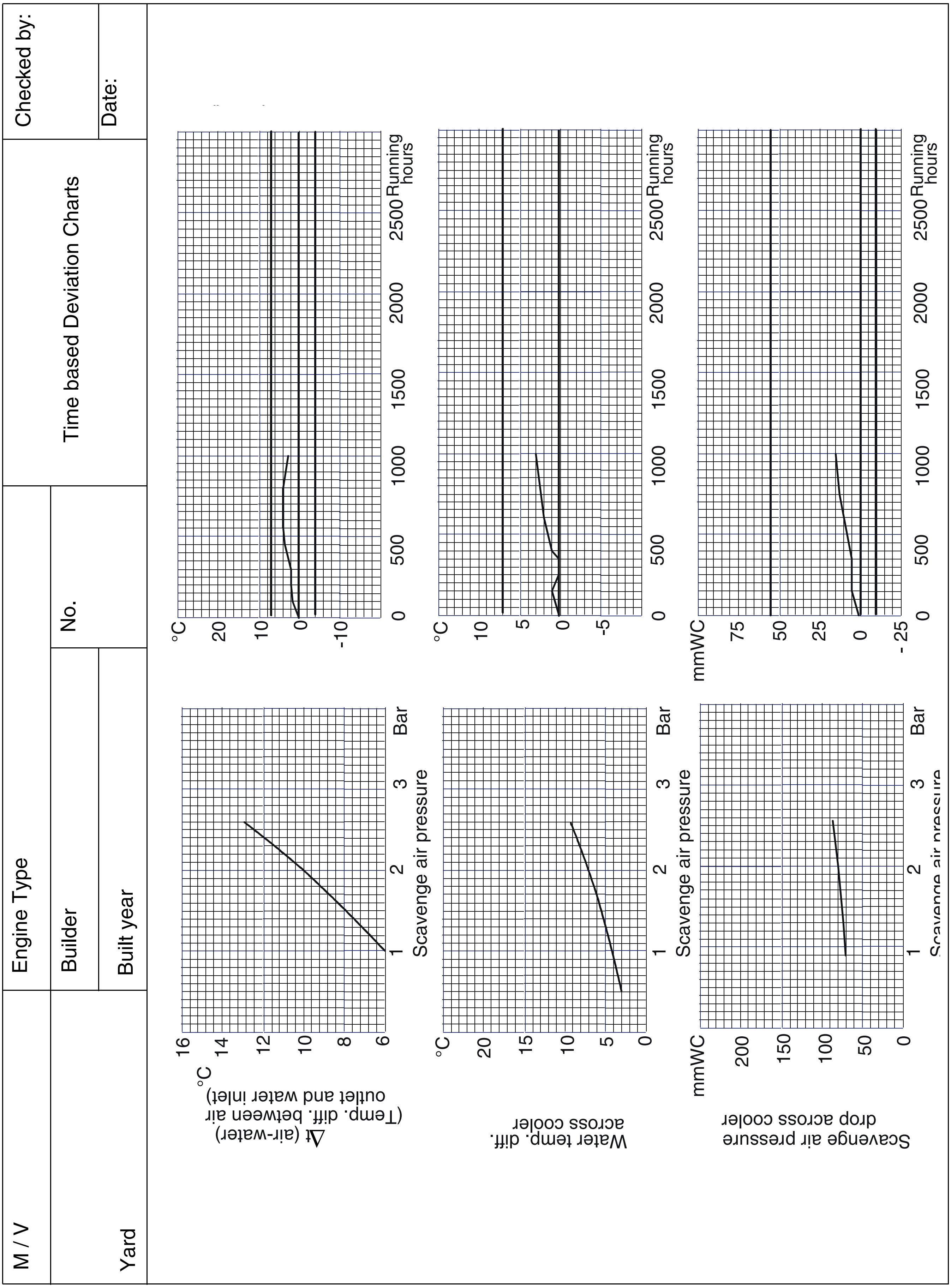
Checked by:		Date:
Time based Deviation Charts		
Engine Type	No.	
	Builder	Built year
M / V		Yard





Synopsis Diagrams – for air cooler

Model curves and time based deviation chart for:
$t_{air\text{-}water}$, t_{water}, and p_{air}, as a function of p_{scav}



Synopsis Diagrams – for air cooler

Time based deviation chart for:
$\Delta\ t_{air\text{-}water}$ $\Delta\ t_{water}$ and $\Delta\ p_{air}$

Checked by:

Date:

Time based Deviation Charts

Engine Type

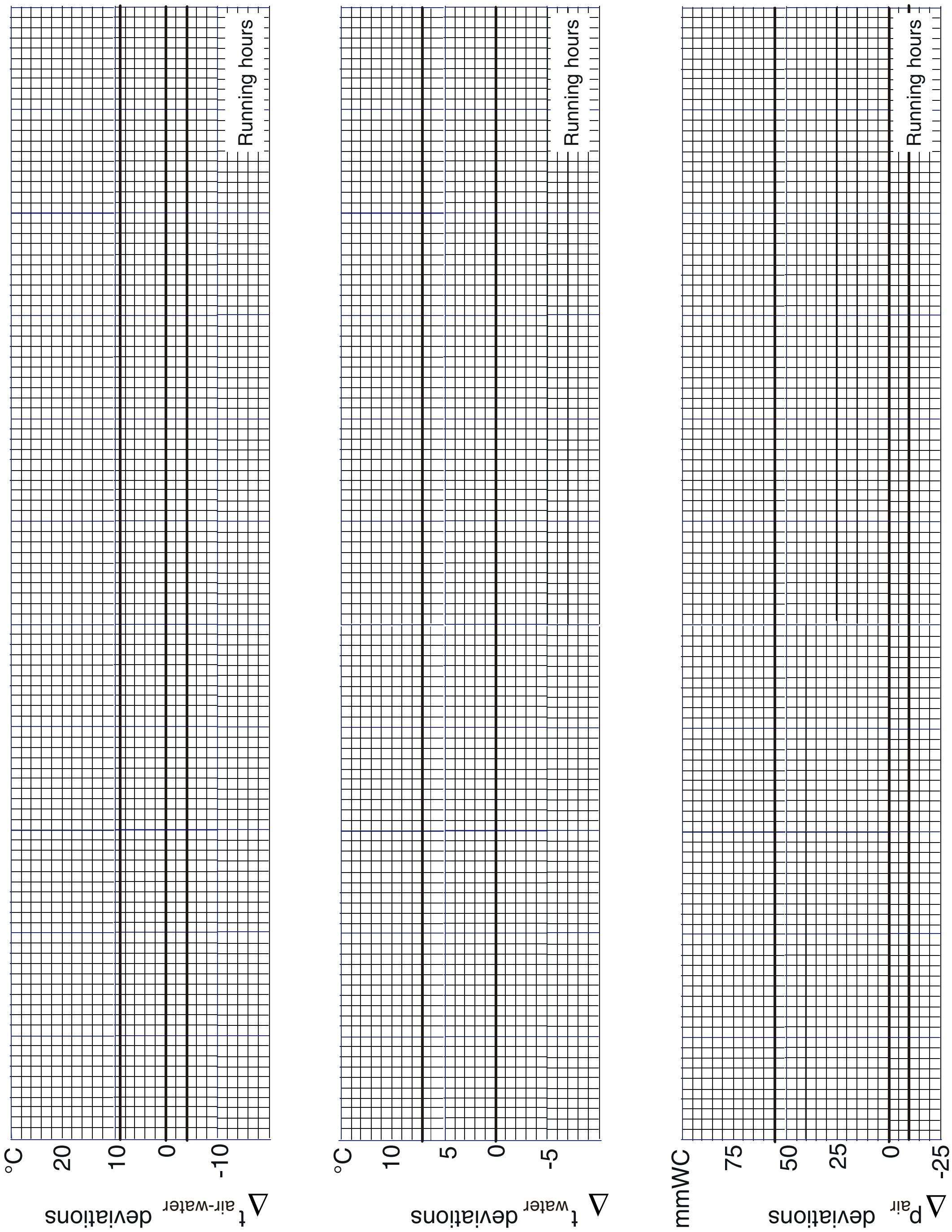
No.

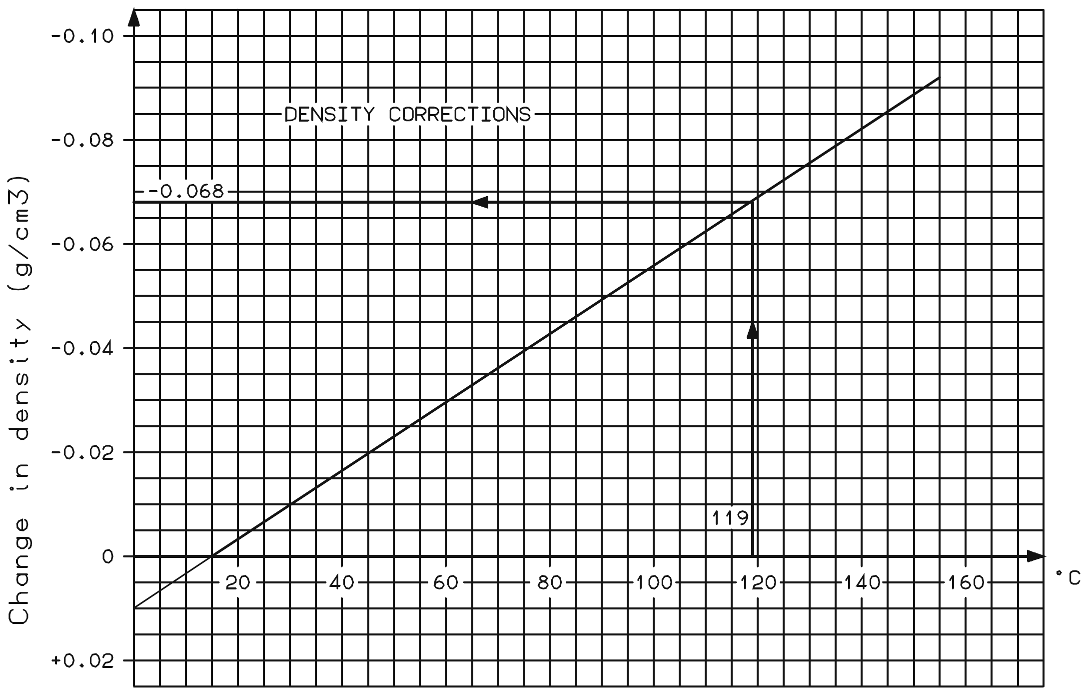
Builder

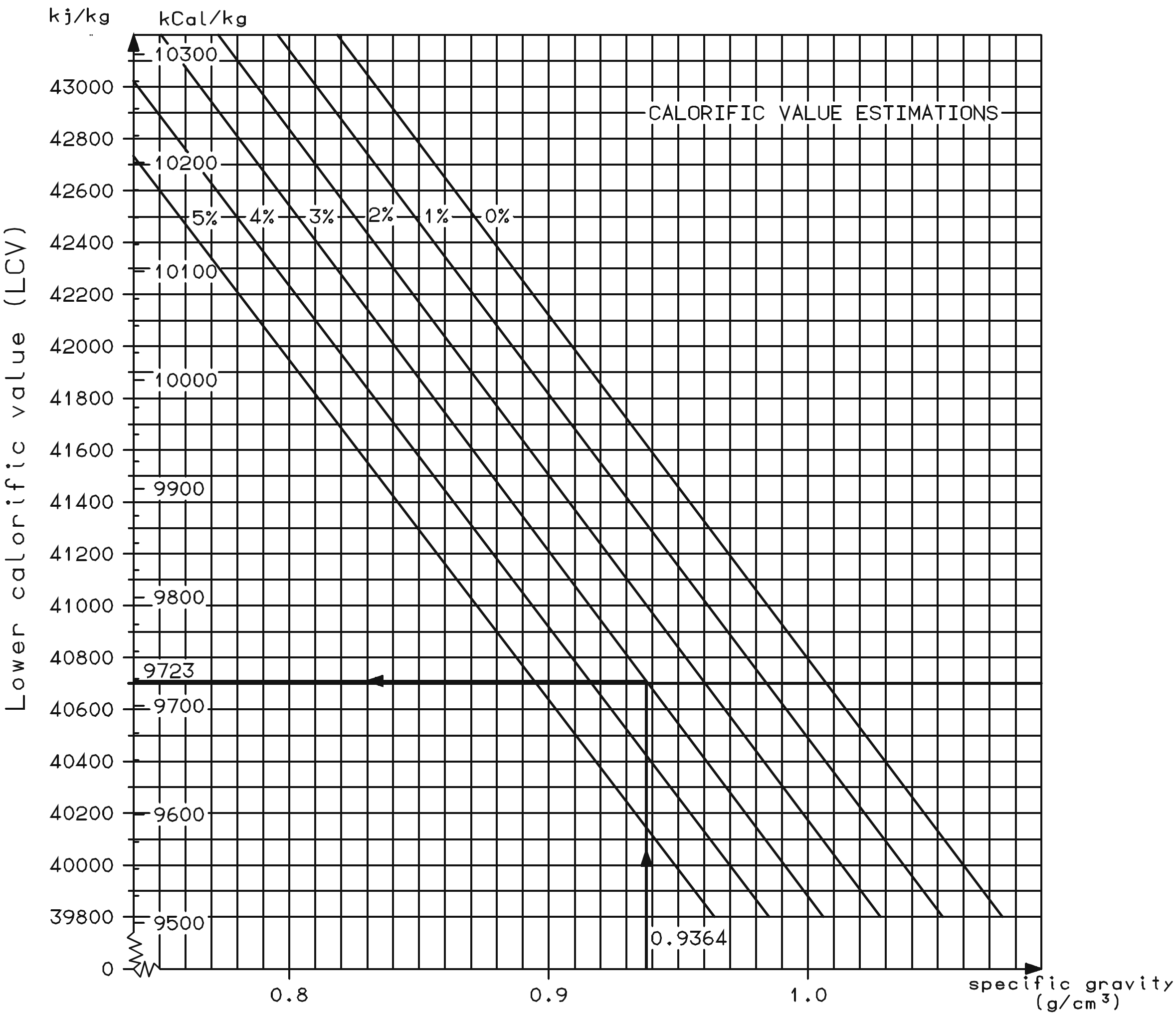
Built year

M / V

Yard

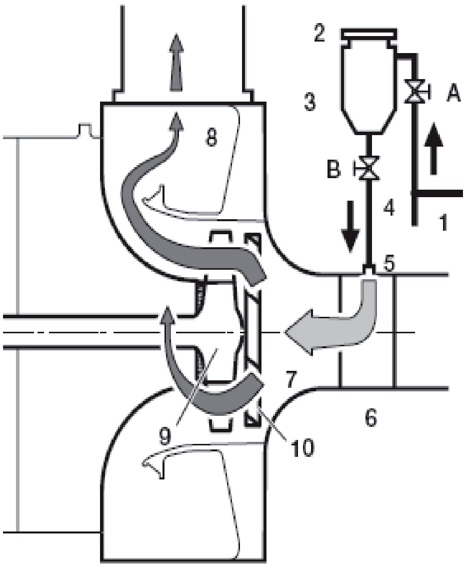



DENSITY CORRECTIONS
Change in density (g/cm3)
-0.10
-0.08
-0.068
-0.06
-0.04
-0.02
0
+0.02
119
20
40
60
80
100
120
140
160
°C


CALORIFIC VALUE ESTIMATIONS
kj/kg
kCal/kg
Lower calorific value (LCV)
43000
42800
42600
42400
42200
42000
41800
41600
41400
41200
41000
40800
40600
40400
40200
40000
39800
0
10300
10200
10100
10000
9900
9800
9723
9700
9600
9500
5%
4%
3%
2%
1%
0%
0.9364
0.8
0.9
1.0
specific gravity (g/cm³)

Dry cleaning is carried out under high engine load (50% - 100%).

It is recommended to perform the cleaning with granules every one to two days.



1 Compressed air pipe
2 Screw plug
3 Granulate container
4 Pipe
5 Connection flange
6 Adapter
7 Gas-admission casing
8 Gas outlet casing
9 Turbine wheel
10 Nozzle ring
A Stop cock (compressed air)
B Stop cock (exhaust gas)

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 conainer 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 tur bine.

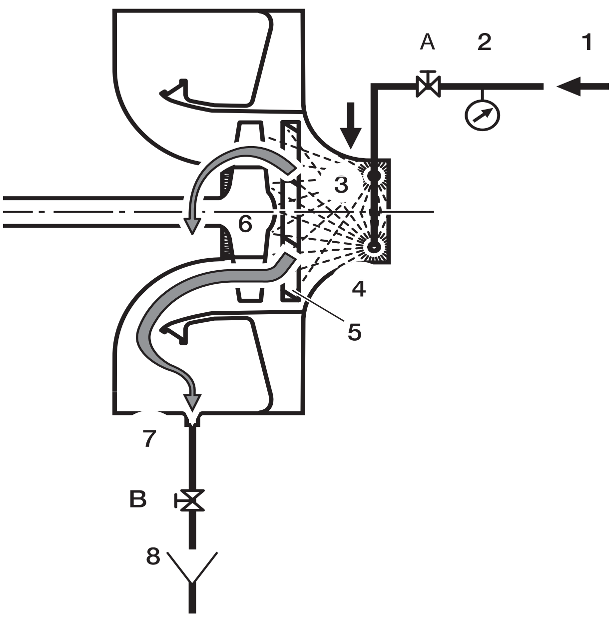
4. After 1 to 2 minutes, close valves B and A.

T/C type	Amount [liter]
TCR22	0.5
TCA55	1.0
TCA66	1.5
TCA77	2.0
TCA88	2.5
TCA99	3.0
MET33	0.4
MET42	0.7
MET53	1.6
MET60	2.1
MET66	2.6
MET71	3.0
MET83	3.5
MET90	3.5
TPL69	1.0
TPL73	1.0
TPL77	1.5
TPL80	2.0
TPL85	3.0
TPL91	3.5

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	TCA 33	TCA 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



1 Washing water
2 Pressure gauge
3 Nozzles
4 Gas-admission casing
5 Nozzle ring
6 Turbine wheel
7 Washing water drain
8 Drain funnel

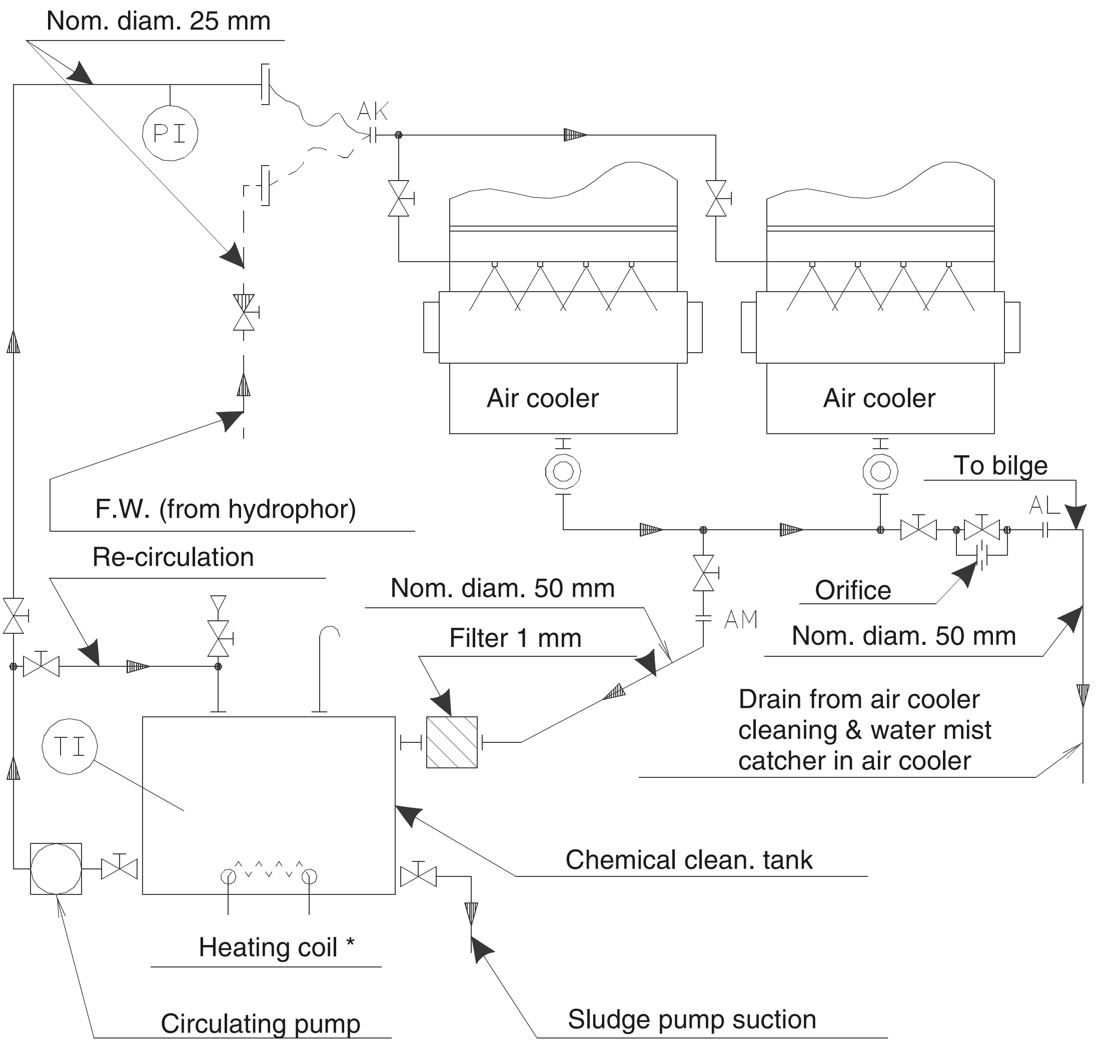
A Water stop cock
B Drainage cock

- Use fresh water without any chemical additives whatsoever.
- 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.

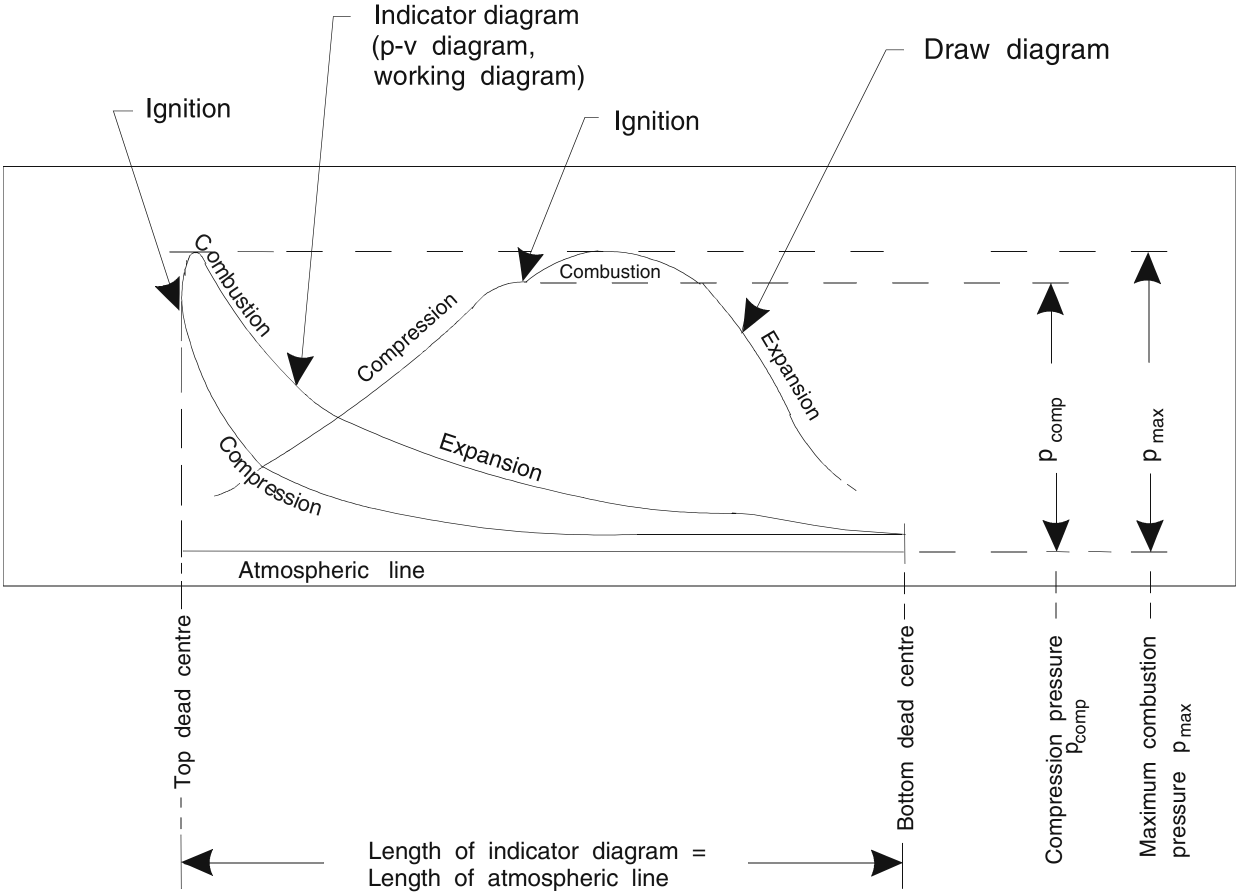
The washing water collects in the gas-outlet casing and runs through the washing water outlet and the drainage cock. The washing water is conducted via a funnel to a sediment tank and collected there.

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

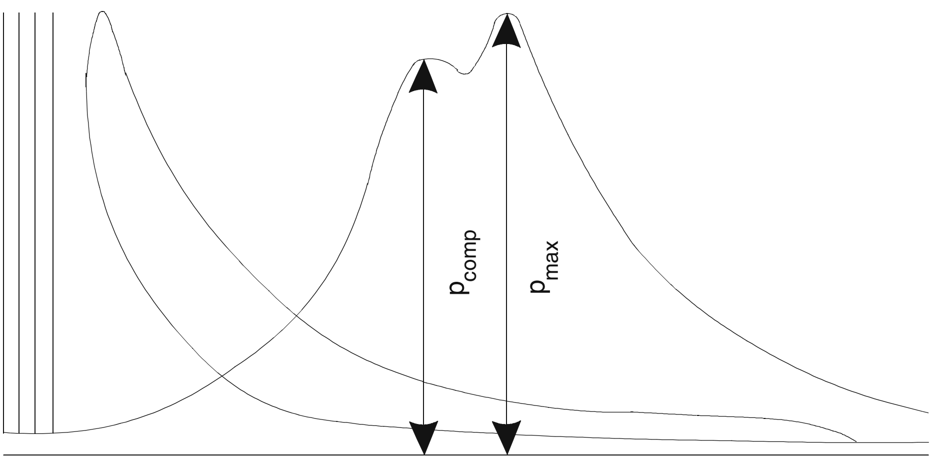
K/L-MC Engines:



S-MC Engines:

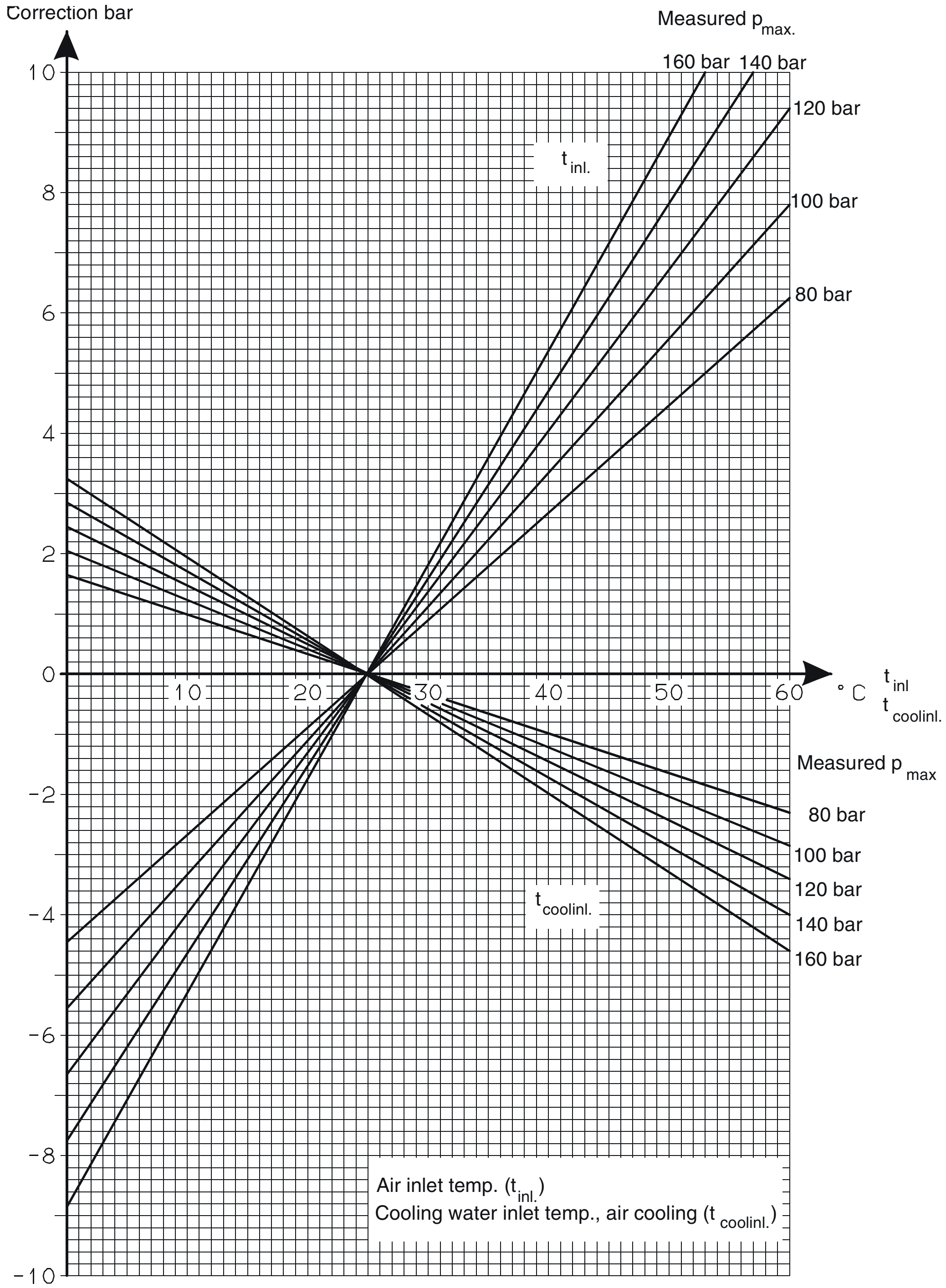
For this type of engine it has been necessary to delay the point of ignition to 2-3° after TDC, in order to keep the pressure rise, p_{comp} - p_{max}, within the specified 35 bar, while still maintaining optimum combustion and thereby low SFOC.

Due to this delay in ignition, the draw diagram will often show two pressure peaks, as shown in the figure below.



Maximum Combustion Pressure

Correction of measured p_{max}
because of deviations between t_{inl} / $t_{coolinl}$ and standard conditions



Calculating the corrections:

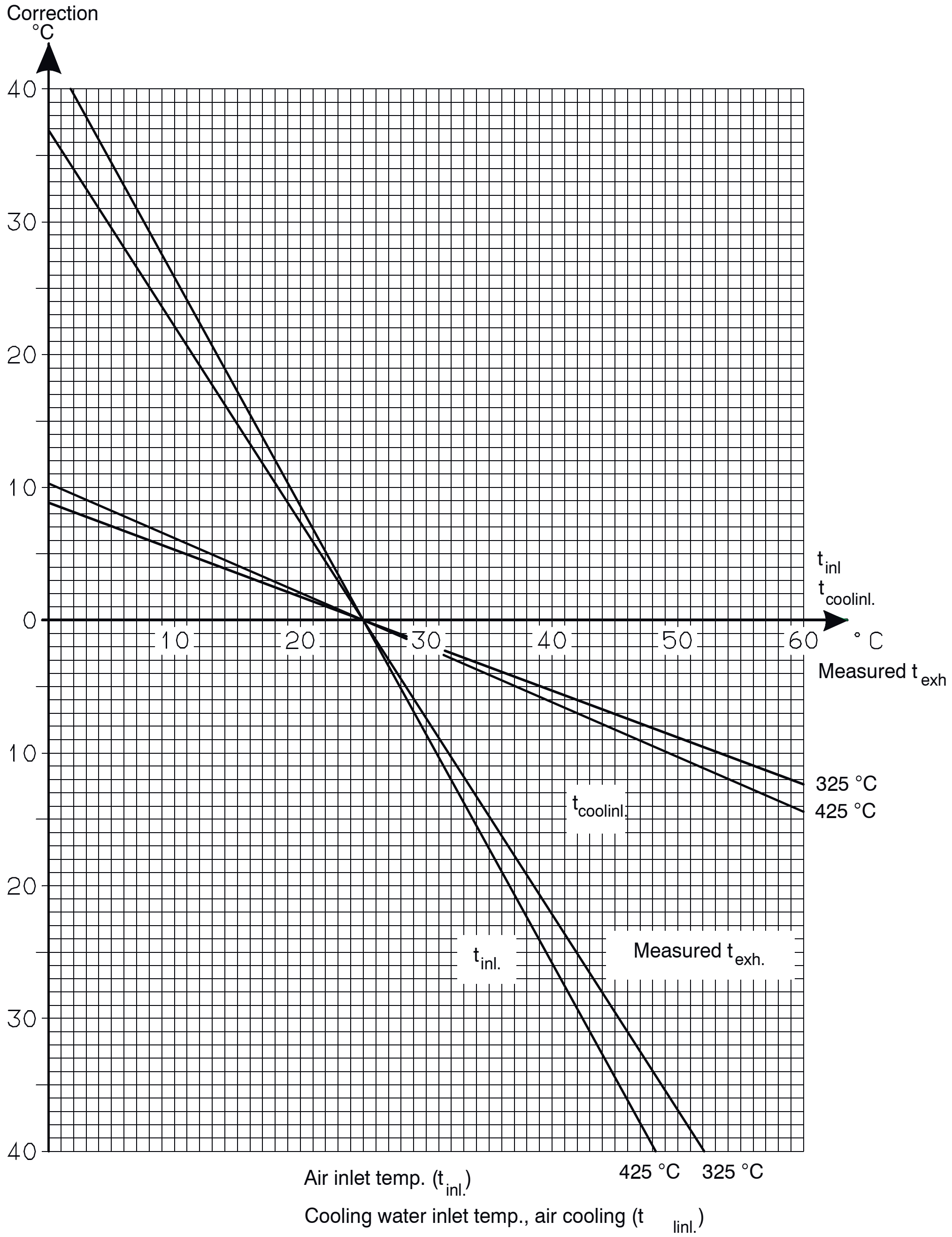
t_{inl} : $A_{corr} = (t_{meas} - 25) \times 2.198 \times 10^{-3} \times (1 + A_{meas})$ Bar

$t_{coolinl}$: $A_{corr} = (t_{meas} - 25) \times -0.810 \times 10^{-3} \times (1 + A_{meas})$ Bar

See also Plate 70624.

Exhaust Temperature (after exhaust valves)

Correction of measured exhaust temperature (t_{exhv})
because of deviations between t_{inl} / $t_{coolinl}$ and standard conditions



Calculating the corrections:

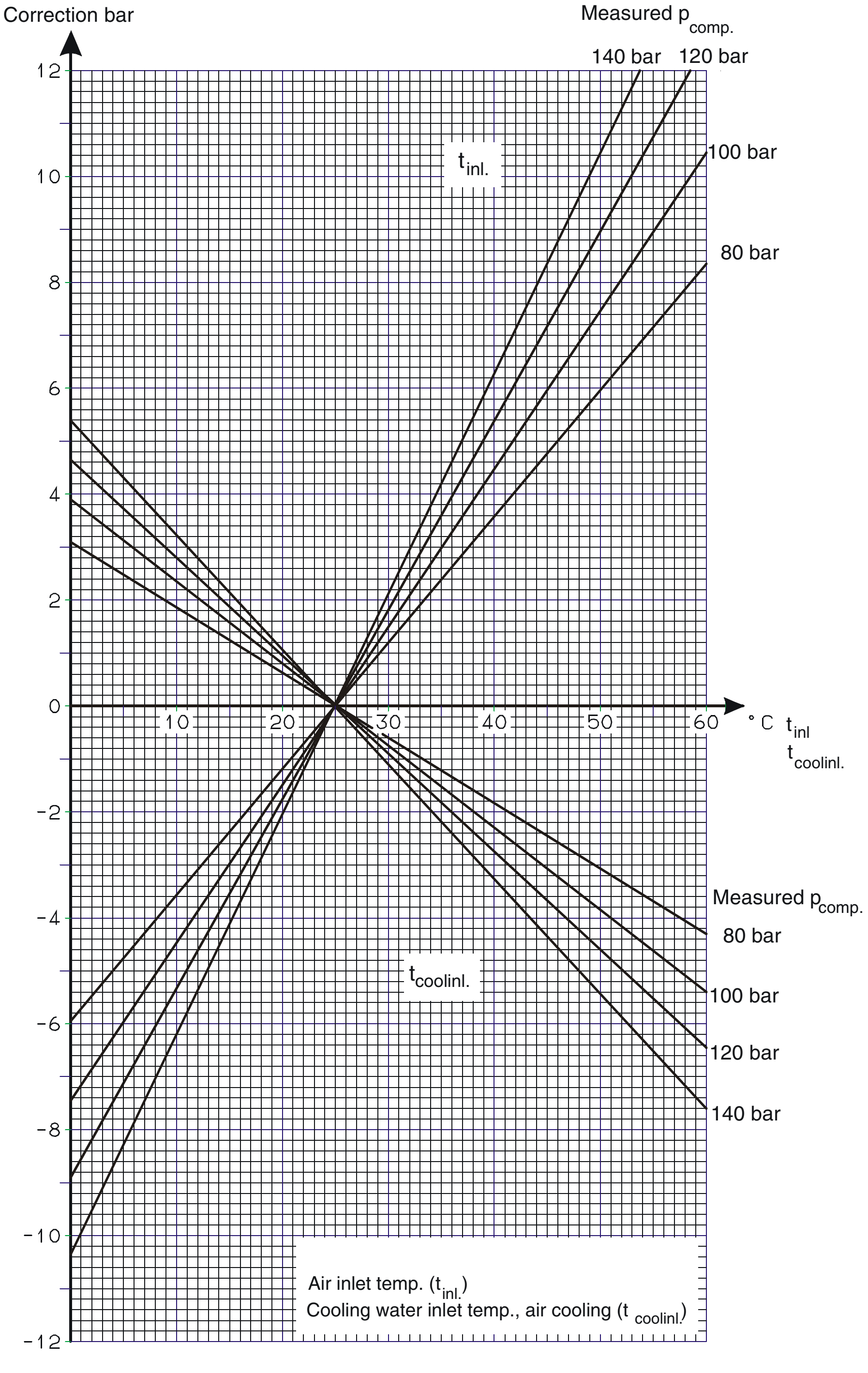
t_{inl} : $A_{corr} = (t_{meas} - 25) \times 2.466 \times 10^{-3} \times (273 + A_{meas})$ ˚C

$t_{coolinl}$: $A_{corr} = (t_{meas} - 25) \times -0.590 \times 10^{-3} \times (273 + A_{meas})$ ˚C

See also *Plate 70624*.

Compression Pressure

Correction of measured compression pressure
because of deviations between t_{inl} / $t_{coolinl}$ and standard conditions



Calculating the corrections:

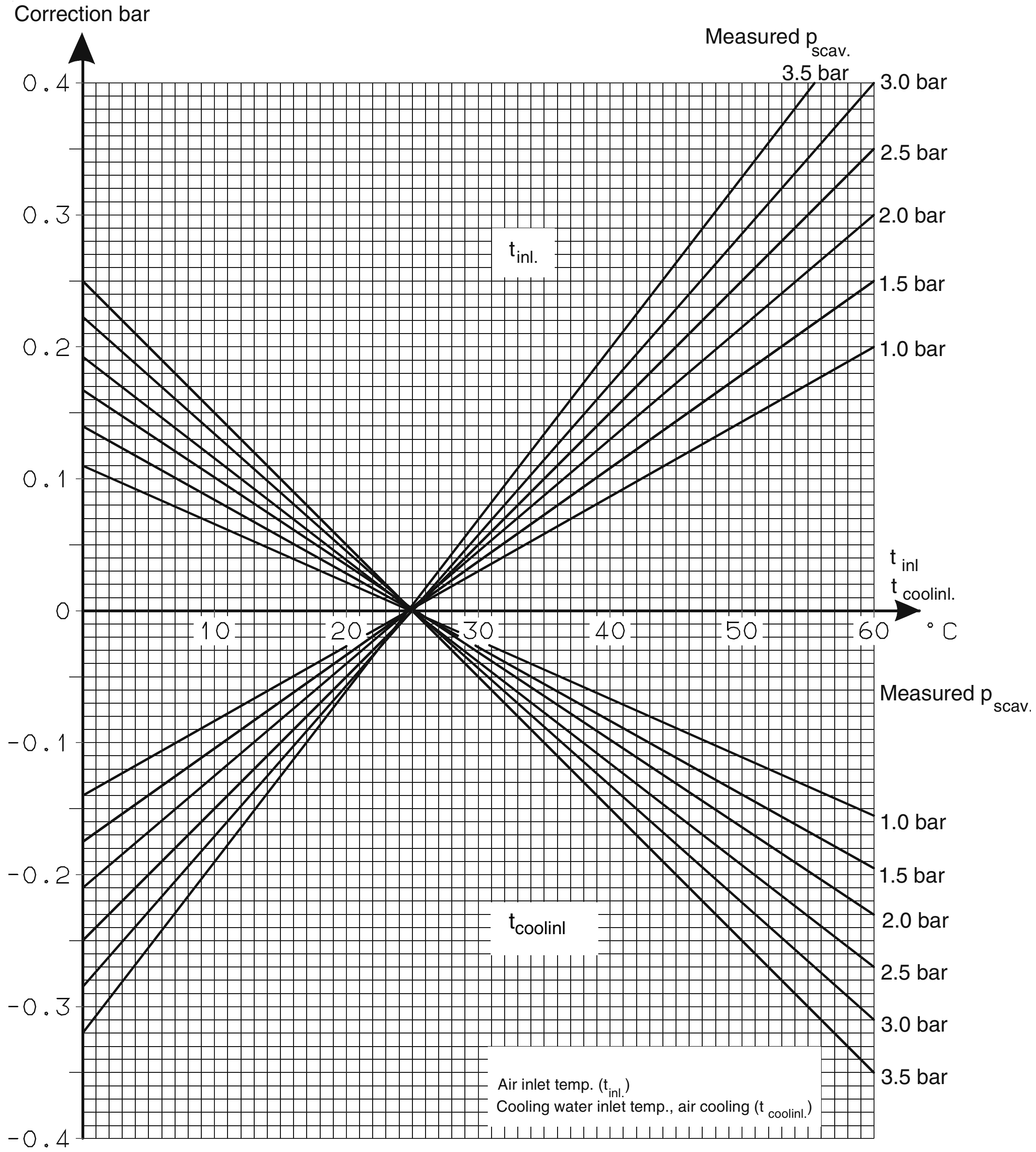
t_{inl} : $A_{corr} = (t_{meas} - 25) \times 2.954 \times 10^{-3} \times (1 + A_{meas})$ Bar

$t_{coolinl}$: $A_{corr} = (t_{meas} - 25) \times -1.530 \times 10^{-3} \times (1 + A_{meas})$ Bar

See also Plate 70624.

Scavenge Pressure

Correction of measured scavenge pressure
because of deviations between t_{inl} / $t_{coolinl}$ and standard conditions



Calculating the corrections:

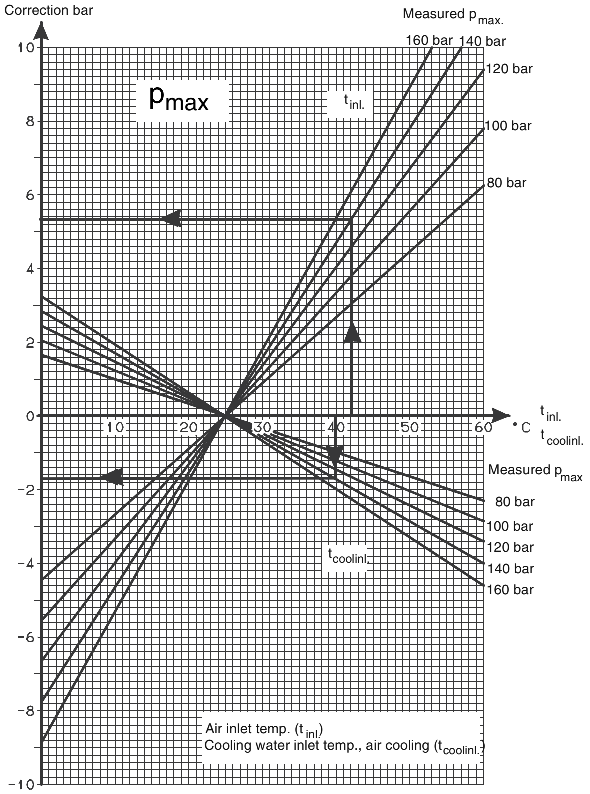
t_{inl} : $A_{corr} = (t_{meas} - 25) \times 2.856 \times 10^{-3} \times (1 + A_{meas})$ Bar

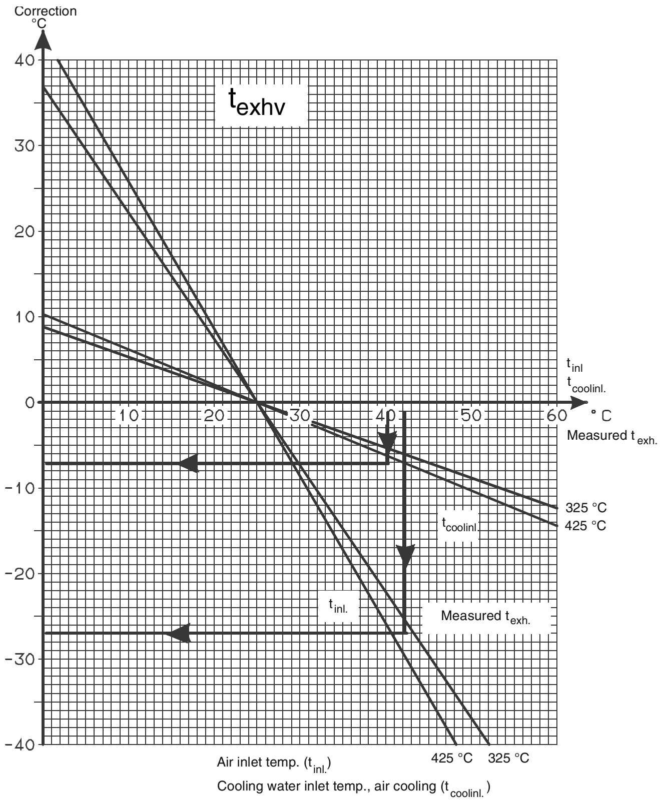
$t_{coolinl}$: $A_{corr} = (t_{meas} - 25) \times -2.220 \times 10^{-3} \times (1 + A_{meas})$ Bar

See also Plate 70624.

Example of readings: p_{max} : 140 bar

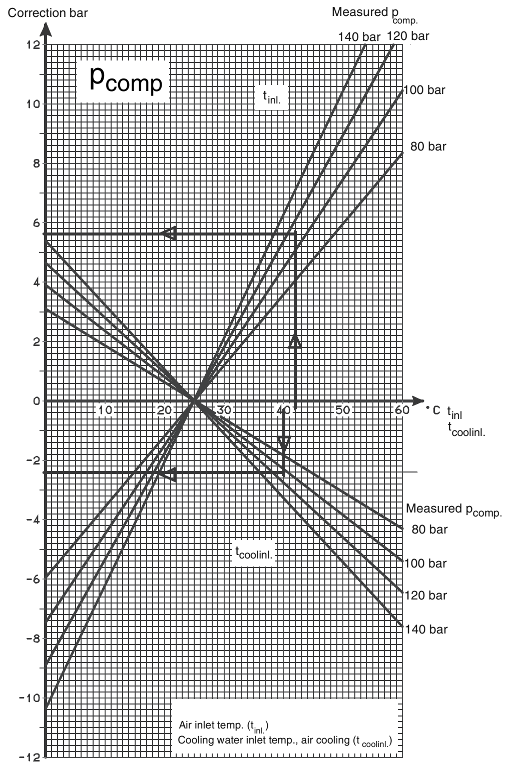
t_{exhv}	: 425 °C	p_{scav}	: 2.0 bar
p_{comp}	: 110 bar	t_{inl}	: 42 °C
		$t_{coolinl}$	: 40 °C

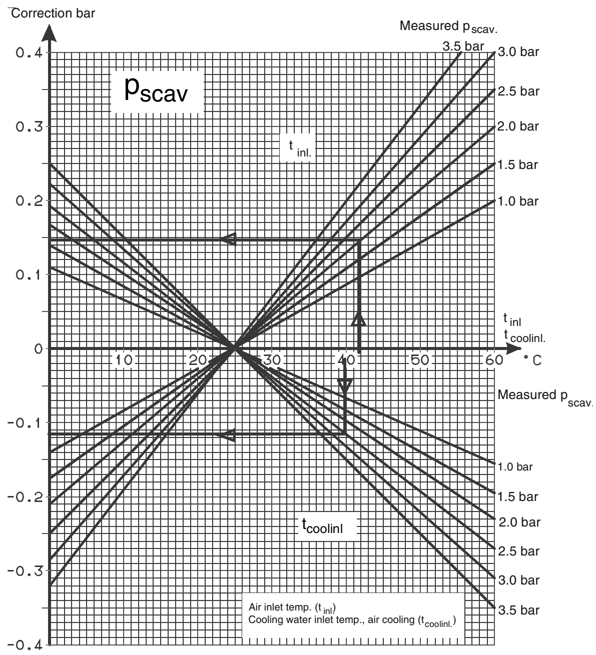




Correction for t_{inl}	:	+5.3 bar
Correction for $t_{coolinl}$	:	- 1.7 bar
Correction 5.3-1.7	:	+3.6 bar

Correction for t_{inl}	:	-27 °C
Correction for $t_{coolinl}$	:	- 6 °C
Correction -29 -6	:	- 33 °C

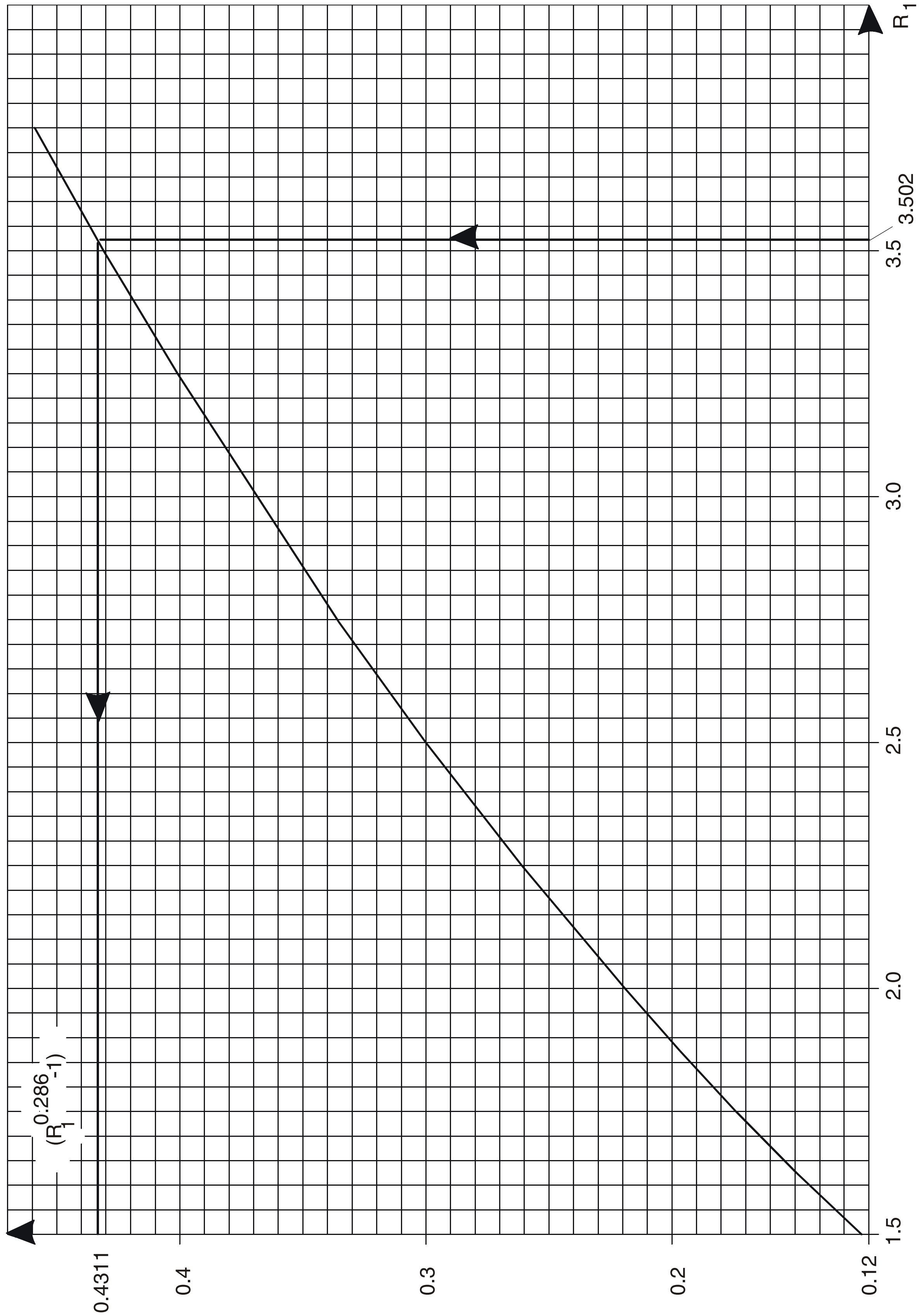




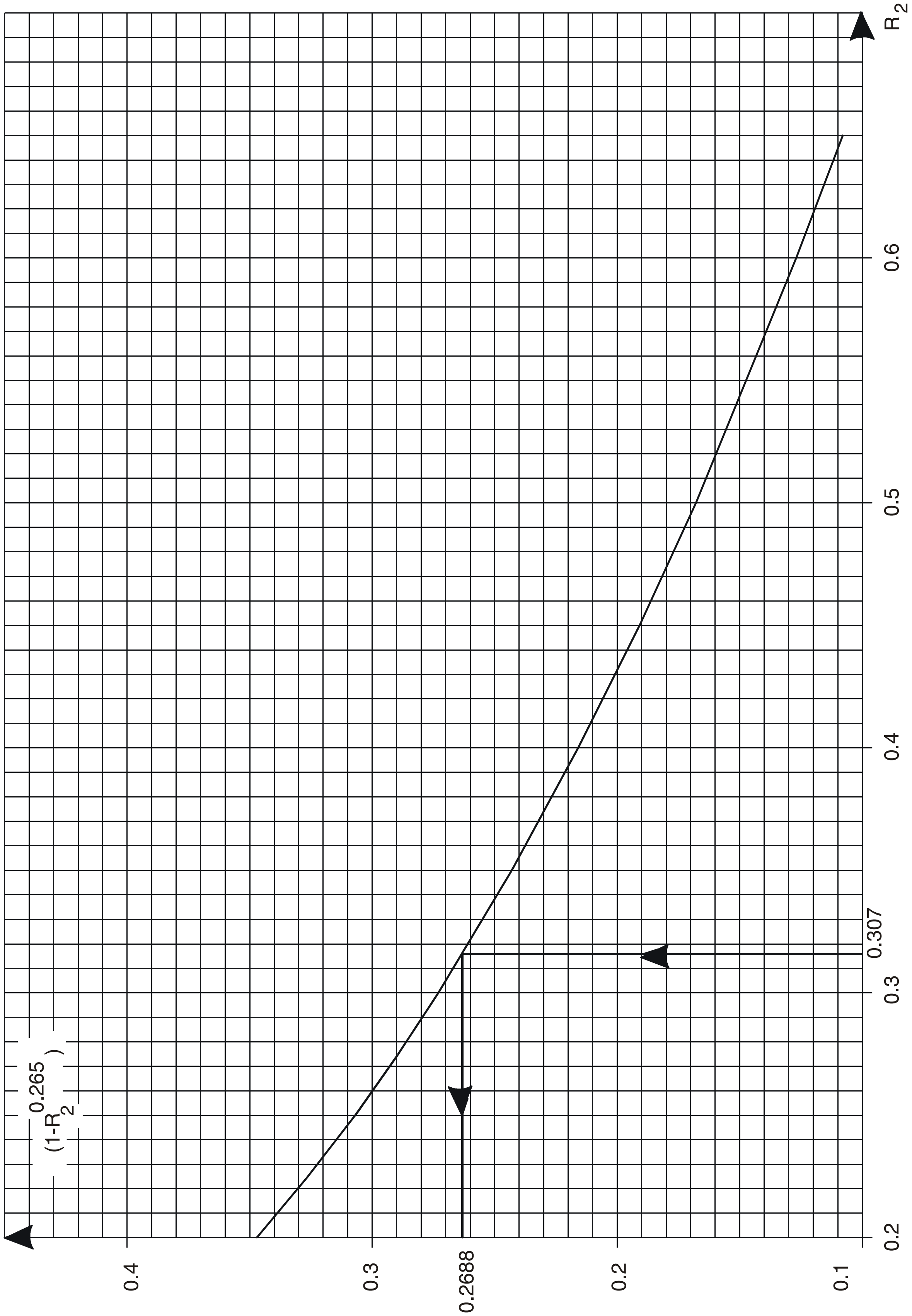
Correction for t_{inl}	:	+5.6 bar
Correction for $t_{coolinl}$	:	- 2.5bar
Correction 5.6-2.5	:	+3.1 bar

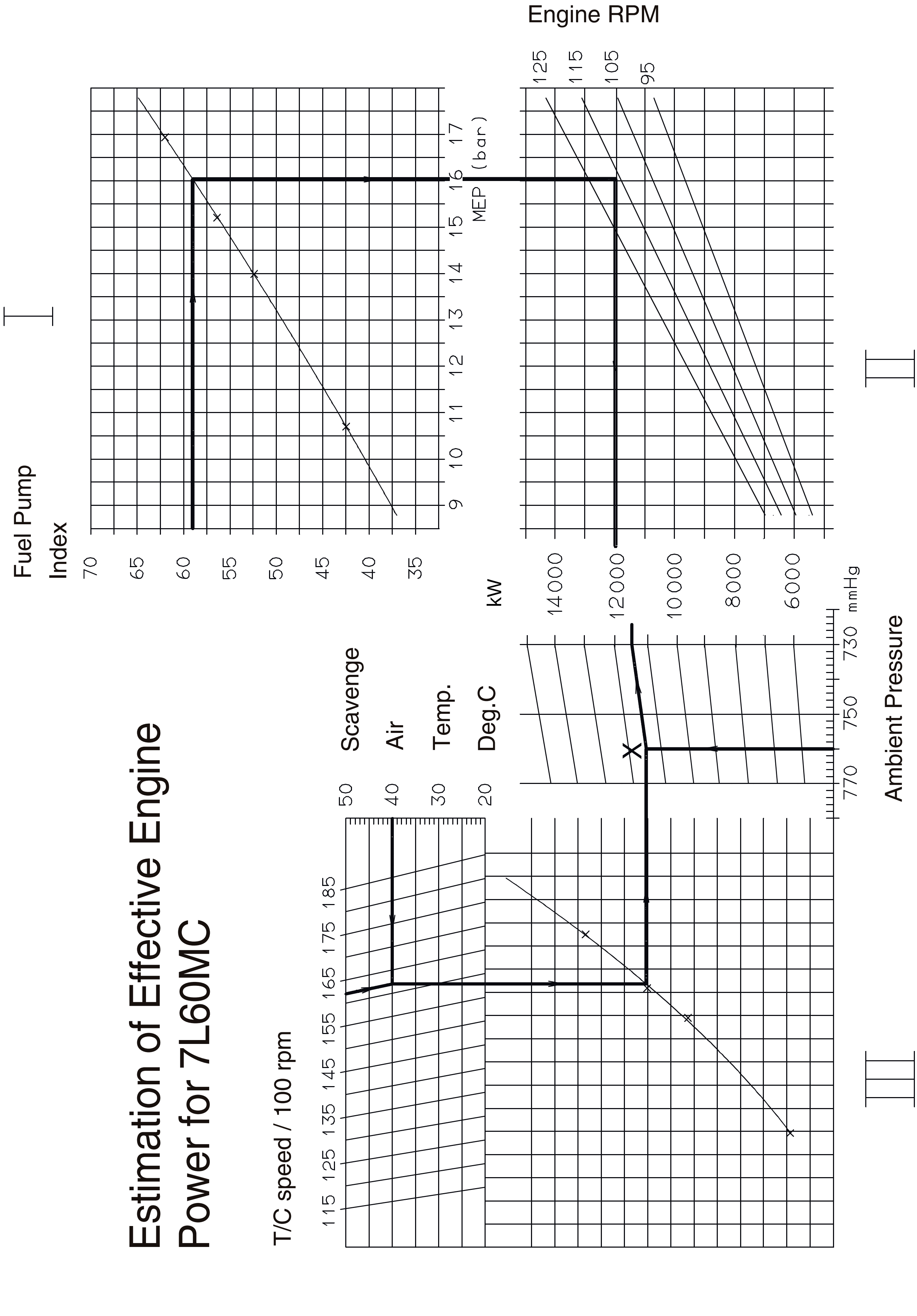
Correction for t_{inl}	:	+0.145 bar
Correction for $t_{coolinl}$	:	- 0.1 bar
Correction 0.145-0.1	:	+0.045 bar

Curve for the factor ($R_1^{0.286}$-1)



Curve for the factor $(1–R_2^{\,0.265})$




Estimation of Effective Engine Power for 7L60MC
I
II
III
Fuel Pump Index
70 65 60 55 50 45 40 35
MEP (bar)
9 10 11 12 13 14 15 16 17
Engine RPM
125 115 105 95
kW
14000 12000 10000 8000 6000
Ambient Pressure
mmHg
730 750 770
Scavenge Air Temp. Deg.C
50 40 30 20
T/C speed / 100 rpm
115 125 135 145 155 165 175 185

Turbocharger Make: MAN B&W			
Type Designation	Diameter, D (m)	No. of Blades	Slip Factor, μ
NR 24/R	0.276	–	0.76
NR 26/R	0.324	–	0.75
NA 34/S	0.408	–	0.70
NA 40/S	0.480	20	0.70
NA 48/S	0.576	20	0.70
NA 57/T9	0.684 0.684	20 18	0.70 0.74
NA 70/T9	0.840 0.840	22 18	0.76 0.74

Turbocharger Make: MAN B&W		
Type Designation	Diameter, D(m)	Slip Factor
TCR18	0.264	0.727
TCR20	0.318	0.727
TCR22	0.415	0.727
TCA44	0.449	0.745
TCA55	0.533	0.745
TCA66	0.633	0.745
TCA77	0.752	0.745
TCA88	0.893	0.745

Turbocharger Make: BBC / ABB					
Type Designation	Diameter, D (m)	Slip Factor µ	Type Designation	Diameter, D (m)	Slip Factor µ
VTR254	0.2943	0.77	TPL65-A10	0.3390	0.69
VTR304	0.3497		TPL69-BA10	0.3999	
VTR354	0.4157		TPL73-B11	0.4879	
VTR454D-VA12	0.5233		TPL73-B12	0.5065	
VTR454D-VA13	0.5756		TPL77-B11	0.5799	
VTR564D-VA12	0.6588		TPL77-B12	0.6020	
VTR564D-VA13	0.7247		TPL80-B11	0.6729	
VTR714D-VA12	0.8294		TPL80-B12	0.6985	
VTR714D-VA13	0.9123		TPL85-B11	0.8239	
			TPL85-B12	0.8553	
			TPL91-B12	0,9430	0,69

Turbocharger Make: Mitsubishi H.I. (MET)						
Type Designation	Diameter, D (m)		Slip Factor µ			
Impeller Profile	V, S or R		V		S 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				
MET66SD,SE	0.689	0.730				
MET71SE		0,790				
MET83SD,SE	0.873	0.924				
MET90SE		1,02				

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707-01 Cylinder Condition

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707-03 Inspection of Nimonic Exhaust Valve Spindles

PLATES

1. General

To obtain and maintain a good cylinder condition involves the optimisation of many factors.

Since most of these factors can change during the service period – and can be influenced by service parameters within the control of the engine room staff – it is of great importance that running conditions and developments are followed as closely as possible.

By means of continual monitoring it is normally possible to quickly discover abnormalities, whereby countermeasures can be taken at an early stage.

In particular, it is advisable to regularly check the cylinder condition by means of inspection through the scavenge ports – especially concentrating on the piston ring condition. See Item 3.1 further on.

In order to cover all aspects, this chapter is divided into seven principal subjects – each having a certain amount of topic overlap.

1. General
2. Piston Ring Function
3. Scavenge Port Inspection
4. Cylinder Overhaul
5. Factors Influencing Cylinder Wear
6. Propeller Performance

and a separate section dealing with: Cylinder Lubrication

2. Piston Ring Function

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.

Experience has shown that unsatisfactory piston ring function is probably 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 how conditions are progressing, see Item 3.1 below. See also Item 3.4 'Replacement of Piston Rings'*

3. Scavenge Port Inspection

3.1 General

Regarding intervals between scavenge port inspection, *see Vol. II, 900-1, 'Checking and Maintenance Schedules'.*

This inspection provides useful information about the condition of cylinders, pistons and rings, at low expense.

The inspection consists of visually examining the piston, the rings and the lower part of the cylinder liner, directly through the scavenge air ports.

To reduce the risk of scavenge box fire, remove any oil sludge and carbon deposits in the scavenge air box and receiver in connection with the inspection.

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.

3.2 Procedure

Scavenge port inspections are best carried out by two men, the most experienced of whom inspects the surfaces, and states his observations to an assistant, who records them. The assistant also operates the turning gear.

Keep the cooling water and cooling oil circulating, so that possible leakages can be detected.

Block the starting air supply to the main starting valve.

Open the indicator valves. Engage the turning gear.

Remove the inspection covers on the fuel pump side of the cylinder frame, and clean the openings. Remove the cover(s) on the scavenge air receiver.

! *Do not enter the scavenge air receiver before it has been thoroughly ventilated.*

Begin the inspection at the cylinder whose piston is nearest BDC.

- Inspect the piston, 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.

  Regarding the sequence, *see Plate 70701*. Regarding description of the conditions, *see Item 3.3, points A) to H).*

  Record the results on *Plate 70702, ‘Inspection through Scavenge Ports’.*

  Use the symbols shown on *Plate 70703* 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. *See Vol. II Procedure 902-1, ‘Maximum Clearance, and Vol. II Data 102-1.*

Continue the inspection at the next cylinder whose piston is 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.

Remove any oil sludge and carbon deposits in the scavenge air boxes and receiver. Record the observations on *Plate 70702.*

3.3 Observations

3.3.A 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 applying to the ring undersides and the “floor” of the ring grooves, which, however, cannot be seen). 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.B Piston Rings: Micro-seizure

If, over a period of time, the oil film partially disappears, 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 *(see Plates 70704 and 70705).*

In case of extensive seizures, 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 seizures have been observed, then it is recommended that the cyl. oil dosage is temporarily increased *(see item 4.12, and Section 707-02).*

3.3.C Piston Rings: Scratched *Plates 70704, 70705*

Scratching is caused by hard abrasive particles originating from the ring itself, or, usually, from the fuel oil. As regards liner and ring wear, the scratching is not always serious, but the particles can have serious consequences elsewhere. *(See item 5.5 ‘Abrasive Wear’).*

3.3.D 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 (may not be visible at port inspection). This indicates lack of sealing, i.e. combustion gas blow-by between piston rings and cylinder liner.

The blow-by will promote oil film break-down, which in turn will increase cylinder 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 ahead and astern, to check the free vertical movement.

3.3.E Piston Rings: Breakage/Collapse

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

- Lack of “elastic tension”, when the rings are pressed into the groove by means of a stick
- Blackish appearance
- Fractured rings
- Missing rings.

Piston ring breakage is mostly caused by a phenomenon known as “collapse”. However, breakage may also occur due to continual striking against wear ridges, or other irregularities in 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 a case, 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 – particularly if the ring ends “slam” against each other.

The above-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)*
- ring-end chamfers *(see below)*
- too large ring-edge radii,
- etc.

“Clover-leafing”, is a term used to describe longitudinal corrosive wear at several separate points around the liner circumference – i.e. in some cases the liner bore may assume a “clover-leaf” shape, *see Item 5.4.D.*

Chamfering at the ring ends is *unnecessary and detrimental* in MAN B&W engines, as the scavenge ports are dimensioned to avoid “catching” the ring ends.

3.3.F Piston Rings: Blow-by

Leakage of combustion gas past the piston rings (blow-by) is a natural consequence of sticking, collapse or breakage *(see points D and E).*

In the later stages, when blow-by becomes persistent, it is usually due to advanced 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 which, however, can only be seen when overhauling the piston (or when exchanging the exhaust valve.
See also Sections 704-04 and 706-02.

3.3.G Deposits on Pistons

Usually some deposits will have accumulated on the side of the piston crown (top land). Carbon deposits on the ring lands indicate lack of gas sealing at the respective rings, *see Plate 70703*.

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 the oil film, resulting in 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 nozzles or insufficient turbocharger efficiency.

3.3.H Lubricating Condition

Note whether the “oil film” on the cylinder wall and piston rings appears to be adequate. All piston rings should show oil at the edges. *However, see also Item 3.1*.

White or brownish coloured areas may sometimes be seen on the liner surface. This indicates corrosive wear, usually from sulphuric acid *(see also Item 5.4),* and should not be confused with grey-black areas, which indicates blow-by.

In such cases it should be decided whether, in order to stop such corrosive attack, a higher oil dosage should be introduced. *(See Item 5.4 and Section 707-02).*

3.4 Replacement of Piston Rings

It is recommended that the complete set of piston rings is replaced at each piston overhaul, to ensure that the rings always work under the optimum service conditions, thereby giving the best ring performance.

4. Cylinder Overhaul

! *To ensure correct recording of all relevant information, we recommend that our ‘Cylinder Condition Report’ (Plates 70711 and 70712) be used.*

4.1 Intervals between Piston Pulling

Regarding guiding, average intervals, *see Vol. II ‘Maintenance’ ‘Checking and Maintenance Schedules’.*

Base the actual intervals between piston overhauls on the previous wear measurements and observations from scavenge port inspections, supplemented with the pressures read from the CoCos-eds or PMI-system.

Regarding procedures for the dismantling and mounting of pistons, *see Vol. II, Procedures 902-2.1 and 902-2.2.*

! *Remove the piston cleaning (PC) ring (if installed) and carefully remove any coke deposits and wear ridges from the upper part of the liner, before the piston is lifted.*
Regarding procedure for checking the PC-ring, see Vol. II Procedure 903-1.1.

4.2 Initial Inspection and Removal of the Rings

Before any cleaning, inspect the piston and liner, as described in Item 3.3, points A) to H).

Measure the free ring gap and compare to that of a new ring, whereby the loss of tension can be calculated. Note down the measurements on *Plate 70711.*

Remove the piston rings.

! *Use only the MAN B&W standard ring opener for all mounting and removal of piston rings.*

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.

It is extremely important that the piston rings are removed by means of the special ring opener, if they are to be reinstalled after inspection. However, it is recommended to replace the complete set of piston rings at each overhaul, *see Item 3.4 above.*

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 *See Plate 70711*

Measure and record the radial width and the height of the rings.

Compare the measured wear to the wear tolerances stated in *Vol. II 'Maintenance', Chapter 902.*

When this value has been reached, scrap the ring. As it is recommended to replace the complete set of piston rings at each overhaul, use these measurements to form the basis for deciding optimal overhaul intervals, *see Item 4.1.*

4.5 Inspection of Cylinder Liner *See Plate 70711*

4.5.A Cylinder Wear Measurements:

! *Before measuring the cylinder wear:*

- *ensure that the tool and cylinder liner temperatures are close to each other*
- *record the tool and cylinder liner temperatures on Plate 70711 to enable correction.*

Measure the wear with the special tool at the vertical positions marked on the tool. Measure in both the transverse and longitudinal directions. This ensures that the wear is always measured at the same positions. *See also Vol. II, Procedure 903-2.*

Record the measurements on *Plate 70711.*

4.5.B 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 °C	Factor
10	0.99988
20	0.99976
30	0.99964
40	0.99952
50	0.99940

Example (S/K/L90MC):
Measured value : 901.3 mm
Δt measured : 30°C
(corrected value : 901.3 × 0.99964 = 900.98
(i.e. a reduction of 901.3-900.98 = 0.32 mm)

4.5.C Maximum Wear:

The maximum wear of cylinder liners can be in the interval of 0.4% to 0.8% of the nominal diameter, depending on the actual cylinder and piston ring performance.

Ovality of the liner, for instance, may form a too troublesome basis for maintaining a satisfactory service condition, in which case the cylinder liner in question should be replaced.

4.5.D Checking Liner Surface:

Inspect the liner wall for scratches, micro-seizure, wear ridges, collapse marks, corrosive wear, etc.

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 items 3.3.E, 3.3.H and 5.4.*

4.6 Piston Skirt, Crown and Cooling Space *Plate 70711*

Clean and check the piston skirt for seizures and burrs.

In case of seizures, grind over the surface to remove a possible hardened layer.

Check the shape of the piston crown by means of the template. Measure any burnings.

If in any place the burning/corrosion exceeds the max. permissible, send the piston crown for reconditioning.

Regarding max. permissible burning, *see Vol. II, Procedure 902-1*. Inspect the crown for cracks.

Pressure-test the piston assembly to check for possible oil leakages, *see Vol. II, Procedure 902-1.*

See Plate 70711

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.
Pressure test the piston after assembling.

4.7 Piston Ring Grooves

Check the piston ring grooves as described in Vol. II, Procedure 902-1.

If the ring groove wear exceeds the values stated in Procedure 902.1, send the crown for reconditioning (new chrome-plating).

4.8 Reconditioning the Running Surfaces of Liner, Rings 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 to horizontal.

This is done to break up the hard surface glaze.

Leave the “scratching marks” as coarse as possible.

It is not necessary to completely remove all signs of “vertical stripes” (micro-seizure).

If there are horizontal wear ridges in the cylinder liner – e.g. at the top or bottom where the rings “turn”: smoothen out carefully with a portable grinding machine.

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.

! *Use only the MAN B&W standard piston ring opener. See also point 4.2.*

4.11 Piston Ring Clearance

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

Furthermore, insert a feeler gauge of the thickness specified in Vol. II, Procedure 902-1, and move it all the way round the groove both above and below each piston ring. Its free movement will confirm the clearances as well as proper cleanliness.

4.12 Cylinder Lubrication and Mounting

Check the cylinder lubrication:

Press pre-lubrication on the HMI Panel and check that the pipes and joints are leak-proof, and that oil flows out from each lubricating orifice.

If any of the above-mentioned inspection points have indicated that the cylinder oil amount should be increased, or decreased: Adjust the feedrate as described in the Alpha Lubricator Manual.

Coat the piston with clean oil.

! *Before mounting the overhauled piston, remove any remaining deposits from the upper end of the liner.*

Mount the piston. *See Vol. II, Procedure 902-1.*

4.13 Running-in of Liners and Rings

After reconditioning or renewal of cylinder liners and/or piston rings, allowance must be made for a running-in period, *see Items 4.13.A – 4.13.D.*

!

- *Refer to Section 703-03.*
- *If only one or two cylinders have been overhauled, see Item 4.13.B.*
- *See also Item 4.13.B regarding manoeuvring and low-load running.*
- *Refer to the maker's special instructions on how to adjust the lubricator's stroke.*

4.13.A Running-in of Liners and Rings (Fixed pitch propeller plants) *Plate 70710 and 70714*

Breaking-in:

Breaking-in of all cylinders, or of individual cylinders having their separate cylinder lubricator:

Adjust the lubricators to 200% of basic setting. *See Section 703-16, Auxiliaries.*

Start the engine. Increase gradually to 55% of MCR-speed.

Increase to 100% of MCR-speed during the next 20 hours, as shown on Plate 70714.

After this 20-24 hour breaking-in period, stop the engine and make a scavenge port inspection.

If the cylinder condition proves satisfactory, decrease the feed rate corresponding to an over-lubrication of 150%, *see Section 703-16, Auxiliaries.*

Running-in:

Running-in of all cylinders, or of individual cylinders having their separate cylinder lubricator:

Maintain the 150% feed rate during the next 600 hours of service.

Make a scavenge port inspection. If the cylinder condition proves satisfactory, decrease the feed rate corresponding to an over-lubrication of 125%, *see Section 703-16, Auxiliaries.*

Maintain the 125% feed rate during the next 600 hours of service.

Make a scavenge port inspection. If the cylinder condition proves satisfactory, decrease the feed rate to the Basic Setting, *see Section 703-16, Auxiliaries.*

Basic Setting:

After the running-in period the Basic Setting should be maintained.

Actual feed rate:

When the cylinder condition has stabilised and proved satisfactory by scavenge port inspections, adjustments towards the actual feed rate may be introduced:

- Make repeated scavenge port inspections.
- If the cylinder condition proves satisfactory, reduce the feed rate by **maximum** 0.05 g/bhph, at intervals of **minimum** 600 hours, *see Plate 70710.*

Increase or decrease the feed rate during the continued service, based on the regular:

- scavenge port inspections, *see Vol. II, Chapter 900, and*
- piston/liner overhauls, *see earlier in this Section 4.1*

See also earlier in this Section 4.8.

4.13.B Special Remarks *(See also Item 4.13.A)*

Running-in only one cylinder:

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

As vibration condition due to 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 be present *(see Chapter 704 ‘Special Running Conditions’).* Thus 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, *see Plate 70714. Regarding the pressure rise* p_{comp} - p_{max}*, see comp max Chapter 703 ‘Running Difficulties, Supplementary Comments’, point 7.*

! 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 in order to safeguard the gear.

Regarding cylinder lubrication, see Item 4.13.A.

Manoeuvring and low load:

In practice, of course, the engine must be able to operate freely in the whole manoeuvring range.

Also the situation where low load has to be maintained for an extended period, e.g. in connection with river/canal passage, has to be coped with in the breaking-in program.

As an example, when the first breaking-in has to take place during a long river passage, we suggest the following program, *(see also Plate 70714)*:

	% rpm	% Load	Duration (h)
Increase to:	55	16	0.5
River passage:	55	16	5.5
Sea passage:	70	34	2.0
–	80	51	2.0
–	85	61	2.0
–	87.5	67	2.0
–	90	73	2.0
–	92.5	79	2.0
–	95	86	2.0
–	97.5	93	2.0
–	100	100	2.0
Total Breaking-in time			24.0

! Do not run for less than two hours at 55% rpm (16% load).

Regarding cylinder lubrication, see Item 4.13.A.

4.13.C Running-in of Rings after a Piston Overhaul (Fixed pitch propeller plants)

When running-in piston rings in already run-in liners, the breaking-in time can be reduced to some 5 hours, e.g. following the dotted line in *Plate 70714, 'Running-in Load'.*

The extra lubrication should follow the same pattern as when running-in new liners; however, the duration of the 150% and 125% steps can be reduced to the time intervals between scavenge port inspections, *see Plate 70710.*

4.13.D Running-in of Liners and Rings (Controllable pitch propeller plants)

Regarding running-in when only one or two cylinders have been overhauled, *see the procedure described in Item 4.13.B.*

Regarding the cylinder oil dosage during breaking-in and running-in, *see the procedure described in Item 4.13.A.*

About half an hour before harbour manoeuvres are expected, start the engine and increase to rated speed, with the propeller in Zero-pitch.

Connect the shaft generator (if installed) to the grid, and let the generator take over the electrical power supply.

This is in order to raise the engine temperature towards the normal service value prior to the harbour manoeuvres.

When manoeuvring is finished, gradually increase the propeller pitch corresponding to about 50% of MCR-load.

The increase to 100% of MCR-load should be effected gradually during the next 20 hours. *See also Plate 70714.*

When running-in piston rings in already run-in liners, the breaking-in period can be reduced to abt. 10 hours.

5. Factors Influencing Cylinder Wear

5.1 General

Plate 70706 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 and cylinder liner materials complies with the engine builder's recommendations.

5.3 Cylinder Oil

Check that the quality and feed rate are in accordance with the recommendations in the latest service letter.

5.4 Corrosive Wear

5.4.A The Influence of Sulphur in the Fuel

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

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

If corrosion arises even so, insulation of the liner and/or insulated steel pipes in the cooling bores can be arranged.

To reduce the risk of corrosive attack:

- Keep the cooling water outlet temperatures within the specified interval, *see Section 701-02.*
- Keep the temperature difference across the cylinder units between 12°-18°C at MCR.
- Use alkaline cylinder lubricating oils, *see also Item 5.3, 'Cylinder Oil'.*
- Preheat the engine before starting, as described in *Chapter 703.*
- Check that the drain from the water mist catcher functions properly, to prevent water droplets from entering the cylinders, *see also Item 5.4.D.*

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

If corrosion is prevailing:

- Check the cylinder feed rate, *see Item 5.3.*
- Increase the feed rate as described in *Section 707-02.*
- Check the alkalinity, *see Item 5.3.*
- Check the timing.
- Check the cooling water temperatures and the drain from the water mist catcher, as described above. The amount of condensate can be read from *Plate 70713. See also Item 5.4.D.*

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 points 3.3.B and 5.4.D, regarding 'clover-leafing'.*

5.4.B Sodium Chloride

Seawater (or salt) in the intake air, fuel, or 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 entering the cylinder, via the fuel and cylinder oil:

- maintain the various oil tanks leak-proof

- centrifuge the fuel carefully.
- do not use the bunker tanks for ballast water.

5.4.C Cleaning Agents (Air Cooler)

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

Follow the supplier's instructions strictly for:

- the dosage of the agent
- the use of the cleaning system

After using chemical agents, flush with clean fresh water 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.*

See also Section 706-03 and Maintenance book Chapter 910.

5.4.D 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 ME engines to prevent water droplets from being carried into the cylinders.

If water enters the cylinders, the oil film may be ruptured and cause wear (cloverleafing) on the liner surfaces between the cylinder lub. oil inlets.

It is very important that the water mist catcher drains function properly.

See Section 706-03. See also Plate 70712 for amount of condensate.

5.5 Abrasive Wear *Plates 70705, 70707, 70708 and 70709*

5.5.A Particles

Abrasive cylinder wear can be caused by hard particles which enter the cylinder via

- The fuel oil, e.g. catalyst fines. *See also point 5.5.C, 'Fuel Oil Treatment'.*

  Particles in the fuel oil can also be caught in the fuel pump suction valve. If this occurs, the suction valve seats can very quickly become so heavily pitted *(Plate 70709, photo 4)* that they leak, causing a reduction of the maximum pressure and an increase of the fuel index.

  The occurrence of the particles is unpredictable. Therefore, clean the fuel oil as thoroughly as possible by centrifuging, in order to remove the abrasive particles.

- The air, e.g. sand.

  Keep the turbocharger intake filter in a good condition. *See also Section 706-03 regarding the use of a thin foam filter. See also Section 701-01.*

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 Plates 70705 and 70708),*

   Usually, micro-seizures do not occur, i.e. the ring surface remains soft. This can be checked with a file, *see Plate 70704*.

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 *(Plates 70707 and 70708)*. “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, (and of the suction valve seats) will reveal the presence of abrasive particles.

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, which protrudes from the piston ring groove, i.e. this is only seen on ring Nos. 2, 3, and 4.

5.5.B Scuffing (micro-seizure)

Abrasive wear may be the result of scuffing (micro-seizure).

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

- unsatisfactory running-in conditions (especially if a previous micro-seizure has not been successfully counteracted during a cylinder overhaul). As regards running-in, *see point 4.13*.
- misalignment, (including machining errors).

5.5.C Fuel Oil Treatment *(See also Chapter 705)*

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:

1. 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, for instance: 95-98°C for fuel oil with a viscosity of 380 cSt at 50°C.

2. 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 the flow rate through the centrifuge.

   Keep the flow rate as low as possible.

6. Propeller Performance

As indicated in *Section 706-01,* special severe weather condition can cause a change to heavy propeller running. In cases where the power/speed combination has moved too much to the left in the load diagram *(see Section 706-01),* continued service may cause thermal overload of the components in the combustion chamber and thereby create heat cracks.

1. Lubricators *Plate 70713*

Each cylinder liner has a number of lubricating quills, through which oil is introduced from the Alpha Lubricators, as outlined in instruction book, Volume III ‘Components’.

The oil is pumped into the cylinder (via non-return valves) when the piston rings pass the lubricating orifices, during the upward stroke. *See also Plate 70713, Fig. 2.* For check of functioning, *see Section 702-01.*

The lubricators are supplied with oil from a pump station to which the oil is supplied from a head tank.

2. Cylinder Oil Film

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.
   (See Alpha Lubricator Manual).
2. The cylinder oil type and TBN must be selected in accordance with the fuel being burned *(see point 3 below)*.
3. New liners and piston rings must be carefully run-in, *see Plate 70710.*
4. The oil feed-rate (dosage) under normal service must be in accordance with the engine builder’s recommendations. Furthermore, the dosage must be adjusted in accordance with the service experience for the actual trade (obtained from the scavenge port inspections).
5. The feed-rate must be increased in the situations described in Item 4.8, ‘Special Conditions’.

3. Cylinder Oils

We recommend the use of cylinder oils of the SAE 50 viscosity grade.

During shop trial and seatrial, we recommend using a cylinder oil with a high detergency level.

Use a “total base number” (TBN) of 70 as a 70 TBN oil will normally give good results. Use higher TBN oils in the event of high sulphur content in the fuel oil.

! Some high alkaline cylinder oils are not compatible with:

- certain low sulphur fuels (having poor combustion properties),
- some diesel oils.

Such incompatibility may be indicated by poor cylinder condition during scavenge port inspection. In such cases, change to a lower TBN cylinder oil.

The table below indicates international brands of oils that have given satisfactory results when applied in MAN B&W diesel engine types (heavy fuel operation).

Do not consider the list complete, as oils from other companies can be equally suitable.

Type	**Cylinder Oil**	
Requirement	SAE50/BN 70-80	SAE50/BN 40-50
Oil Company		
BP	CLO 50-M	CL/CL-DX 405
Castrol	S/DZ 70 cyl.	CL/CL-DX 405
Chevron	Delo Cyloil Special	Taro Special HT 50
Elf	Talusia HR70	Talusia LS 40
Exxon	Exxmar X70	Mobilgard L540
Mobil	Mobilgard 570	Mobilgard L540
Shell	Alexia 50	Alexia LS
Texaco	Taro Special HT70	Taro Special HT50

Further information can be obtained by contacting the engine builder or MAN B&W Diesel A/S, Copenhagen.

4. Cylinder Oil Feed Rate (dosage)

4.1 General

The following guidelines are based on service experience, and take into consideration the specific design criteria of the MC/ME engines (such as mean pressure, maximum pressure, lubricated liner area) as well as today's fuel qualities and operating conditions.

The recommendations are valid for fixed pitch and controllable pitch propeller plants as well as stationary plants (generator application).

This Section is based on our Service Letter 03-417/HRJ, which recommends:

- Adjusting the lubricators to the Basic Setting.
- Over-lubricating during breaking-in and running-in.
- Gradually reducing the feed rate based on scavenge port inspections.

4.2 Running-in

Regarding increased feed rate during breaking-in and running-in, and the stepwise reduction towards the actual feed rate, *see Plate 70710.*

4.3 Basic Setting

The Basic Setting for S/K/L-ME/ME-C engines is 0.8 g/bhph. *See Plate 70710.*

Service experience has now demonstrated that it is also possible to reduce the feed rate for the super-long-stroke S-MC/MC-C engines fitted with Alpha Lubricators, even down to the same low level as for the K/L engines, i.e. to a basic feed rate of 0.8 g/bhph and a minimum of 0.6 g/bhph.

4.4 Alpha ACC (Adaptive Cylinder oil Control)

The actual need for cylinder oil quantity varies with the operational conditions such as load and fuel oil quality. Consequently, in order to obtain the optimal lubrication, the cylinder oil dosage should be adapted to such operational variations.

With the introduction of the electronically controlled Alpha Lubricator system, featuring the easy-to-operate “HMI” panel, such adaptive lubrication has become feasible. The Alpha Lubricator system offers the possibility of saving a considerable amount of cylinder oil per year and, at the same time, to obtain a safer and more predictable cylinder condition.

Intensive studies of the relation between wear and lube oil dosage have revealed thatthe actual need for cylinder lubrication follows the amount of fuel being burnt and the fuel quality.

This calls for part-load lube oil control which is proportional to the engine output, as load and oil consumption in this connection are practically proportional. This is, at the same time, the most economical control mode, compared to the previous practice where part-load dosages were controlled proportionally with either engine speed or cylinder mean pressure.

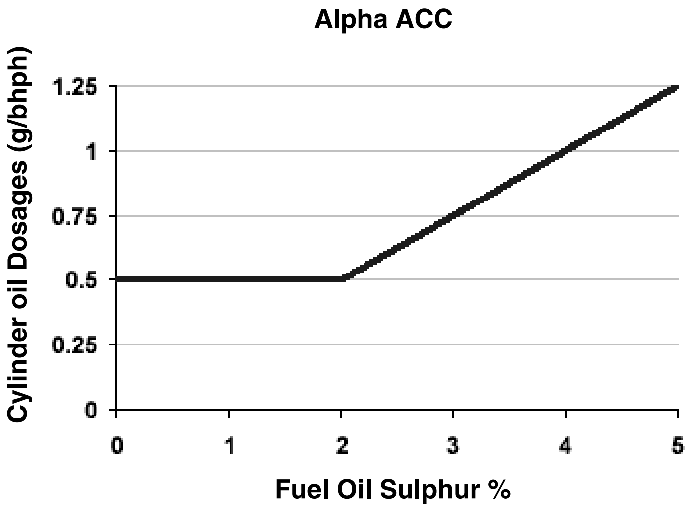
The basic feed rate control should be adjusted in relation to the actual fuel quality being burnt at a given time. Of course, fuel quality is rather complex. However, studies have also shown that the sulphur percentage is a good indicator in relation to wear, and an oil dosage proportional to the sulphur level will give the best overall cylinder condition.

This new cylinder oil control principle is called the “**Alpha Adaptive Cylinder oil Control**”, or abbreviated “**Alpha ACC**”.

Tests with Alpha ACC on K and S engines of various engine sizes have shown that a safe and optimum lube-economical control is obtained with a basic setting according to the below formula:

Basic lube oil setting = 0.25 g/bhph x S%,

with a minimum setting of 0.5 g/bhph, i.e. the setting should be kept constant from 2% sulphur and down.



4.5 How to adjust the dosage according to the Alpha ACC principle

First of all, knowledge of the sulphur percentage of the fuel oil being burnt at any time is a condition for obtaining the savings with Alpha ACC. Therefore, we recommend that the ships in question join one of the well-known fuel analysis programmes on the market, and that burning of the oil is not started until the analysis result is known. This will normally take two to four days after bunkering.

One of the key parameters in Alpha ACC lubrication is part-load control proportional to engine load. This is important in order to prevent over-lubrication at low loads, and it is one of the main parameters to save oil, compared with conventional lubrication.

If “load-proportional control” is not already preset from delivery of your Alpha Lubricator system, we suggest that you contact MAN B&W Diesel A/S in order to get instructions on how to change the software from either speed-proportional control or cylinder-mean-pressure proportional control.

When starting to burn new bunker oil, the HMI setting of the Alpha ACC should be adjusted according to the bunker analysis results. For reference, the below table should be used:

Sulphur	Dosage		HMI
%	g/bhph	g/kWh	Setting
0.0-2.0	0.50	0.68	63
2.2	0.55	0.75	69
2.4	0.60	0.82	75
2.6	0.65	0.88	81
2.8	0.70	0.95	88
3.0	0.75	1.02	94
3.2	0.80	1.09	100
3.4	0.85	1.16	106
3.6	0.90	1.22	113
3.8	0.95	1.29	119
4.0	1.00	1.36	125
4.2	1.05	1.43	131
4.4	1.10	1.50	138
4.6	1.15	1.56	144
4.8	1.20	1.63	150
5.0	1.25	1.70	156

Our ‘basic setting’ is traditionally chosen to obtain a dosage which, in average conditions, results in a safe and lube-oil-economical cylinder condition. This leaves possibilities for further individually based reductions, towards the recommended minimum setting.

In the case of the Alpha ACC, the basic factor of 0.25 g/bhph x S% may, of course, also be lowered. Currently, we have experienced down to a factor of 0.21 g/bhph x S%.

1. Lubricators *Plate 70713*

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1. The cylinder lubricators must be correctly timed.
   (See Alpha Lubricator Manual).
2. The cylinder oil type and TBN must be selected in accordance with the fuel being burned *(see point 3 below)*.
3. New liners and piston rings must be carefully run-in, *see Plate 70710.*
4. The oil feed-rate (dosage) under normal service must be in accordance with the engine builder's recommendations. Furthermore, the dosage must be adjusted in accordance with the service experience for the actual trade (obtained from the scavenge port inspections).
5. The feed-rate must be increased in the situations described in Item 4.8, 'Special Conditions'.

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Exxon	Exxmar X70	Mobilgard L540
Mobil	Mobilgard 570	Mobilgard L540
Shell	Alexia 50	Alexia LS
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Further information can be obtained by contacting the engine builder or MAN B&W Diesel A/S, Copenhagen.

4. Cylinder Oil Feed Rate (dosage)

4.1 General

The following guidelines are based on service experience, and take into consideration the specific design criteria of the MC/ME engines (such as mean pressure, maximum pressure, lubricated liner area) as well as today's fuel qualities and operating conditions.

The recommendations are valid for fixed pitch and controllable pitch propeller plants as well as stationary plants (generator application).

This Section is based on our Service Letter 03-417/HRJ, which recommends:

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Service experience has now demonstrated that it is also possible to reduce the feed rate for the super-long-stroke S-MC/MC-C engines fitted with Alpha Lubricators, even down to the same low level as for the K/L engines, i.e. to a basic feed rate of 0.8 g/bhph and a minimum of 0.6 g/bhph.

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Intensive studies of the relation between wear and lube oil dosage have revealed thatthe actual need for cylinder lubrication follows the amount of fuel being burnt and the fuel quality.

This calls for part-load lube oil control which is proportional to the engine output, as load and oil consumption in this connection are practically proportional. This is, at the same time, the most economical control mode, compared to the previous practice where part-load dosages were controlled proportionally with either engine speed or cylinder mean pressure.

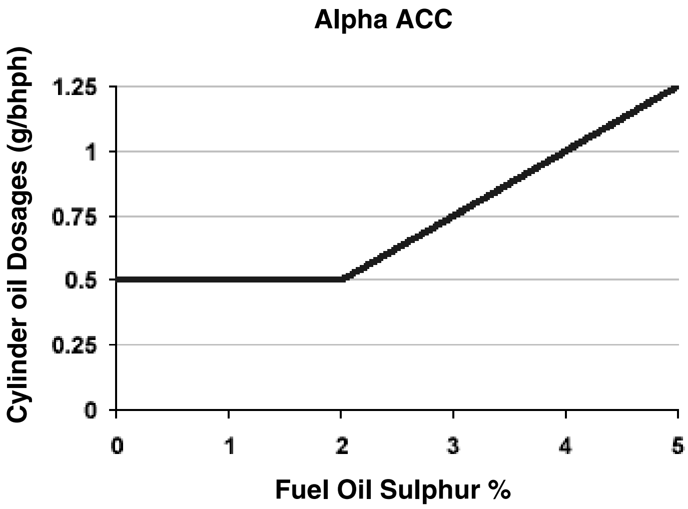
The basic feed rate control should be adjusted in relation to the actual fuel quality being burnt at a given time. Of course, fuel quality is rather complex. However, studies have also shown that the sulphur percentage is a good indicator in relation to wear, and an oil dosage proportional to the sulphur level will give the best overall cylinder condition.

This new cylinder oil control principle is called the “**Alpha Adaptive Cylinder oil Control**”, or abbreviated “**Alpha ACC**”.

Tests with Alpha ACC on K and S engines of various engine sizes have shown that a safe and optimum lube-economical control is obtained with a basic setting according to the below formula:

Basic lube oil setting = 0.25 g/bhph x S%,

with a minimum setting of 0.5 g/bhph, i.e. the setting should be kept constant from 2% sulphur and down.



4.5 How to adjust the dosage according to the Alpha ACC principle

First of all, knowledge of the sulphur percentage of the fuel oil being burnt at any time is a condition for obtaining the savings with Alpha ACC. Therefore, we recommend that the ships in question join one of the well-known fuel analysis programmes on the market, and that burning of the oil is not started until the analysis result is known. This will normally take two to four days after bunkering.

One of the key parameters in Alpha ACC lubrication is part-load control proportional to engine load. This is important in order to prevent over-lubrication at low loads, and it is one of the main parameters to save oil, compared with conventional lubrication.

If "load-proportional control" is not already preset from delivery of your Alpha Lubricator system, we suggest that you contact MAN B&W Diesel A/S in order to get instructions on how to change the software from either speed-proportional control or cylinder-mean-pressure proportional control.

When starting to burn new bunker oil, the HMI setting of the Alpha ACC should be adjusted according to the bunker analysis results. For reference, the below table should be used:

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%	g/bhph	g/kWh	Setting
0.0-2.0	0.50	0.68	63
2.2	0.55	0.75	69
2.4	0.60	0.82	75
2.6	0.65	0.88	81
2.8	0.70	0.95	88
3.0	0.75	1.02	94
3.2	0.80	1.09	100
3.4	0.85	1.16	106
3.6	0.90	1.22	113
3.8	0.95	1.29	119
4.0	1.00	1.36	125
4.2	1.05	1.43	131
4.4	1.10	1.50	138
4.6	1.15	1.56	144
4.8	1.20	1.63	150
5.0	1.25	1.70	156

Our ‘basic setting’ is traditionally chosen to obtain a dosage which, in average conditions, results in a safe and lube-oil-economical cylinder condition. This leaves possibilities for further individually based reductions, towards the recommended minimum setting.

In the case of the Alpha ACC, the basic factor of 0.25 g/bhph x S% may, of course, also be lowered. Currently, we have experienced down to a factor of 0.21 g/bhph x S%.

Introduction

These instructions are a **supplement to "Procedure 908-2", in our Volume II, Maintenance" instruction book**, and should be used **in combination with that Procedure** during inspection and overhaul of all Nimonic spindles on MAN B&W engines.

All general data, including specified wear limits for the spindle used on your engine type, are given in Procedure 908-2, DATA. 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:

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 B&W Diesel A/S, Copenhagen.

2. Inspection Intervals

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

*) The normal hours of service between overhauls for Nimonic exhaust valve spindles is 16,000 hours *(see instruction book Volume II, Chapter 900)*.

**) 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.

3. Inspecting the Contact Condition of the Seat

What to do

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.

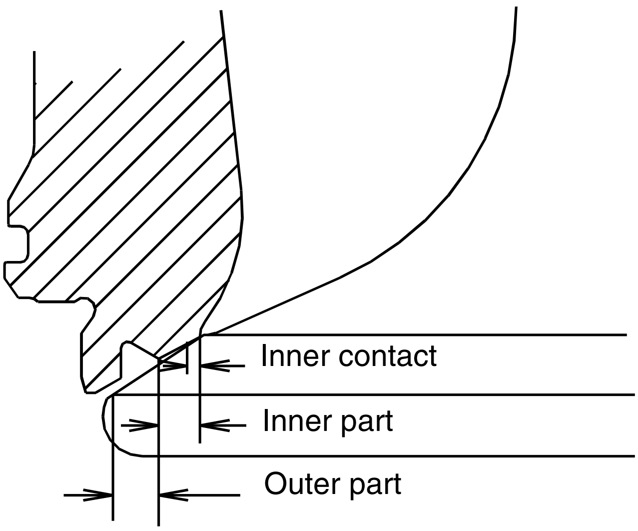


Fig. 1: Inner contact, and zone designation

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.

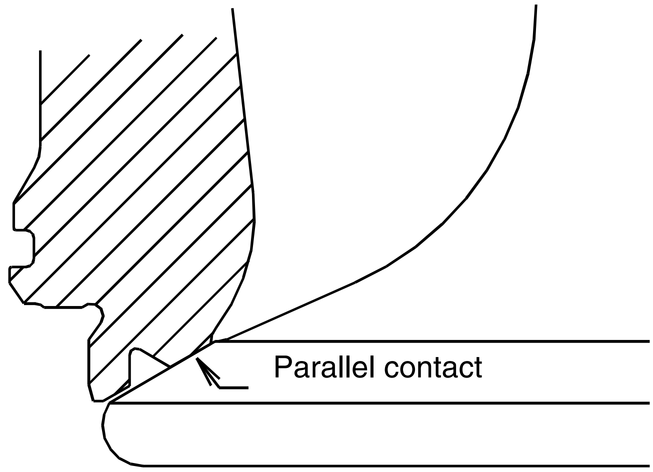


Fig. 2: Contact condition during running

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

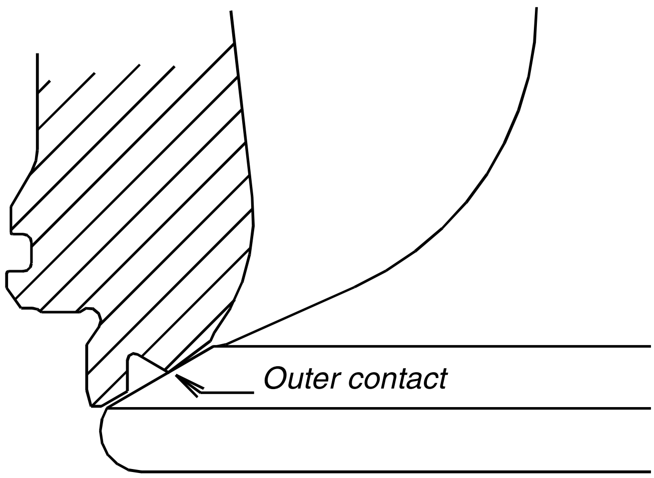


Fig. 3: Outer contact, increased risk of blow-by

Further action:

✍ Fill in Page 11 ‘Exhaust Valve Condition Report’.

If the seat contact is incorrect, grind the spindle seating, as described in Step 7.

However, before grinding, proceed to Steps 4, 5 and 6.

4. Checking the Seat for Gas Leakage

What to do

Do not clean the spindle disc before inspection

- Visually check the inner part of the seating for blow-by (Fig. 4 and Photo 1).

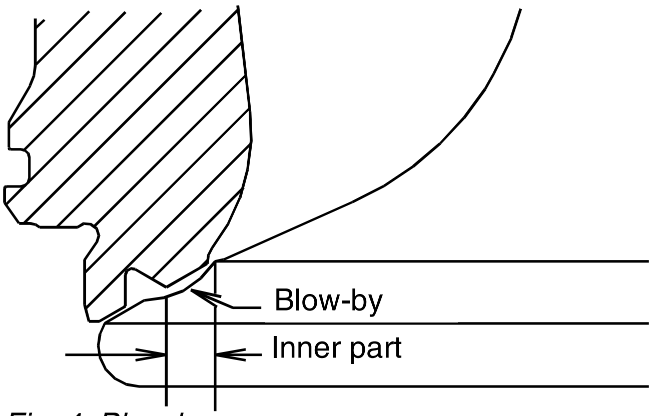


Fig. 4: Blow-by

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 Page 11, ‘Exhaust Valve Condition Report’.

If blow-by has been found, then grind the seat, as described in Step 7.

However, before grinding, proceed to Steps 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).*

.

Inner part

Outer part

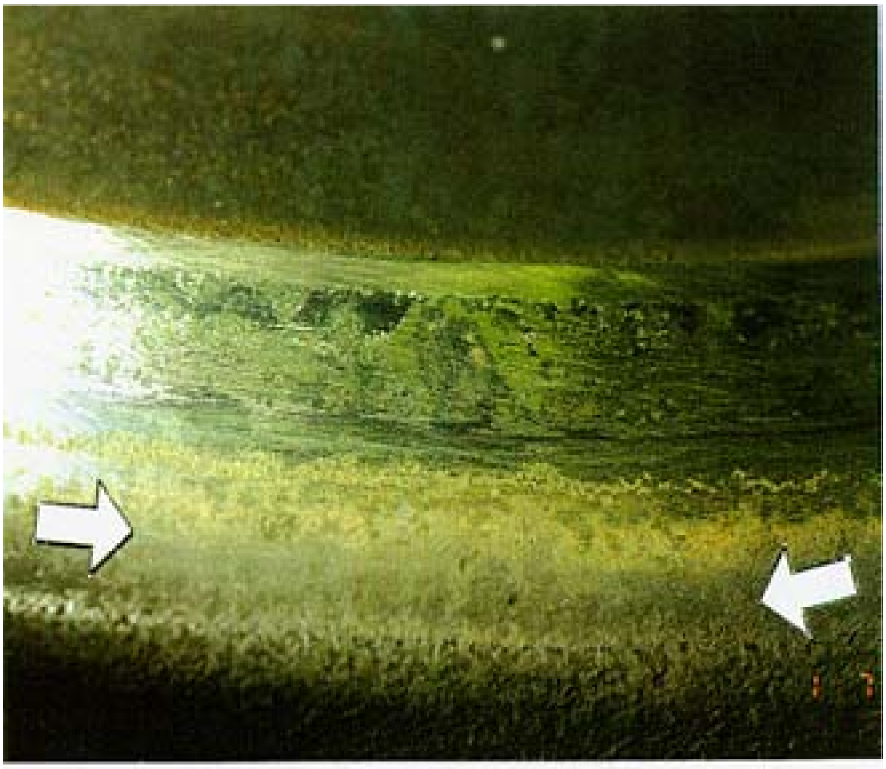


Photo 3: Example of high-temperature corrosion at outer part after 33,000 hours

- 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 Vol. II Procedure 908-2

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 B&W Diesel A/S.

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.

Fill in data from Procedure 908-2
F_1:
G_1:

Wear allowances:.

- Burn-off on disc underside, (F_1)
- Total grinding of seat, (G_1).

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 *(Table 1)*

Engine Type: *)	Max. permissible burn-off (mm)
26MC	5
35MC	6
42MC	7
46MC-C	8
50MC/MC-C 50ME/ME-C	8
60MC/MC-C 60ME/ME-C	9
70MC/MC-C 70ME/ME-C	10
80MC/MC-C 80ME/ME-S	11
90MC/MC-C 90ME/ME-C	12

**) Also valid for stationary engines (power plants)*

Table 1: Permissible burn-off rate before reconditioning of spindle disc underside

Further action:

✍ Fill in Page 11, 'Exhaust Valve Condition Report'.

If the burn-off or grinding limits have been reached, contact MAN B&W Diesel A/S for advice on reconditioning.

If the seat and the disc underside are acceptable with respect to Steps 3, 4, and 5, then the spindle can be reinstalled without grinding after step 6 has been carried out. Otherwise, proceed to Steps 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 *Volume II, Procedure 908-2.*
- Check the surface condition of the chrome-plated/HVOF-coated area.

Acceptance criteria:.

Fill in data from DATA 908-2
D-__________: min. diameter of spindle stem:

Min. diameter: Must not be less than that stated in Vol. II, Procedure 908-2, DATA**Cracking ("network 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.

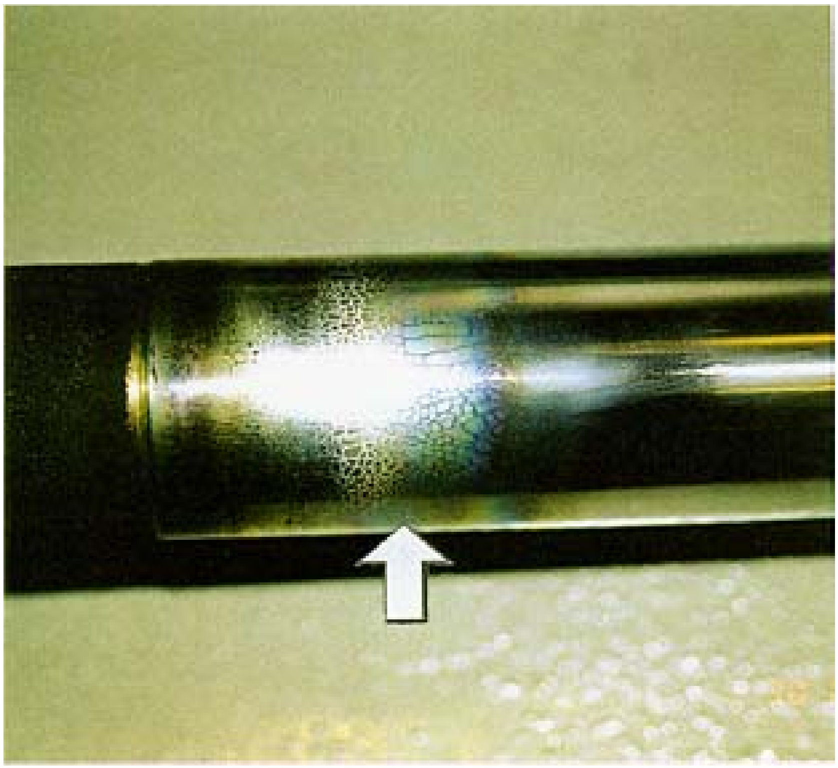


Photo 4: Slight cracking ("network cracking") of wear layer

Further action:

✍ Fill in Page 11, 'Exhaust Valve Condition Report'.

If the spindle stem is acceptable, proceed to Step 7.

Otherwise, contact MAN B&W Diesel A/S 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.

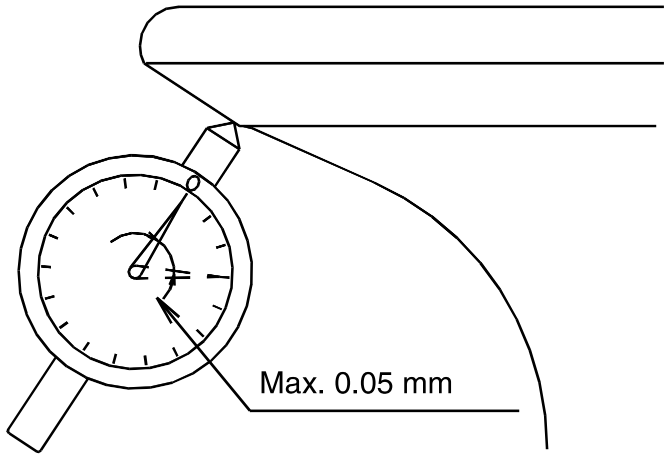


Fig. 5: Truing-up the spindle

- Grind the seat according to the special instructions from the grinding machine supplier.

  See also MAN B&W Service Letter SL95-332/UM, "Grinding of Nimonic Exhaust Valve Spindles".

Fill in data from DATA 908-2
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 (G_1) stated in Vol. II, Procedure 908-2, DATA.

Fill in data from DATA 908-2
G_1:

If the seat surface is still not acceptable when the max. grinding depth has been reached, contact MAN B&W Diesel A/S for advice on reconditioning.

8. Exhaust Valve Condition Report

Exhaust Valve Condition Report

MAN B&W

Vessel:		Engine type:	Builder/no.:
Valve dismounted from cyl.:	Date:	Engine hours (total):	**Valve no.:**
Valve checked/overhauled by:	Date:	Place:	Remarks:
Valve mounted on cyl.:	Date:	Engine hours (total):	Kept as spare (yes/no):

BOTTOM PIECE

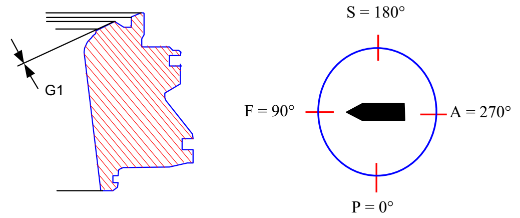
Marking:	Base material:	Hours after overhaul:
Type:	Seat material:	Hours total:

Seat contact (inner/outer/parallel):		No. of dent marks larger than Ø = 7 mm:
Cracks (yes/no):	Blow-by (yes/no):	Maximum deposit thickness in duct (mm):
Deposit in chamber, extent (mm):		at position (degrees, 0° = port side):

Total grinding, G1 (mm):

Note! Max grinding, G1 = 2.0 mm

Remarks:



SPINDLE

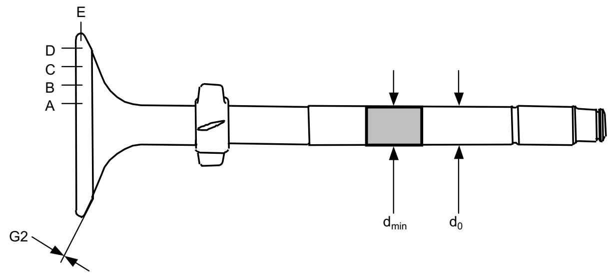
Marking:	Base material:	Hours after overhaul:
Disc coating:	Seat material:	Hours total:
Cracks (yes/no):	Seat contact (inner/outer/parallel):	Blow-by (yes/no):
Spindle disc max burn-off (mm):	at position (A, B, C, D or E):	Burn-off rate (mm/1000h):

No. of dent marks larger than Ø = 7 mm:	Total grinding, G2 (mm): *Note! Max grinding, G2 = 2.0 mm*

Stem diameter d_0 above sealing area (mm):

Min. stem diameter d_{min} at sealings (mm):

		1st	2nd	3rd
Extent of reconditioning				
Welding of seat	(Tick off)			
Seat welding material:				
Welding of disc	(Tick off)			
Disc welding material:				
Stem recond. (Tick off)	Chr.-plating			
	HVOF-Cermet			



Remarks:

HOUSING

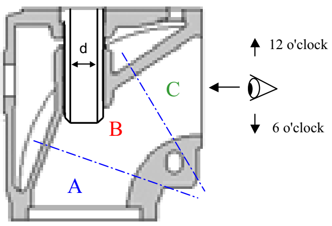
Marking:	Hours after overhaul:

Spindle guide diameter, d	Top	Bottom	Extent of reconditioning	1st	2nd	Hours total:
Minimum (mm)			Repair welding (Tick off)			Max coke deposit thickness (mm):
Maximum (mm)			Coating:			

Corrosion

Area	A		B		C	
mm						
position (o'clock)						

Remarks:



1. Dismount the small covers on the scavenge air boxes, and clean the openings.

2. When the piston has been turned below the level of the scavenge air ports, inspect the cylinder liner walls and the piston crown.

3. A tiltable mirror fixed to a telescopic rod can be used as illustrated. Use a powerful light source for inspection.

4. In order to inspect a larger area of the cylinder liner and piston, it is expedient to enter the scavenge air receiver and make observations from the “exhaust side”. This should be done every time the sludge is cleaned out from the scavenge air receiver and box.

5. While the piston is passing the scavenge air port, examine the piston crown, the rings, and the skirt.

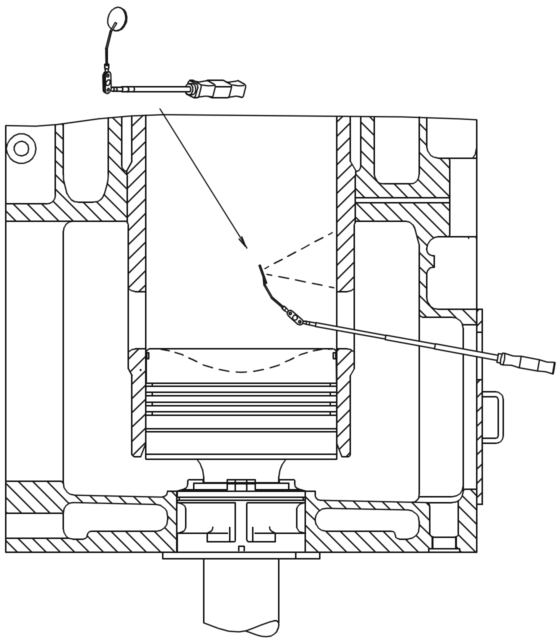
   In order to be able to correctly observe the running surfaces of the piston rings, clean them with a rag.

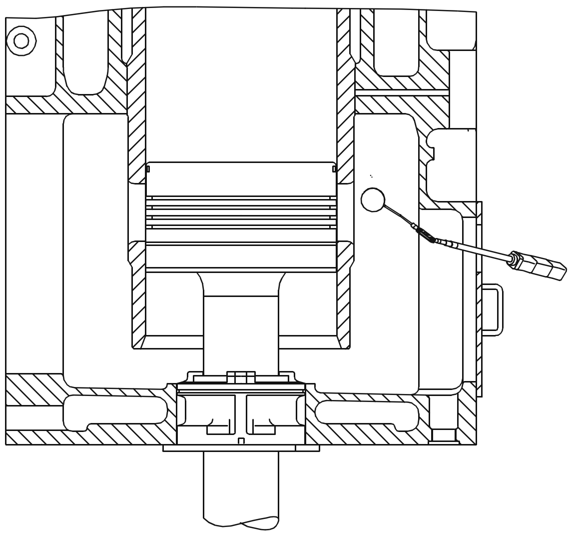
   Check the free movement and the tension of the piston rings, by pressing them with a wooden stick.

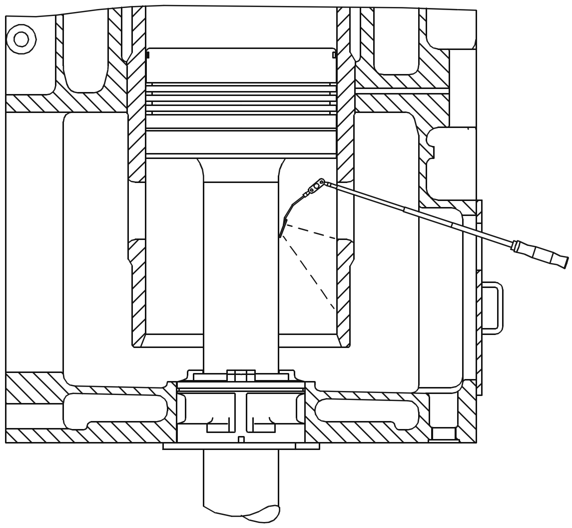
6. Measure the total clearance between the piston rings and the ring grooves.

7. When the piston has been turned upwards past the scavenge air ports, inspect the piston rod.

8. Note down the results on Plate 70702.





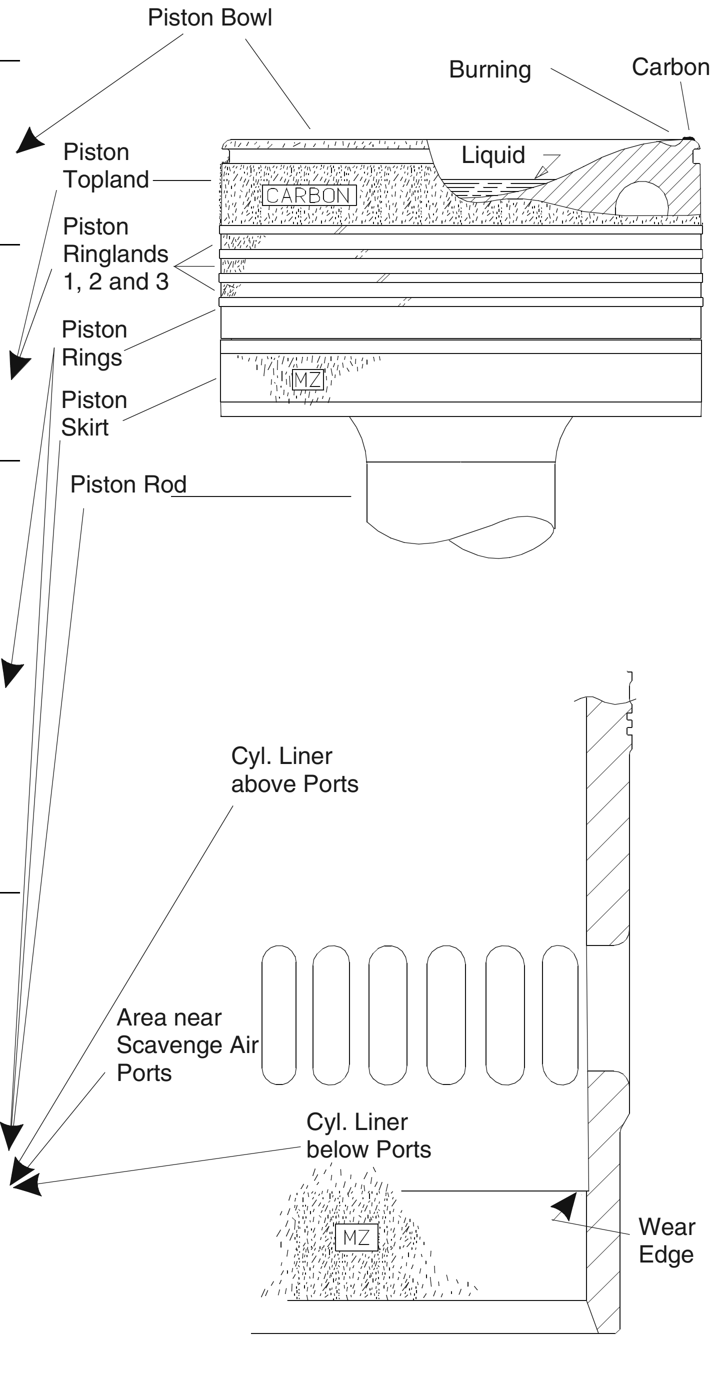


Inspection through Scavenge Ports

Vessel:		Ll. no.:		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	1	2	3	4	5	6	7	8	9	10	11	12
	Intact - * Burning - BU Leaking oil - LO Leaking water - LW	Piston crown												
Deposits	No deposit - * Light deposit - LC Medium deposit - MC Excessive deposit - EC Polished deposit - PC	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 movement	Loose - * Sluggish - SL Sticking - ST	Ring 1												
		Ring 2												
		Ring 3												
		Ring 4												
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 1												
		Ring 2												
		Ring 3												
		Ring 4												
		Piston skirt												
		Piston rod												
		Cylinder liner abv. scav. ports												
		Cylinder liner near scav. ports												
Lubrication condition	Optimal - * Too much oil - O Slightly dry - D Very dry - DO Black oil - BO	Ring 1												
		Ring 2												
		Ring 3												
		Ring 4												
		Piston skirt												
		Piston rod												
		Cylinder liner												
Deposits	No Sludge - * Sludge - S Much sludge - MS	Scavenge box												
		Scav. receiver												
	Intact - *	Flaps and nonreturn valves												
Running hours since last overhaul														

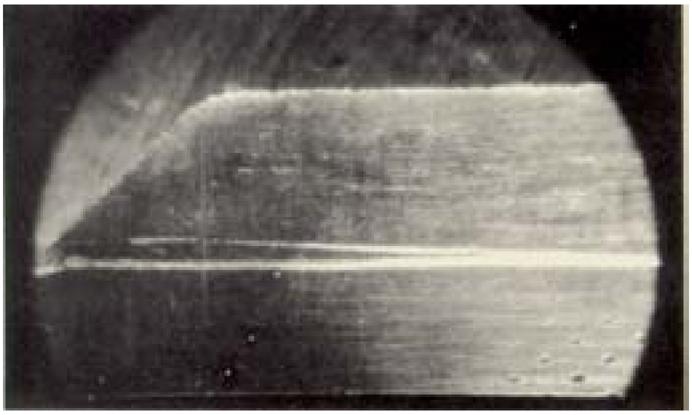
Sym-bol	Condition of inspection part	
• C BU LO LW	Satisfactory Carbon Deposit Burning Leakage Oil Leakage Water	Deposits, etc.
• LC EC PC	Satisfactory (no deposits) Light carbon deposit Excessive carbon deposit Thick carbon deposit worn bright by rubbing against cyl. liner	Deposits
• BO BN SP M COL	Intact Broken, opposite ring gap Broken, near ring gap Broken in several pieces Entirely missing Collapsed	Broken
• SL ST B (B)	Loose Sluggish in groove Sticking Black running surface, over-all Black running surface, parly	Sticking
• S mz MZ MAZ OZ WR CO CL T/B	Clean, smooth Vertical scratches (abrasive particles) Micro Seizures in spots (local) Micro Seizures, all over Micro Seizures still active Old (nearly recovered) MZ Wear ridges near bottom Corrosion Clover-leaf wear Rings sharp-edged Top/Bot.	Surface condition
• O D DD BO	Oil film normal Too much oil Too dry Very dry Black oil	Lubr. condition



A dot (•) always means that the inspected condition is satisfactory, e.g. small deposits, no leakage, no breakages, no sticking, clean smooth surfaces, normal oil film, etc. However, this shall be recorded in order to show that the condition has been noted.

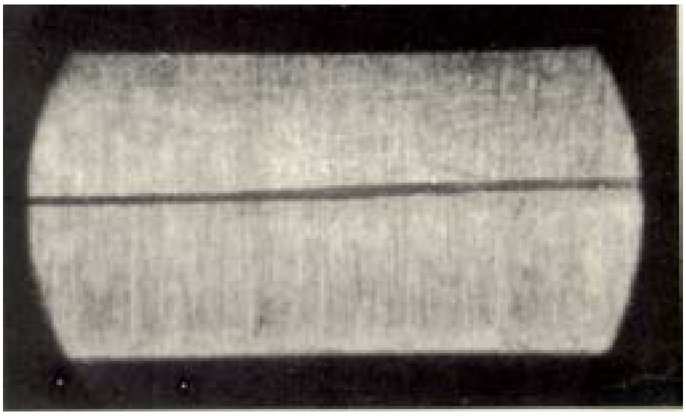
Running Surface of Piston Rings *(see also Plate 70705)*

NB: In file tests, use a new very finely cut file



"Polished Mirror Surface"
Photo 1 (about X3)

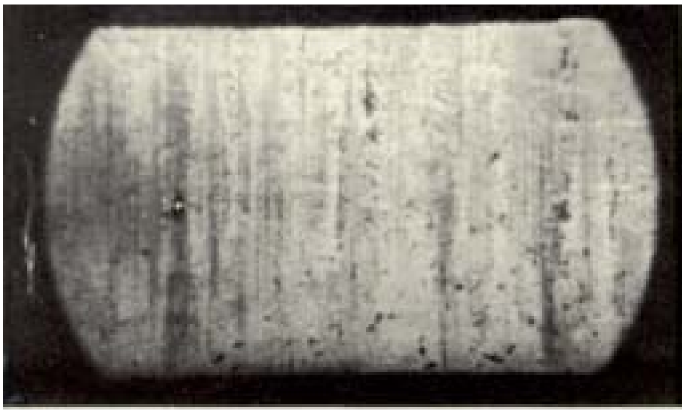
A normal, good running surface is smooth, clean, and without scratches. The horizontal line is a scratch mark resulting from a file test, which indicates that the surface is not hardened.



"Vertically Scratched"
Photo 2 (about X3)

Here the running surface has been scratched by sharp, hard abrasive particles, e.g. grains of sand.

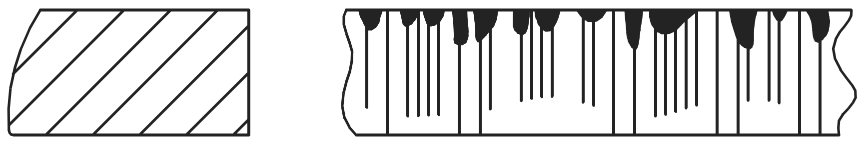
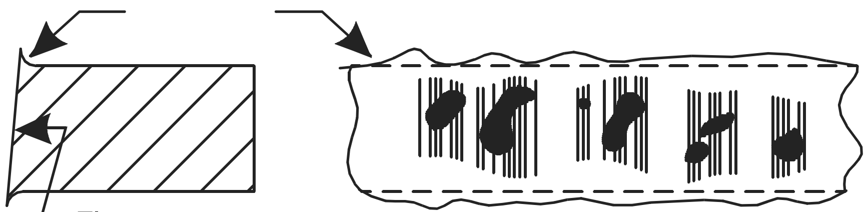
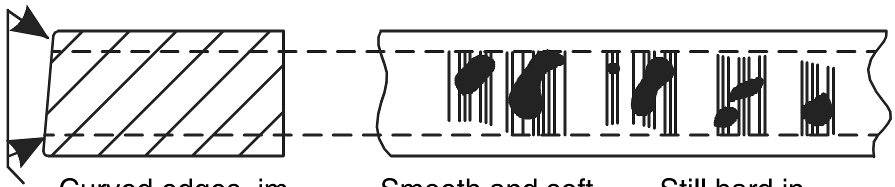
The file test shows that the surface is not hardened.



"Micro-Seizures"
Photo 3 (about X3)

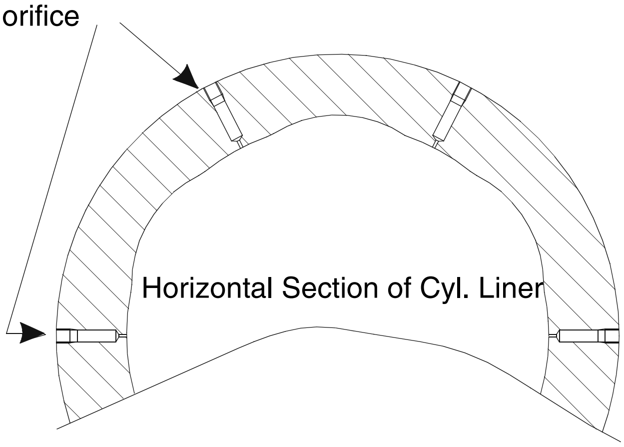
A micro-seized running surface can appear as shown here.

The file test gives almost no horizontal scratch, which indicates that the surface is covered by a hard glaze, i.e. has been hardened due to micro-seizure.

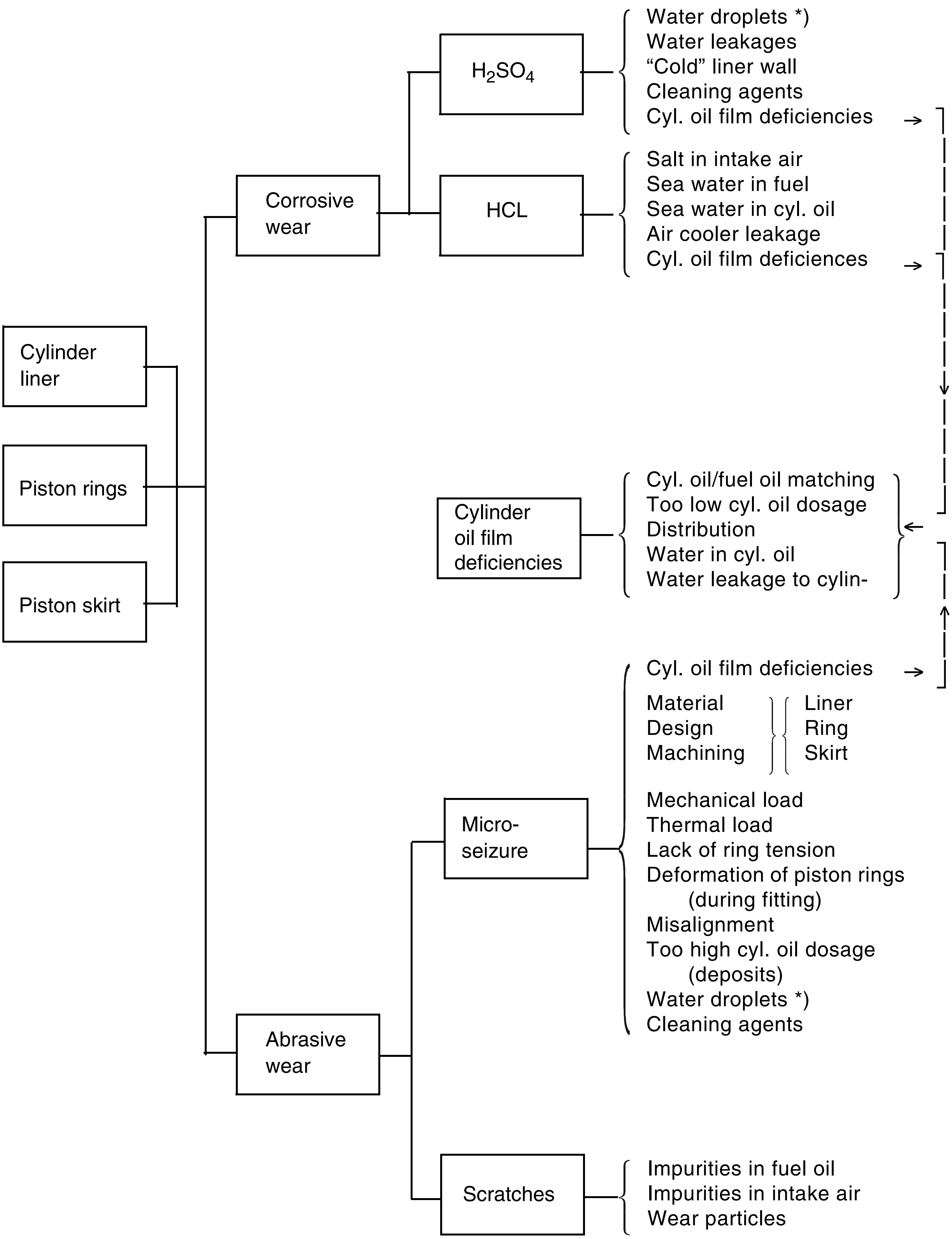
Surface Condition	Profile	Running Surface
Normal good "mirror surface" "•"	 Barrel-shaped	Clean, smooth, soft
Scratched by hard abrasive particles "S"		Uniform scratches, dull, soft
New Micro seizures (still active) "MAZ"	Sharp burrs  Flat	Irregular marks, hardened
Old Micro seizures (restoration has begun) "OZ"	 Curved edges, implies that restoration has begun	Smooth and soft along the edges Still hard in centre area

Clover-leaf formation:
heavy wear at several areas around the cylinder liner, in the case illustrated concentrated between the lubrication orifices

"CL"

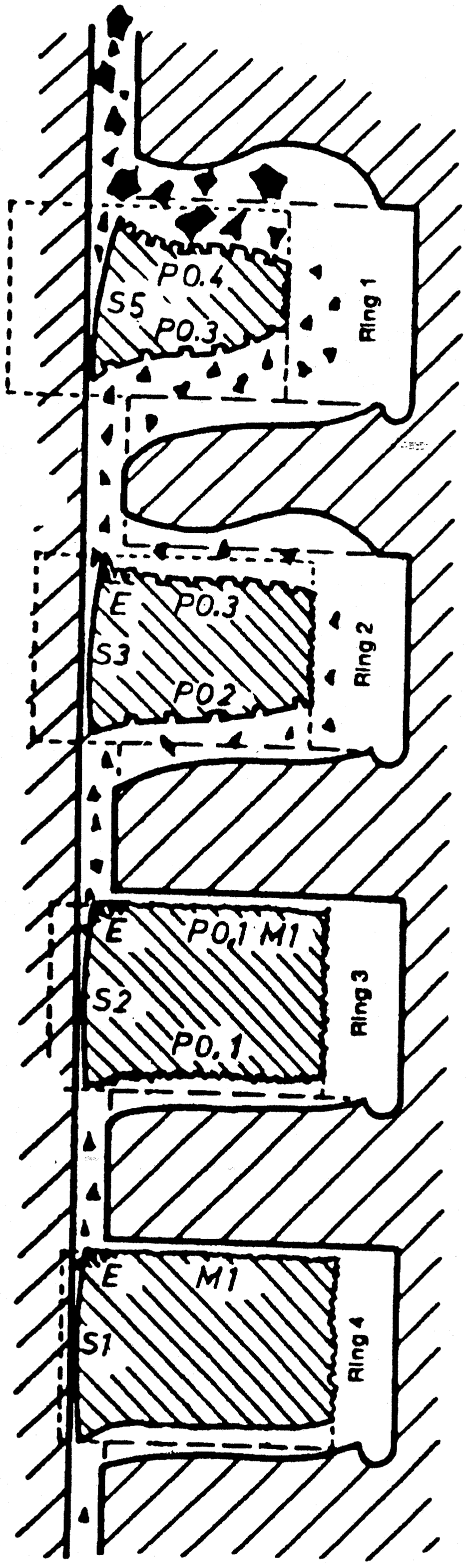


Schematic summary of the most widely recognized causes of “cylinder wear”



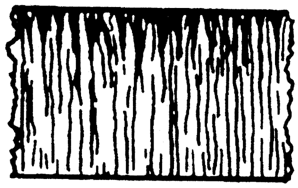
*) Drain for condensed water in scavenge air receiver blocked or out of function.
See also Section 706-03 ‘Cleaning of Turbochargers and Air Coolers’

Typical observations when particles penetrate from the combustion chamber into the piston ring zone

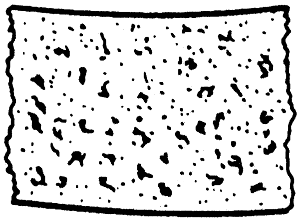


Exaggerated illustration of “worn and eroded” piston rings No. 1 to 4, in “worn” grooves. It is typical for particle wear that it excessively affects the upper ring (both the running face and the horizontal surfaces) as well as the groove. Some degree of micro-seizure sometimes occurs on the lower rings, decreasing upwards. This is contrary to the scratching intensity (or roughness) which decreases, from ring to ring, downwards.
When particle-wear prevails, the cylinder liner wear rate usually rises to between 0.30 and 0.50 mm/1000 hours.

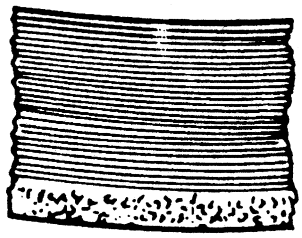
Running face ring No. 1
The “trumpet-shaped” scratches indicate that the hard particles have penetrated from above.



Upper side of the uppermost rings
The horizontal faces, especially the upper side, often become pock-marked due to hard grains being crushed when the rings are pressed upwards by the gas trapped between the rings. However, such an appearance can also be the result of mechanical impact due to ring collapse.



Upper side of the lower rings
The part sheltered in the groove still shows intact machining marks. The exposed part, protruding from the groove, becomes sand-blasted by the hard particles blown down through the ring gap above.



Designations
“S” – Scratched running face
“PO” – “pock-marked”

“E” – Erosion. Outer edge sand-blasted
“MI” – Machining marks intact.

Numbers 1 to 5 give degree of damage (5 being most).

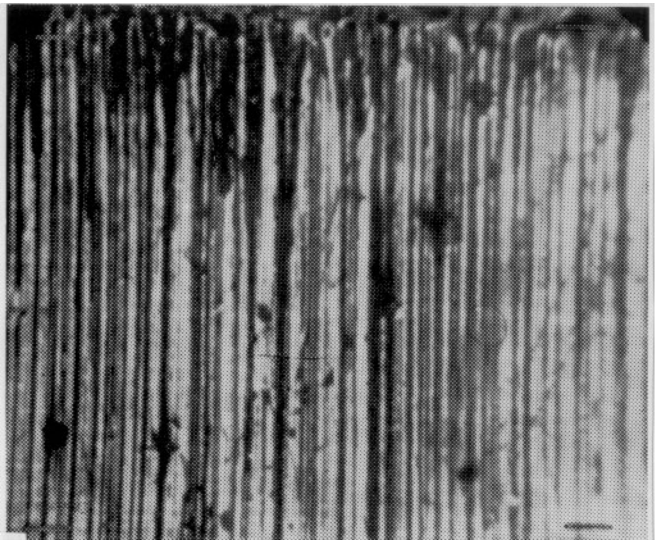


Photo 1 (X30)
Rough scratching (degree 5) of a top piston ring running face. The photo shows the upper edge, where the hard particles enter between ring and liner wall. This scratching is quite fresh, i.e. recovery or restoration has not yet commenced. Designation S5NEW.

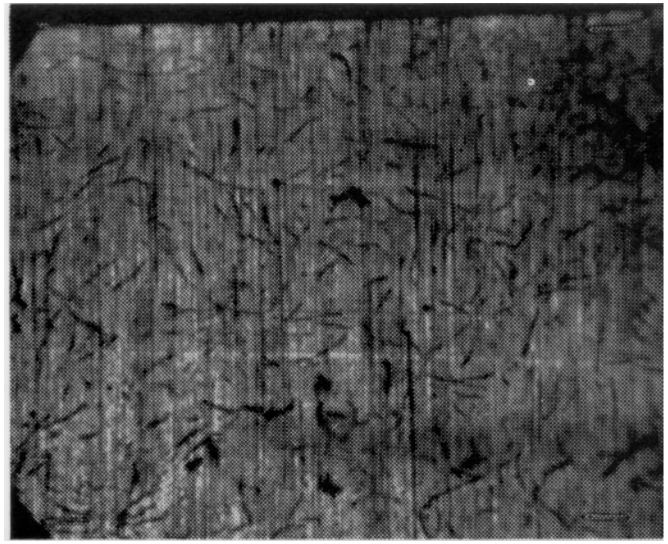


Photo 2 (X30)
Typical “older” much **finer scratching.** That recovery or restoration is at work, can be ween from the fact that the graphite flakes are distinct. Designation S2OLD.

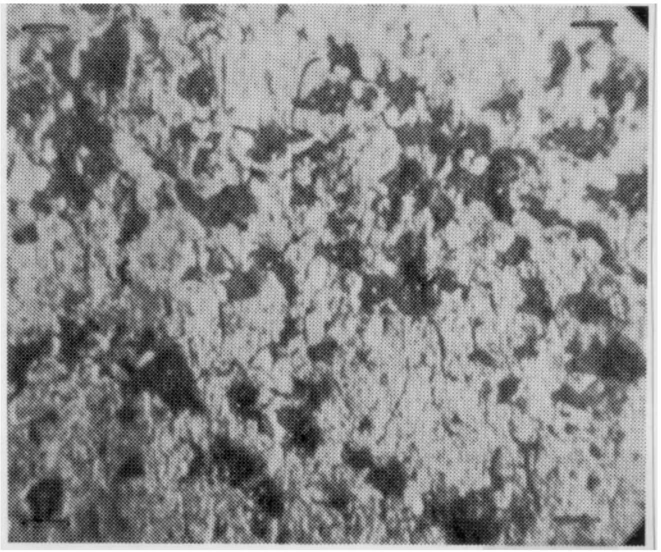


Photo 3 (X30)
Typical **“pock-marking”** of a ring upper side, caused by hard particles penetrating into the clearance above the ring and being crushed. This is most often seen on the two uppermost rings, which, during the last part of the expansion stroke, are pressed upwards, against the ceiling of the groove, by the gas trapped between the rings

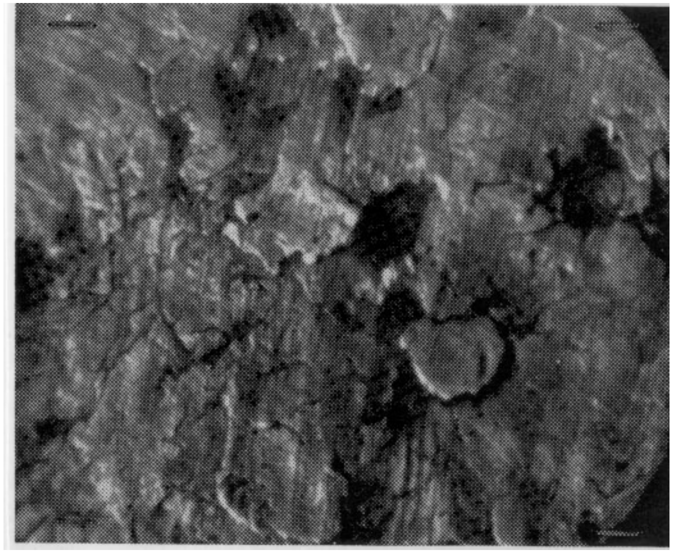


Photo 4 (X30)
This photo illustrates how small pieces of cast iron are “torn out” of the top surface, by the masticating effect of the hard particles. The pieces probably loosen due to shear stresses, which cause fractures in the material between the graphite flakes. Also ring collapse can cause “torn out” material.

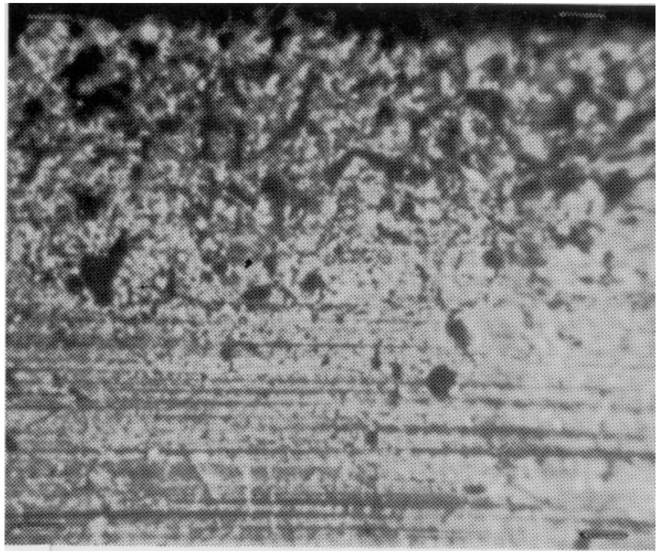


Photo 1 (X30)
Typical erosion or **sand-blasting** on the part of the ring topside which protrudes out of the groove. This is due to hard grains being blown down through the gap in the ring above (NB: The rings “turn” in the grooves). Such erosion is only seen on rings Nos. 2, 3 and 4.

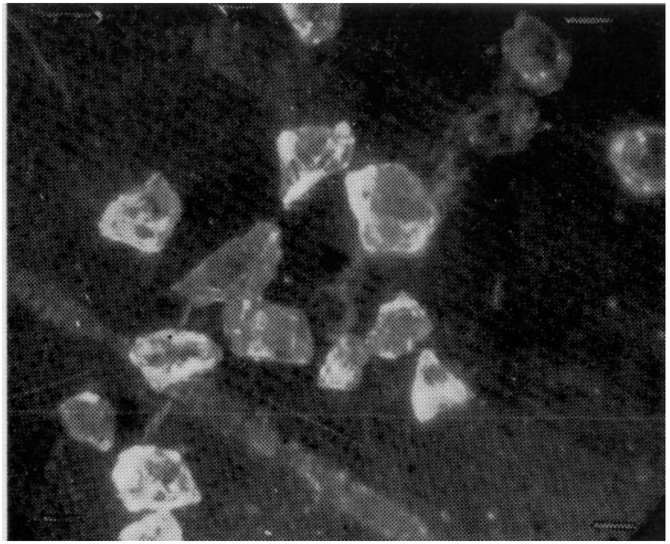


Photo 2 (X30)
Hard particles (sand) separated from a sample of **piston crown deposit**. Oil and carbon have been removed by incineration, other matter by acid, magnetic separation and filtration. Theoretically these particles could have come into the combustion chamber either with the air or with the fuel.

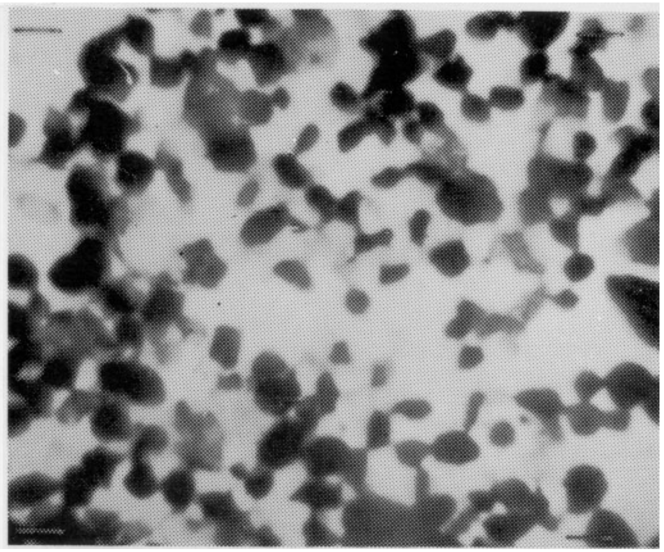


Photo 3 (X250)
Sand (or sand-like grains) separated from **centrifuge sludge**. In this case the centrifuge treated the fuel oil **after** the oil had passed a full flow (fabric) filter. The particles size is 10μ to 15μ.

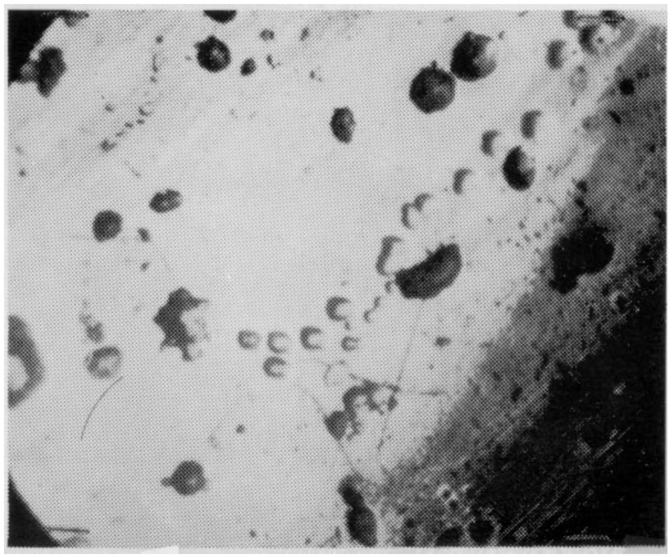
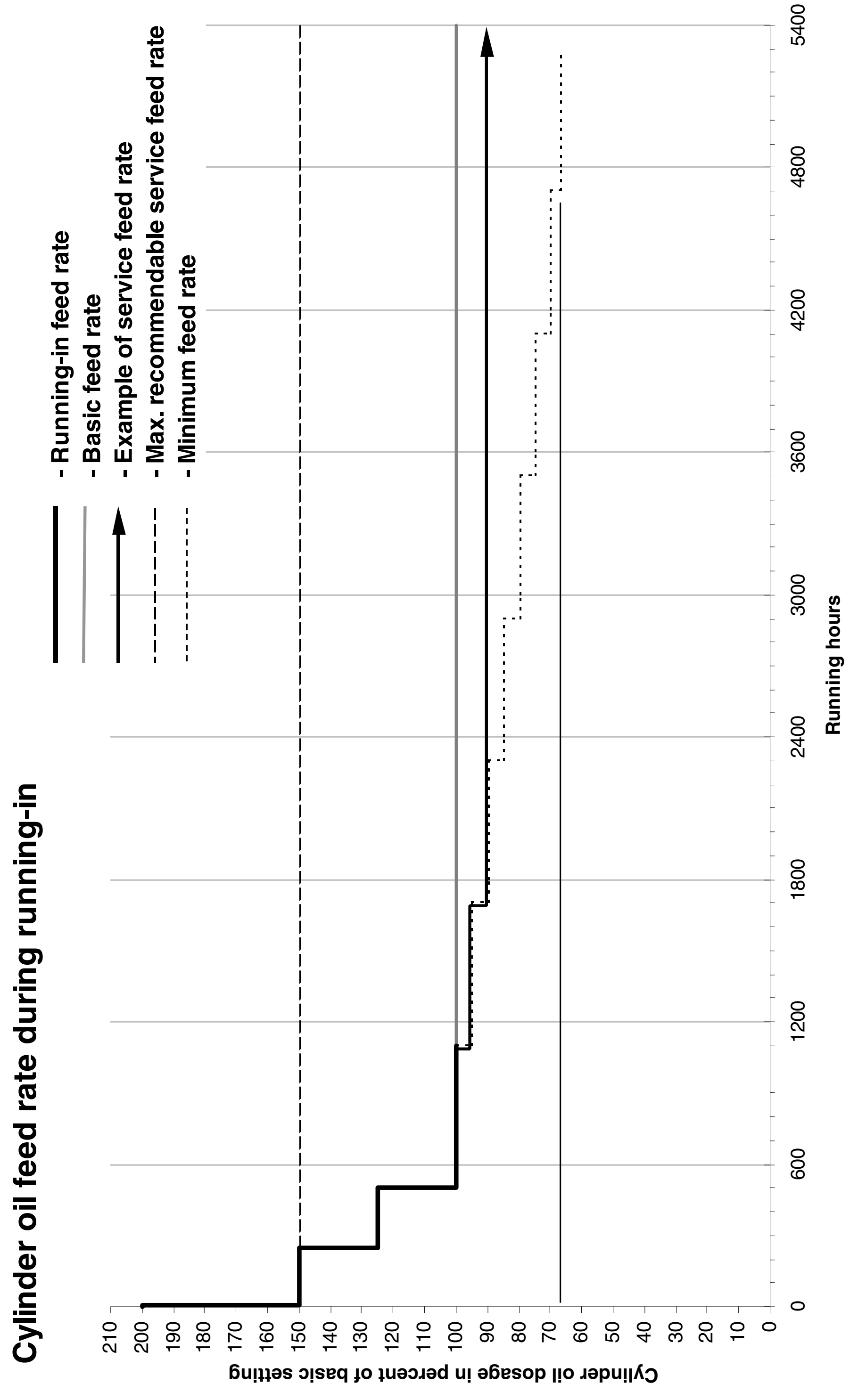


Photo 4 (X30)
Fuel pump suction valve flap after only a few service hours (the lapping marks are still visible. The depressions in the surface are in many cases made by one and the same particle (repeated and identical in shape and size). Usually the edge around the holes is raised, and often the original lapping marks are still visible in the bottom of the depression


Cylinder oil feed rate during running-in
- Running-in feed rate
- Basic feed rate
- Example of service feed rate
- Max. recommendable service feed rate
- Minimum feed rate
Cylinder oil dosage in percent of basic setting
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Running hours
0
600
1200
1800
2400
3000
3600
4200
4800
5400

<table>
<tr><td colspan="5">Guiding Cylinder Oil Feed Rates
S/L/K-MC/MC-C/ME/ME-C engines with Alpha Lubricators, based on a BN 70 cylinder oil</td></tr>
<tr><td colspan="2"></td><td colspan="2">Standard guidelines
(ref. to MCR load)</td><td>Alpha Adaptive Cylinder oil Control (Alpha ACC)</td></tr>
<tr><td colspan="2">Basic setting</td><td colspan="2">0.8 g/bhph
1.1 g/kWh</td><td>0.25 g/bhph x S%
0.34 g/kWh x S%</td></tr>
<tr><td colspan="2">Minimum feed rate</td><td colspan="2">0.6 g/bhph
0.8 g/kWh</td><td>0.5 g/bhph
0.7 g/kWh</td></tr>
<tr><td colspan="2">Maximum feed rate during normal service</td><td colspan="2">1.25 g/bhph
1.7 g/kWh</td><td>1.25 g/bhph
1.7 g/kWh</td></tr>
<tr><td colspan="2">Part-load control</td><td colspan="2">Proportional to mean cylinder pressure</td><td>Proportional to engine load</td></tr>
<tr><td colspan="2"></td><td colspan="3">Below 25% load, proportional to engine speed.</td></tr>
<tr><td rowspan="4">Running-in new liners and piston rings</td><td rowspan="2">Feed rate:</td><td>Alu-coat piston rings:</td><td colspan="2">First 5 hours: 1.6 g/bhph
From 5 to 250 hours: Basic setting +50%
From 250 to 500 hours: Basic setting +25%</td></tr>
<tr><td>Non-coated or hard-coated rings:</td><td colspan="2">First 15 hours: 1.6 g/bhph
From 15 to 250 hours: Basic setting +50%
From 250 to 500 hours: Basic setting +25%</td></tr>
<tr><td rowspan="2">Engine load:</td><td>Alu-coat piston rings:</td><td colspan="2">Stepwise increase to max. load over 5 hours</td></tr>
<tr><td>Non-coated or hard-coated rings:</td><td colspan="2">Stepwise increase to max. load over 15 hours</td></tr>
<tr><td colspan="2">Running-in new rings in already run-in liners:</td><td colspan="3">Alu-coat piston rings: No load restrictions
Non-coated or hard-coated rings: Stepwise load increase to max. load over 5 hours.
Feed rate: Basic setting +25% for 24 hrs.</td></tr>
<tr><td colspan="2">Load change device (LCD)</td><td colspan="3">During starting, manoeuvring and load changes, regulation proportional to load or mean effective pressure should be replaced by rpm proportional control, and the dosage increased by 25%.</td></tr>
<tr><td colspan="2">Lubrication of cylinders that show abnormal conditions:</td><td colspan="3">Frequent scavenge port inspections of piston rings and cylinder liners are very important for maintaining a good cylinder condition.
If irregularities are seen, adjustments of the lube oil rate should be considered.
In case of scuffing, sticking piston rings or high liner temperature fluctuations, the feed rate should be raised by 25–50%.</td></tr>
</table>

If a liner or piston crown is exchanged, two reports must be filled-in!

Cylinder Condition Report

Vessel:	Ll. no.:	Eng. builder:	Eng. no.:	Checked by:
No. of cyl.:	Eng. type:	Eng. hrs.:	Date (yymmdd):	**Inspected unit no.:**

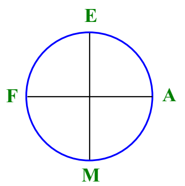
Voyage info

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:	

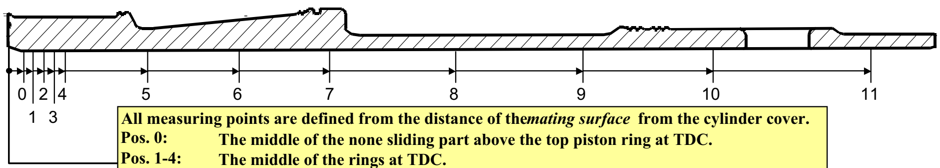
Cylinder liner

Liner hours:	Insulation pipe (Y/N):	PC ring (Y/N):	Liner material:
Drawing no.:	Frame type:	Liner cool type:	
Producer/Marking:	Wear type:	Liner honed (Y/N):	
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.

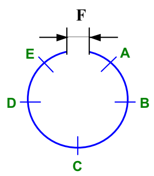
Pos. 0:	**The middle of the none sliding part above the top piston ring at TDC.**
Pos. 1-4:	**The middle of the rings at TDC.**
Pos. 5 & 6:	**Equally positioned between pos. 4 and 7 (1/3 of distance).**
Pos. 7:	**Lubrication quill level.**
Pos. 8 & 9:	**Equally positioned between pos. 7 and 10 (1/3 of 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							

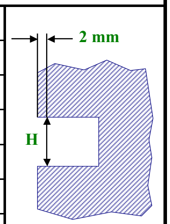
	Width of ring (mm)					Free ring gap "F" (mm)
	A	B	C	D	E	
Degrees						
Ring 1						
Ring 2						
Ring 3						
Ring 4						
Ring 5						



"F" to be measured before dismantling

Ring grooves

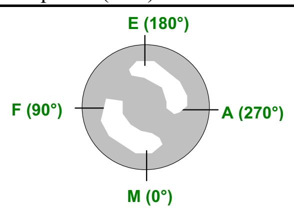
Height, H (mm)			
F	E	A	M



Hours since last overhaul:

Piston

Crown hours:	High topland (Y/N):
Bronze ring (Y/N):	Oros piston (Y/N):
Max burning 1 (mm)	
Position 1 (degree)	
Max burning 2 (mm)	
Position 2 (degree)	
Max burning 3 (mm)	
Position 3 (degree)	

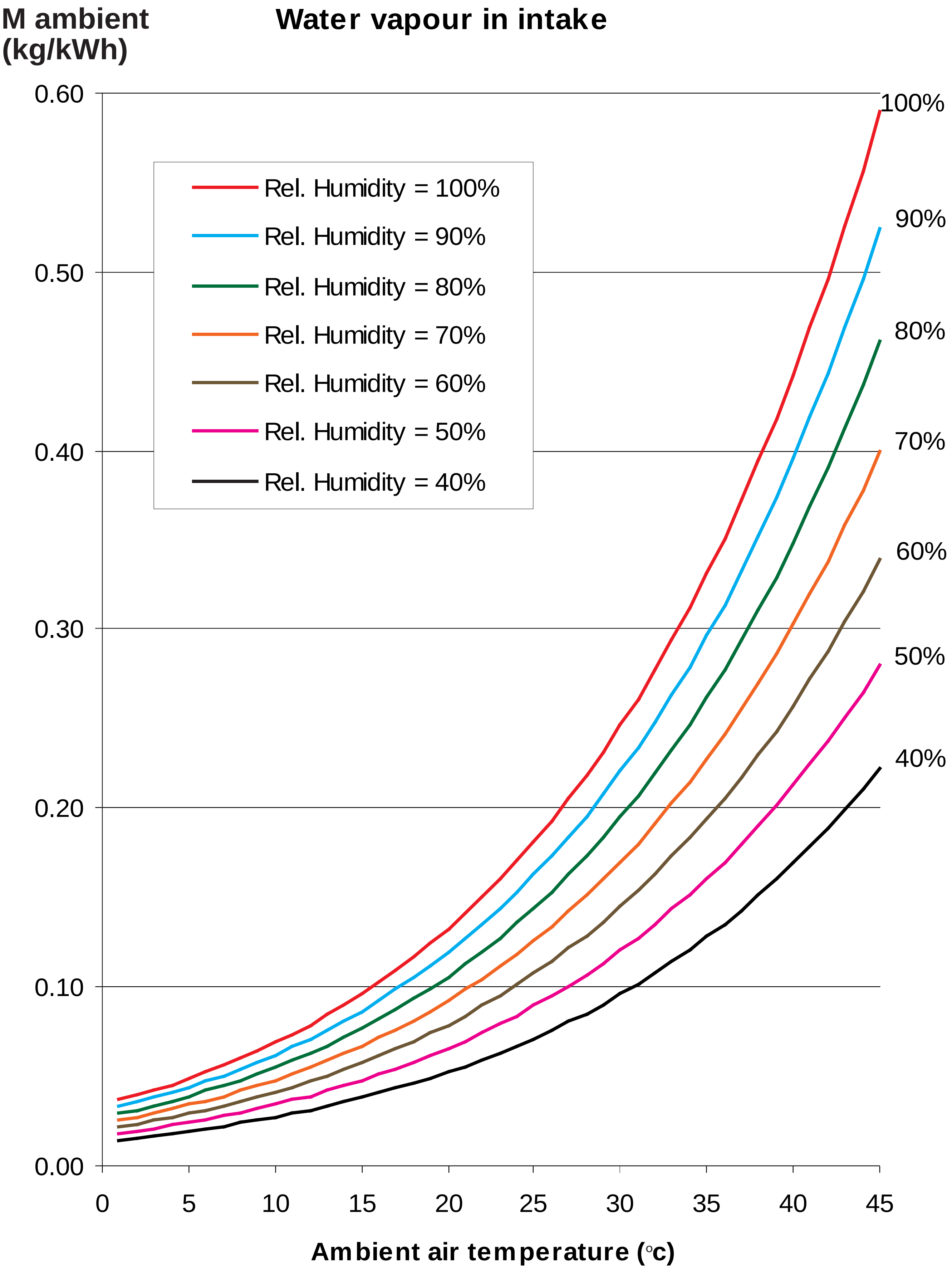


Reason for examination

Routine piston overhaul ☐
Test ☐
(If either of these boxes are ticked, below boxes must be kept blank)

Liner		Piston Crown		Piston Rings		Piston Skirt	
Cracks	☐	Burning	☐	Broken	☐	Leaking	☐
Scuffing	☐	Cracks	☐	Collapsed	☐	Scuffing	☐
Leak	☐	Leaking	☐	Scuffing	☐	Piston Rod	
		High Groove Wear	☐	Sticking	☐	Stuff. box	☐

Piston remarks	


M ambient
(kg/kWh)
Water vapour in intake
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rel. Humidity = 100%
Rel. Humidity = 90%
Rel. Humidity = 80%
Rel. Humidity = 70%
Rel. Humidity = 60%
Rel. Humidity = 50%
Rel. Humidity = 40%
100%
90%
80%
70%
60%
50%
40%
0
5
10
15
20
25
30
35
40
45
Ambient air temperature (°c)

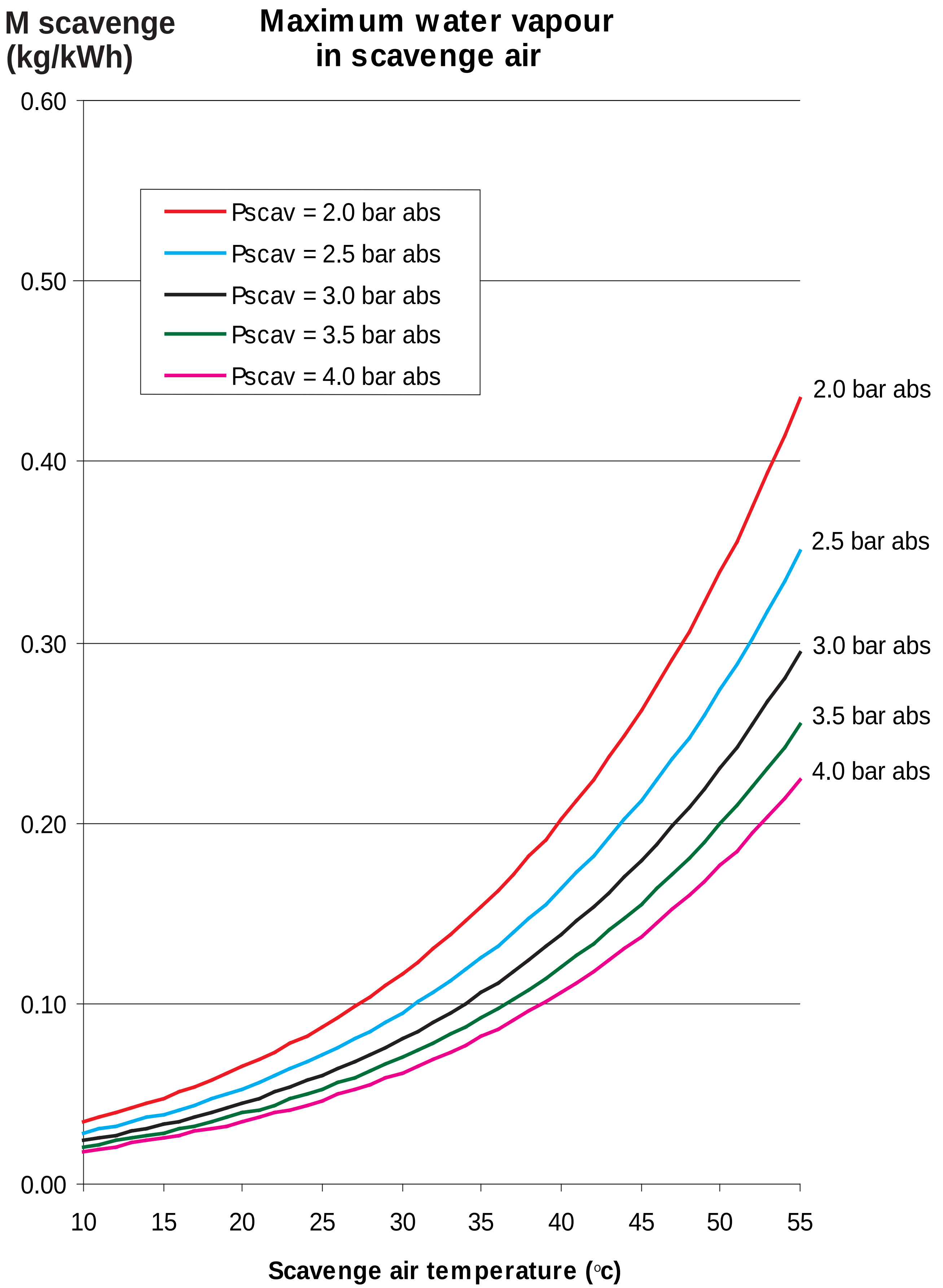

M scavenge
(kg/kWh)
Maximum water vapour
in scavenge air
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Pscav = 2.0 bar abs
Pscav = 2.5 bar abs
Pscav = 3.0 bar abs
Pscav = 3.5 bar abs
Pscav = 4.0 bar abs
2.0 bar abs
2.5 bar abs
3.0 bar abs
3.5 bar abs
4.0 bar abs
10
15
20
25
30
35
40
45
50
55
Scavenge air temperature (°c)

Fig. 1

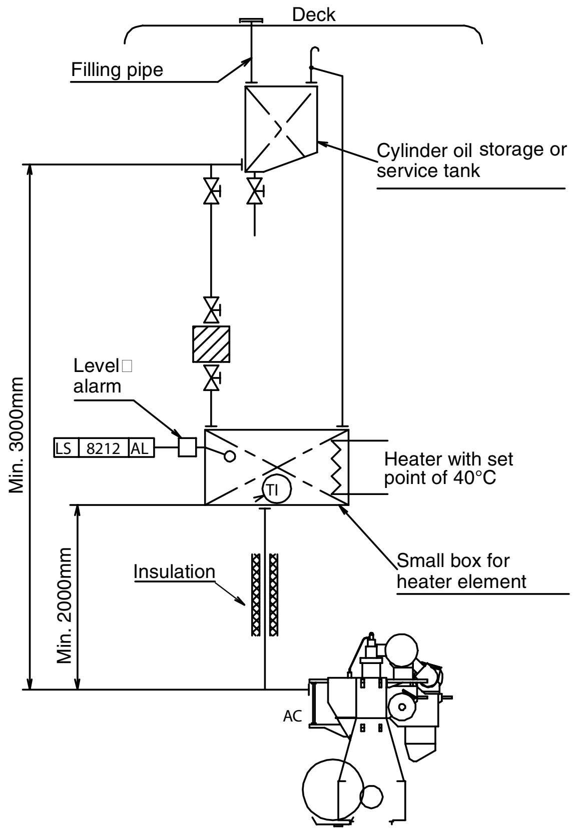
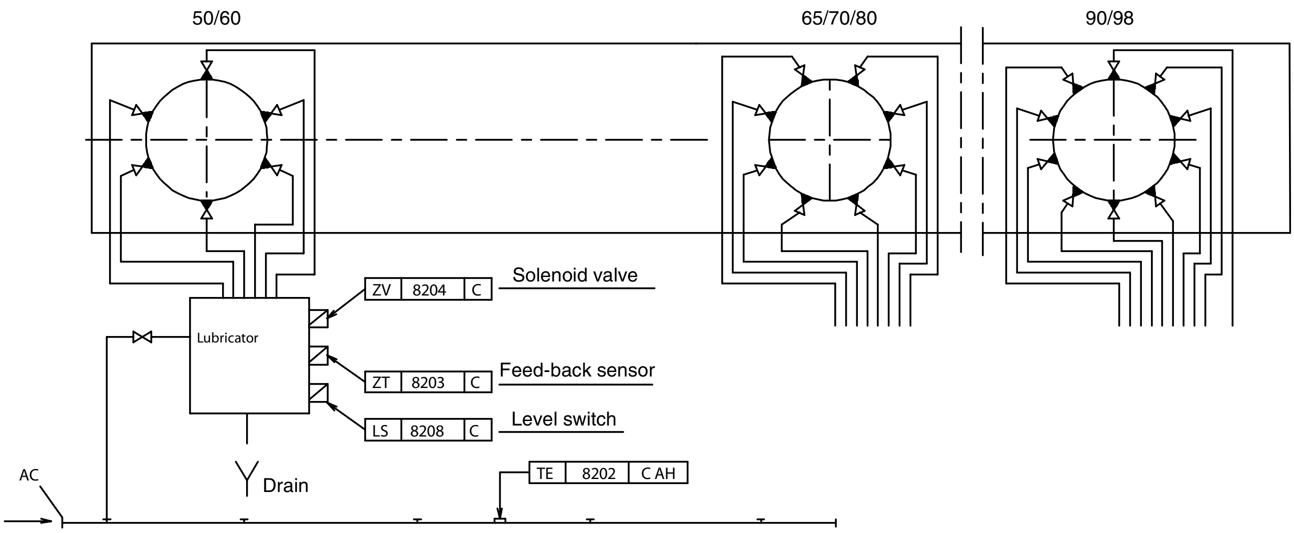
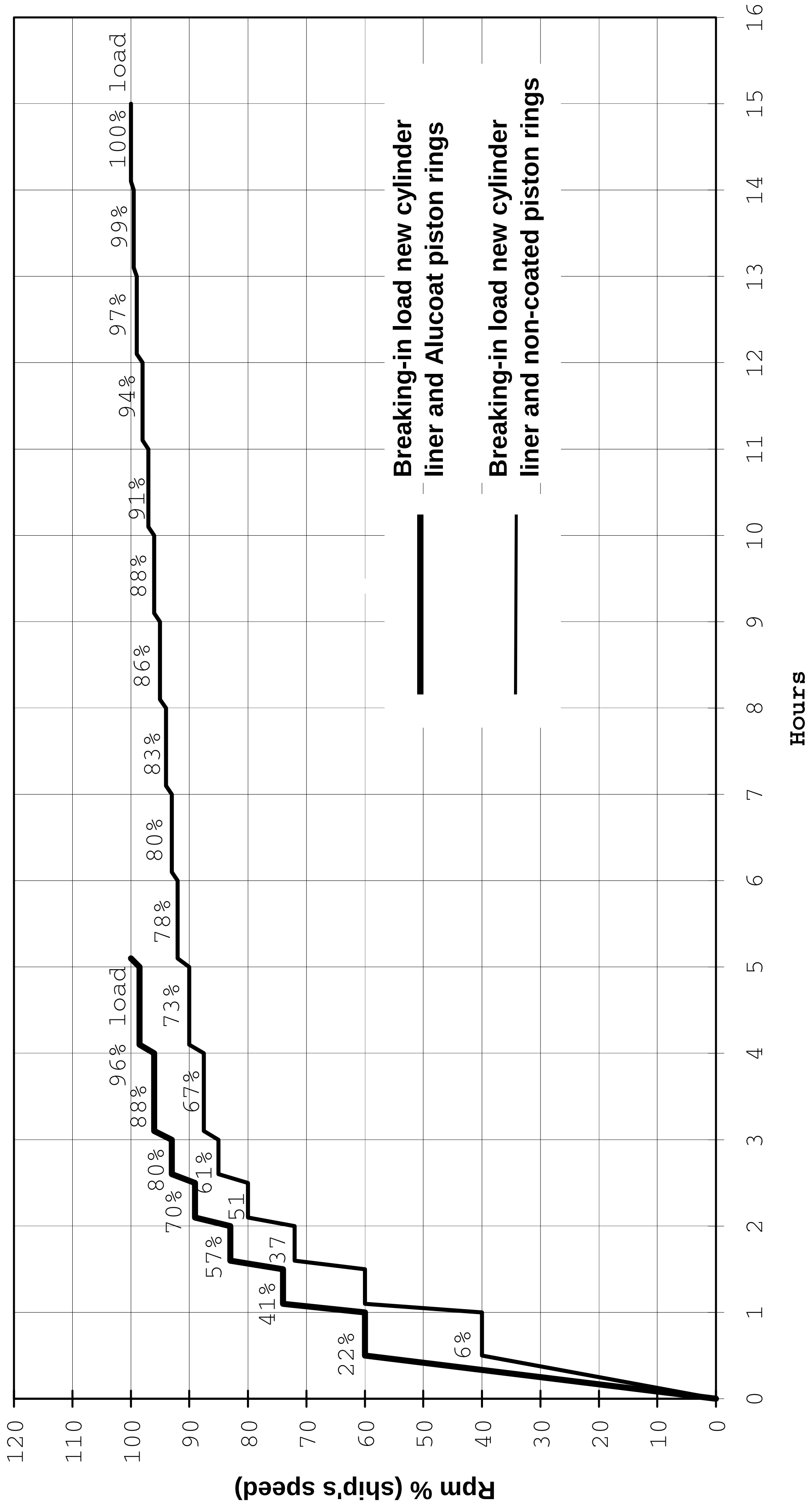
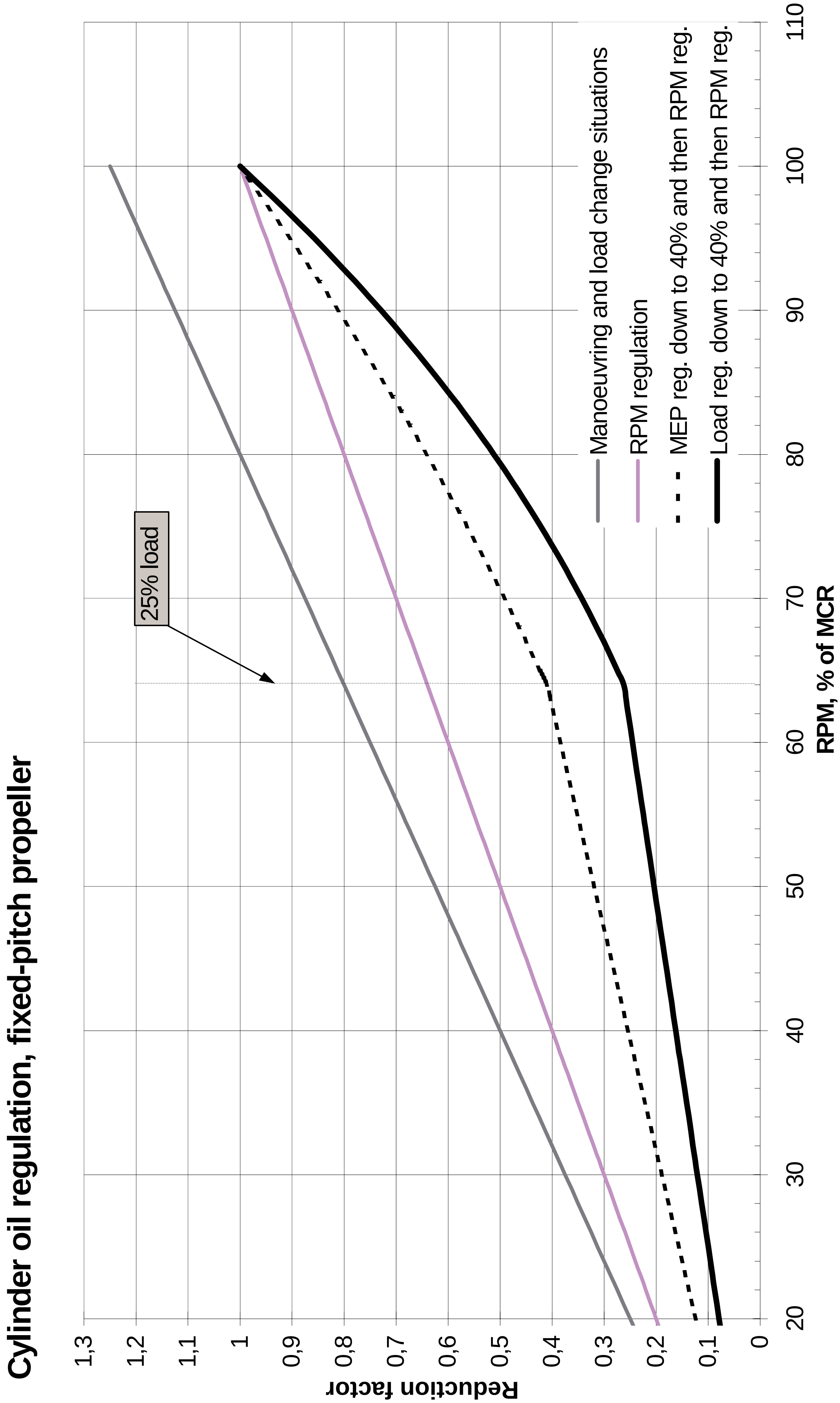

Deck
Filling pipe
Cylinder oil storage or service tank
Level alarm
LS 8212 AL
Min. 3000mm
Heater with set point of 40°C
TI
Small box for heater element
Insulation
Min. 2000mm
AC

Fig. 2


50/60
65/70/80
90/98
ZV 8204 C
Solenoid valve
Lubricator
ZT 8203 C
Feed-back sensor
LS 8208 C
Level switch
TE 8202 C AH
AC
Drain

Breaking-in load programme




Cylinder oil regulation, fixed-pitch propeller
Reduction factor
1,3
1,2
1,1
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
20
30
40
50
60
70
80
90
100
110
RPM, % of MCR
25% load
Manoeuvring and load change situations
RPM regulation
MEP reg. down to 40% and then RPM reg.
Load reg. down to 40% and then RPM reg.

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708-04 Maintenance of the Circulating Oil

708-05 Turbocharger Lubrication

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708-08 Hydraulic System for ME Engines

PLATES

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1. General Bearing Requirements and Criteria

Bearings are vital engine components; therefore, the correct bearing design and the proper choice of bearing metal is necessary for reliable engine performance.

Bearing design criteria depend on the bearing type and, in general, on:

a. Bearing load
   - Static
   - Dynamic

b. Bearing load direction

c. Journal/housing movement

d. Revolutions

e. Cooling used.

The compactness of engines and the engine ratings influence the magnitude of the specific load on the bearing and make the correct choice of bearing metals, production quality and, in certain bearings, the application of overlayer necessary. *(See Item 3., 'Overlayers').*

Scraping of the bearing surfaces is not advisable, except in those repair situations mentioned in Items 7.7 and 7.10. It is strongly recommended to contact MAN B&W Diesel for advice before starting any repairs, as incorrect scraping has often proved to have an adverse effect on the sliding properties of the bearing, and has resulted in damage.

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 loading capacity of this material is higher than tin based white metals for the same working temperature; this is due to the ideal combination of tin and aluminium, where tin gives the good embedability and sliding properties, while the aluminium mesh functions as an effective load absorber.

3. Overlayers

An overlayer is a thin galvanic coating of mainly lead (Pb) 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 embeddability and conformity between the bearing sliding surface and the pin surface geometry. Overlayer is mainly used in XH-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 an effective dry lubricant when new bearings are installed and when the crankshaft is turned.

5. Bearing Design *(Plates 70801, 70802, 70803, 70804)*

Plain bearings for MC 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 *(Plates 70801, 70802, 70804, 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 reduces the resistance to the flow of oil towards the loaded area of the bearing *(Main bearing Plates 70801, 70802 and crankpin bearing Plate 70804).*

5.2 Bore Relief *(Plates 70801, 70802, 70804, Fig. A-A)*

The bearing sliding surface is machined at 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 (Plates 70801, 70802), and crankpin bearing (Plate 70804).*

5.3 Axial Oil Grooves and Oil Wedges *(Plates 70803, 70806, Fig. A-A)*

Oil grooves and wedges have the following functions:

1. To enance the oil distribution over the load carrying surfaces. (The tapered areas give improved oil inlet conditions).
2. Especially in the case of *crosshead bearings (Plate 70803)* – 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 *(Plate 70801)*

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 clearances in this bearing design are adjusted with shims, while the side clearances are a predetermined result of the summation of the housing bore, shell wall thickness, journal tolerances, and the influence of the staybolt 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 *(Plate 70802)*

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 overlength (crush/nip) which, when the shells are mounted and tightened up, will produce the required radial pressure between the shell and the bearing housing.

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 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 stabilizing 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 re-assembly of the bearing.
   For **new** bearings the clearances should lie within the limits specified in the maintenance manual *(see Volume II, 904 and 905).*
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 e.g. Plate 70813).*

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.

5.8 Undersize Bearings

1. <u>Crankpin bearings</u> 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 B&W Diesel.
2. The <u>main bearings</u> for the MC engine series can be of the thick or thin shell type *(see 70801, 70802)*; the information under point 1 is also valid here.
3. <u>Crosshead bearings</u> are only available as standard shells, as the reconditioning proposal for offset grinding of the pin (refer to 6.4 2.b) facilitates the use of standard shells.
   It is recommended to contact MAN B&W Diesel 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. 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’).*

6.2 Spark Erosion

Spark erosion is caused by a voltage discharge between the main bearing and journal surface.

The cause of the potential is the development of a galvanic element between the ship’s hull, sea water, and the propeller shaft/crankshaft.

The oil film acts as a dielectric. The puncture voltage 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.

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 80 mV*, which is feasible with a high efficiency earthing device. If an earthing device is installed, its effectiveness must be checked regularly. *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 B&W Diesel 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 geom-

etry and misalignment may occur after a journal grinding repair.
It is recommended to contact MAN B&W Diesel 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. The final undersize should as far as possible be selected as a half or full millimetre. This is advisable in order to simplify production and availability of undersize bearings, as for example in the following cases:

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 B&W Diesel for advice.*
2. In service, crossheads pins can be:
   a. Polished to ($D_{nominal}$ – 0.15 mm) as the *minimum* diameter.
   b. Offset to a *maximum* of 0.3 mm and ground.

   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 B&W Diesel for advice.*

7. Practical Information

7.1 Check without Opening up

Follow the check list in accordance with the programme stated in *Vol. II 'Maintenance', 904 and 905. 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.
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 crankthrow for the relevant cylinder unit to a suitable position and stop the lube oil circulating pump (it is recommended to trial the engine for ½-1 hr with the pumps off to let the oil drip off).
5. a. Check the top clearance with a feeler gauge. The change in clearances must be negligible when compared with the readings from the last inspection (overhaul). If the total increase in top 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 Vol. II: 'Maintenance', 904.*

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 item Volume II, 'Maintenance', 905.*

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 0.05 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.

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.

7.2 Open up Inspection and Overhaul *(Plates 70809)*

! *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) is 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.

   ! *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 Table 1 on Plate 70810.*

   Whether the intermediate layer is exposed can be determined if the layer is Ni (for Daido produced bearings) with a knife test, as the knife will leave only a faint or no cut mark in the intermediate layer.

2. <u>Wiping of overlayer</u> manifests itself by parts of the overlayer being smeared out. Wiping of 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. <u>Bearing metal wiping</u> 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.

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. Hard particles 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:
      - 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 the salt water content in the lube oil is higher than 1%. 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 bottom tank. Therefore, keep the internal surface, especially the "ceiling", clean.

3. Inadequate lube oil supply.

4. Misalignment.

7.5 Cracks

Crack development is a fatigue phenomenon due to increased dynamic stress levels in local areas of the 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.

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 for 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.

! *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)

! *It is strongly recommended to contact MAN B&W Diesel 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 Plate 70803*.

! *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.).*

<u>For white metal crosshead bearings,</u> the wear limit is confined to about 50% reduction of the oil wedge length, see Plate 70803. 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 B&W Diesel A/S.

7.9 Surface Roughness (journal/pin)

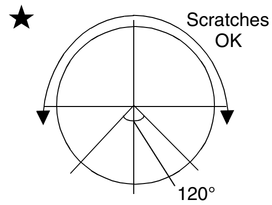
1. <u>Limits to surface roughness</u>
   The surface roughness of the journal/pin should always be within the specified limits.

   a. For main and crankpin journals: 0.4 Ra AlSn 40-layer

   - New journals — 0.8 Ra WM-layer
   - Roughness approaching (journal to be reconditioned) — 1.6 Ra WM-layer; 0.8 Ra AlSn 40-layer

   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



3. <u>Determination of the pin/journal roughness</u>
   Measure the roughness with an electronic roughness tester, or

   Evaluate the roughness with a Ruko tester, by comparing the surface of the pin/journal with the specimens on the Ruko tester. When performing this test, the pin surface and the Ruko tester 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 Ruko specimens to compare and determine the roughness level.

7.10 Repairs of Bearings on the Spot

❗ *It is recommended to contact MAN B&W Diesel 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 overlay. This is occasionally seen when inspecting newly installed bearings and is remedied by relieving these areas with a straight edge or another suitable 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.

   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.

   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

1. 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.

   ! 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* 0.05 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 the spot.

   a. Polishing with microfinishing film
      The polishing process is carried out with a "microfinishing film", e.g. 3M aluminium oxide (30 micron and 15 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 ashore.

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.

b. Braided hemp rope method
This method is executed with a braided hemp rope and *jeweller's rouge.*

Before the rope is applied all frontending 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.

2. Journals (Main and crankpin journals)

a. 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.

b. 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 B&W Diesel for advice before such a repair is carried out. But as temporary repair the 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 B&W Diesel, we recommend to follow the guidelines for inspection, which are stated in *Plates 70809 – 70814. See the example of an Inspection Record on Plate 70813.*

8. Crosshead Bearing Assembly *(See Vol. III, 'Components', Plate 90401)*

8.1 Bearing Type

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 overlayer coating.

See also Item 3, ‘Overlayers’. The upper shell is a bimetal shell, as it does not have the overlayer 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 overlayer (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 MC engine series can be equipped with “Thick shell bearings” *(Item 5.5)* or “Thin shell bearings” *(Item 5.4)*.

The bearing type, i.e. “thick shell” or “thin shell” determines the main bearing housing assembly described below *(see table of installed bearing types, Plate 70801, and housing assemblies, Plate 70805).*

9.1 The Thick Shell Bearing Assembly *(Plate 70805, 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 Plate 70801.*
2. the bearing bore is furnished with a *bore relief (Item 5.2)* at the mating faces of the upper and lower shell, *see Plate 70801.*

9.2 The Thin Shell (Insert Bearing) Bearing Assembly *(Plate 70805, Fig. 2)*

This is 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 pretensioned, will ensure a positive locking of the cap in the bedplate.

The lower shell is positioned by means of screws (Pos. 3). 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 Vol. II, Maintenance, 905.*

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 Vol. III, 'Components', Plate 90401)*

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 *(Plate 70806)*

(See also Vol. III, 'Components', Plate 90401)

1. 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 crosshead 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', Plate 70806).*

   For inspection of guide shoes and guide strips, *see Item 7.1, 7.3.3 and 7.4.1 a) and b) and Vol. II, 'Maintenance', 904.*

12. Thrust Bearing Assembly *(Plate 70807)*

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 Vol. II, 'Maintenance', 905-3.*

13. Check of Bearings before Installation *(Plate 70824)*

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 *Plate 70824, Fig. 1*.

Measure the crown thickness, with a ball micrometer 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 Plates 70809 – 70814.*

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

The lower main bearing shells should be so positioned, that they under the different conditions (hot or cold engine) in the best possible way keep the main bearing journals centred in a straight line, in which also bearings for the generator shaft are centred.

Deviations from this centre line, will cause the crankshaft to bend and for those bearings situated too high the load will be increased

2. Alignment of Main Bearings

See Plates 70816 and 70817

The bearing alignment can be checked by *deffection 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 Plate 70816

As the alignment is infl uenced 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 lub. oil temperatures in *Plate 70816.*

<u>Procedure</u>
Turn the crankpin for the cylinder concerned to Pos. B1, *see Fig. 2, Plate 70816.* Place a dial gauge axially in the crank throw, opposite the crankpin, and at the correctdistance from the centre, as illustrated in Fig. 1. The correct mounting position is marked with punch marks on the crankthrow. Set the dial gauge to "Zero".

Make the deflection readings at the positions indicated in Fig. 2.

"Closing" of the crankthrow (compression of the gauge) is regarded as negative and *"Opening"* of the crankthrow (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 Plate 70817 and Testbed Report

The results of the deflection measurements *(see Plate 70816, Fig. 5)* should be evaluated with the commisioning test measurements (recorded by the engine builder in the commisioning test report on site). If re-alignment 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 *Plate 70817.*

! *The values shown on Plate 70817 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 Plate 70817

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.

2.6 Shafting Alignment, Bearing Load, "Jack-up" Test

This can be checked by measuring the load at:

- the main bearings near to the generator
- the intermediate shaft bearings (plummer blocks)
- in the 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.

1. Circulating Oil (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/detergency properties.

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 B&W diesel engine installation(s).

Company	Circulating oil SAE 30, TBN 5-10
Elf-Lub	Atlanta Marine D3005
BP	Energol OE-HT30
Castrol	Marine CDX 30
Chevron	Veritas 800 Marine
Exxon	EXXMAR XA
Fina	Fina Alcano 308
Mobil	Mobilgard 300
Shell	Melina 30/30S
Texaco	Doro AR 30

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 B&W Diesel A/S, Copenhagen.

2. Circulating Oil System *(Plates 70817 and 70818)*

Pump (4) draws the oil from the bottom tank and forces it through the lub. oil cooler (5), the filter (6), (with an absolute fineness of minimum 50 μm (0.05 mm), corresponding to a nominal fineness of approx. 30 μm at a retaining rate of 90%) and thereafter delivers it to the engine via two flanges: U and R.

U. 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.

R1. The remaining oil goes to lubrication of the main bearings, thrust bearing and turbocharger if the system oil and camshaft oil are separate systems

R2. Common system oil system.

The relative amounts of oil flowing to the piston cooling manifold, and to the main bearings, are regulated by the butterfly valve (7), or an orifice plate. The oil distribution inside the engine is shown on *Plate 70818.*
Circulating Oil Pressure: *See Chapter 701.*

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 Section 701-02.

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 Plate 70311, ‘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 lub. oil pressure falls below the pressures stated in *Chapter 701*, 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 Plate 70311, ‘Sequence Diagram’.*

Find and remedy the cause of the pressure drop.

Check for traces of melted white metal in the crankcase and oil pan.
See also Section 702-01.

“Feel over” 15-30 minutes after starting, again one hour later, and finally also after reaching full load *(see also Section 703-02).*

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 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 Lub. Oil System

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, lub. oil centrifuges and the bottom tank layout.

Cleaning is carried out by using the lub. 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) (MAN B&W , MET)
e. The axial vibration damper
f. The torsional vibration damper (if installed)
g. The moment compensators (if installed)

See also Plates 70821, 70822.

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.

$$R_e = \frac{V \times D}{V} \times 1000, \text{ where}$$

R_e = Reynold number
V = Average flow velocity (m/s)
v = 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 cm^2, and made from 0.050 mm filter gauze). Proposals for checkbag housings are shown on *Plate 70822*.

To ensure cleanliness of the oil system after the filter, two bags are placed in the system, one at the end of the main lub. oil line for the telescopic pipes, and one at the end of the main lub. 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, whereafter 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 lub. oil is checked by particle counting, in order to find particle concentration, size and type of impurities. When using particle counting, the flushing is acceptable when the cleanliness level equals ISO 4406 xx/19/15 or better.

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.

! *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 lub. 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 Plate 70823*, 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, and ship movements in heavy seas.

Important: When only a visual inspection of the lub. 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 lub. 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 lub. 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 *Plate 70818*.

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 (Peq) 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.

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 illustrates that the amount of pentane insolubles removed will decrease with rising Q.

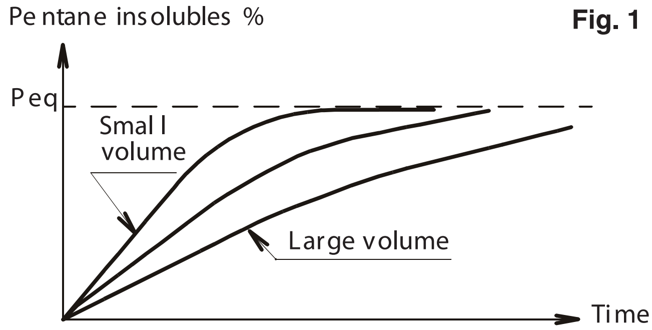


Fig. 1

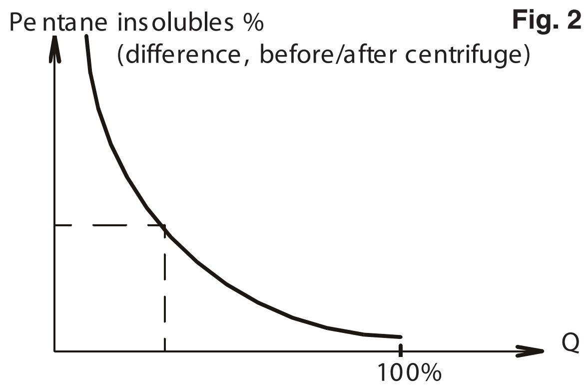


Fig. 2

It can be seen that:

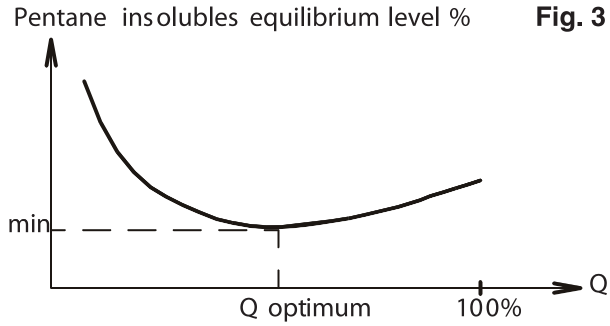
a. At low Q, only a small portion of the oil is passing the centrifuge/hour, but is being cleaned effectively.

b. 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)*.

Fig. 3



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 insol-ubles - will, in a detergent oil, be present as smaller, but more numerous particles than in a straight oil.

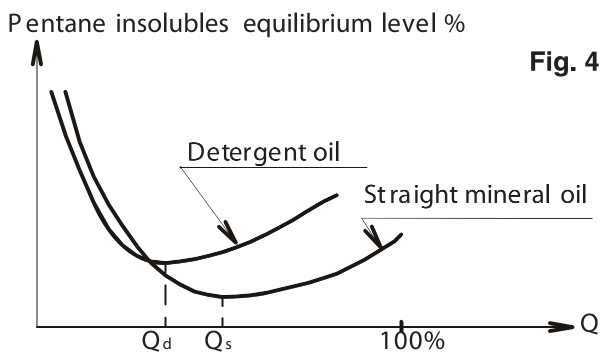
Furthermore, the particles in the detergent oil will be surrounded by additives, which results in a specific gravity very close to that of the oil itself, thereby hampering particle settling in the centrifuge.

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:

Fig. 4



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 *80°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.A 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.B Air Admixture

Good venting of the bottom tanks 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.C 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 702-01*, 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 (acrid 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 rods, etc. *(see e.g. Section 708-01)*.’
- tend to form tin-oxide on white metal *(see Section 708-01)*.

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

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 die-sel 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. *See also Service Letter SL02-408/KEA.*	max.+ 100% min.-30% (of initial values)
Water	Risky if TAN and SAN are high. Salt water has a higher corrosive effect than freshwater. *See previous point 4.4.*	fresh:0.2% (0.5% f. short periods) Saline: trace
Conradsen 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_6H_6) and normal pentane (C_5H_{12}) or heptane (C_7H_{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 *(Plate 70824)*

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.

Plate 70824 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, recircu-lated 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 T/C, System Details

See Plate 70828

The lub. oil system for the MAN Diesel type of turbocharger is shown separately on *Plate 70828*.

The system is supplied from the main lub. oil system.
See also Plate 70820.

The oil is discharged to the main lub. oil system. The discharge line is connected to the venting pipe, E, which leads to open air.
See also Plate 70818.

In case of failing lub. oil supply from the main lub. 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 lub. oil until the rotor is at a standstill, or until the lub.oil supply is re-established.

2. MET T/C, System Details

The MET turborchargers are also lubricated via the main lub. oil system. *See description of turbocharger lub. oil system in Item 1 'MAN Diesel T/C, System Details'.*

3. ABB TPL T/C, System Details

The ABB TPL turbochargers are designed either with an integrated lub. oil system or with a similar system as MBD TC. Please refer to the relevant ABB TPL-instruction manual.

This chapter describes the system layout, components and operating principle of the hydraulic systems shown in Plate P70830, etc.

All position numbers are described and their intended use explained.

Also shown is a Plate 70840 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 must 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 plates P70830, 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, 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 valves (ELFI, ELVA valves or the FIVA valve, respectively) 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, the high-pressure pipes and the 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 that 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” on Plate 70318.*

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 at either 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 (10 microns on the first engines built). 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 becomes abnormally large.

2.1.2 Electrically Driven Start-up or Start-up/Back-up Pumps

The Hydraulic power supply is available in two 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, but the electrically driven start-up pumps have a capacity sufficient to give at least 15% engine power (Back-up power or also named “Combined”). The electric power consumption should be taken into consideration in the specification of the auxiliary machinery capacity.

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.

After 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.

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, 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 and the same direction of flow. This is necessary as most engines are reversible. On reversing of the engine, the displacement control of the ECS must alter the swash plate to the opposite direction of flow.

The engine driven pumps are the engine’s main hydraulic suppliers when the engine 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 100% 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 allow a failing engine driven pump, which pumps in the wrong direction, to draw from the suction 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 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 doublewalled piping or hoses on some newer engines. Double piping is also used for highpressure pipes between the individual HCU units. The inner and outer bores of the double piping are connected by separate lines in the distribution blocks (not shown on the diagram).

The space between the inner and outer pipes is connected to a leak line, in which a restriction and a pressure controlled valve are installed. In the event of a small leak from the inner pipe, the flow transmitter (leak indicator) (pos. 355) will release an alarm. In the event of a severe leak, the restriction causes a pressure loss leading to increased pressure in the leak line and outer pipe. This pressure increase closes the pressure controlled valve (pos. 345) and the system pressure is now contained by the outer pipe. The pressure transducer (pos. 330) issues an alarm indicating that the outer pipe is now pressurised – unrestricted service is allowed until repair is possible.

The HPS and its internal piping are all shielded by a container fitted around the HPS. This shielding is designed to contain a leak flow and lead it to the drip pan.

The piping, as described above, is designed to ensure the safety of the crew, and that a single failure, e.g. a leak from the inner pipe, will not affect the operation of the engine.

On Plate 70845 the double wall pipe design of larger (80-98) ME-engines is shown.

Due to the relative movement between the pipe and the flanges (large engines 80 - 98), the sealing rings *(see Fig 1. Plate 70845)* must be lubricated. This lubrication is maintained by letting a small amount of hydraulic oil seep into the outer space between the pipes. The oil amount lead to the outer pipe is matched and supplied in a rate through the orifice Pos. 347 so that the oil pressure in the space between the pipes is kept from 0-10 bar.

The orifice(s) is normally placed in the end flanges on the foremost and aftmost HCU block (depending on the engine cylinder amount). *See Plate 70845 fig. 2.*

Should the pressure (seen on the MOP) rise above 10 bar, a leak in the double wall pipe might have appeared. As described above the line break valve Pos. 345 will close and normal running is continued. The line break valve is normally situated on the accumulator block. *See Plate 70845 Fig. 3*

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 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 the engine down.

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 by its name indicates, 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 a HCU during overhaul.

WARNING !

To protect the accumulators from unnecessary stresses (fast accelleration of the membrane) and oil jets, the valve Pos. 420 must not be opened at pressurised oil system.

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 the oil push rod with its supply. 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.

After the injection has 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 to keep the system heated during engine standstill.

6. Functional description of the Throttle Valve on the Fuel Oil Pressure Booster

As seen in the drawing on plate 70841, 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 (FIVA valve activated) the oil pressure in the space underneath the Fuel Oil Pressure Booster will raise significantly to lift the piston. At the same time, the highpressure 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 twostage 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 by 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 build (2003 -2005).

Pos. 107
Mini-mess valve installed by the filter unit outlet (for connection of portable pressure gauge).

Pos. 108
Mini-mess valve installed by the system inlet. (for connection of portable pressure gauge).

Pos. 109
(Only used on the L42MC/ME engine).
Butterfly valve. Normally open. Used for shutting off the bypass valve during overhauls.

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.

<u>Pos. 120</u>
(Only used on the L42MC/ME engine).
Bypass valve. Normally closed. This valve has two main functions:

1. The main purpose of this valve is to secure oil supply to the highpressure pumps. When/if the Automatic back flushing filter becomes heavily contaminated, the oil pressure on the outlet side of the filter and bypass valve will drop.

   The lower oil pressure on the outlet side is transmitted via a pipe connection to the membrane on the valve, the valve will open and lead the oil past the filter unit to the high- pressure pumps (the bypass valve starts to open when the oil pressure drops below 0.8 bar).

   Simultaneously, a proximity switch, measuring on the bypass valve spring, will measure the spring movement and raise an alarm on the MOP panel. To rectify this alarm (as specified in the alarm field under suggested action) the engineer must open the manual filter (valve 103) and, thereby, secure filtration of the oil running to the pumps.

2. If for some reason the engine load is raised rapidly, e.g. fast acceleration ordered from the manoeuvring handle on the bridge, the consumption of oil is suddenly increased. This could cause the pressure on the outlet side of the filter to drop and the bypass valve will, as described above, open at 0.8 bar.

<u>Pos. 121</u>
(Only used on the L42MC/ME engine).
Proximity switch (function described in Pos. 120).

<u>Pos. 130</u>
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.

<u>Pos. 131</u>
An orifice, ø 0.5 mm, for above pressure transducer (130) is installed to protect the transducer against pulsations and ensure a steady amount of oil to the transducer.

<u>Pos. 155</u>
Mini-mess valve installed in the low-pressure line (for connection of portable pressure gauge).

<u>Pos. 201</u>
Highpressure Axial Piston Pumps. Type Rexroth A4VSO. Driven by either a gear or electric motors.

<u>Pos. 202</u>
Mini-mess valve installed in the lowpressure inlet before the pump (for connection of portable pressure gauge).

Pos. 203
Mini-mess valve installed in the highpressure pump outlet (for mounting of portable pressure gauge).

Pos. 204
Line break valve. Normally open. The valve protects the system in case of pilotline (Sp) failure.

Pos. 205
Safety coupling (el-motor, gear – Rexroth pump).

Pos. 206
El-motor (driving the Rexroth pump).

Pos. 210
Electronically controlled proportional valve situated on the highpressure 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 el-driven pumps).

Pos. 220
A positional transducer situated on the pump. The transducer sends an electrical 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 highpressure pump suction side. Normally open.

Pos. 235
Check valve.

Pos. 236
Check valve.

Pos. 240
Orifice.

Pos. 241
Orifice.

Pos. 276
Mini-mess valve installed on the start-up pump pressure side.

Pos. 277
Start-up pump.

Pos. 277a
Throttle valve.

Normally Open. This valve is 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 175 bar) to pressure relief valve 277c (adjusted to 220 bar). The electrically driven pumps are all limited mechanically on all engines (to 50% of maximum pump displacement). In the failure situations described above the mechanically stroke limitation have to be cancelled. 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 for this special running of your specific engine.

Pos. 277b
Pressure relief valve.

Pos. 277c
Pressure relief valve.

Pos. 278
Electric motor.

Pos. 279
Coupling house.

Pos. 280
Coupling.

Pos. 280a
Coupling part.

Pos. 285
Inlet valve at start-up pump unit. Normally open.

Pos. 304
Non-return valve. The non return valve is installed on the highpressure 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, thereby violently stress and maybe destroy the pump. This is avoided when the nonreturn valve closes immediately after pressure drop at pump standstill.

Pos. 305
Nonreturn valve. The nonreturn valve (placed by the accumulator block inlet) is installed on the start-up pump pressure side to protect the pump against a 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 230 bar).

Pos. 310a
Pilot valves arrangement situated on pos.310 pressure relief valve.

Pos. 310b
Orifice.

Cyl. Bore	50	60	70	80	90	98	cm
Orifice dia.	10	12	15	18	22	28	mm

Pos. 311
Pressure relief valve. Normally closed. The pressure relief valve is mechanically adjusted to an opening pressure of 250 bar. If the oil consumption drops, the pressure will rise, and if the pressure rises above 250 bar, the relief valve will open and lead the oil back to the main tank.

Pos. 312
Pressure relief valve. Normally closed. The pressure relief valve is mechanically adjusted to an opening pressure of 175 bars. Should the oil consumption suddenly fall, the pressure will rise and should the pressure rise to more than 250 bar the relief valve will open and lead the oil back to the main tank.

Pos. 315
Ball valve. Normally closed. Used when the system needs to be drained off during repairs etc.

Pos. 316
Ball valve. Normally closed. This valve is used when testing the double wall pipe for leakages, normally used during commissioning, but also after major repairs of the piping system. In the event of a leak from inner to the outer pipe that cannot be repaired immediately, ball valve pos. 316 is opened and normal running via the outer pipe is maintained.

Pos. 320
Pressure transducers. The system is supplied with three (3) transducers for redun-

dancy 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, ø 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. 330
Pressure transducer. The transducer is used for surveillance of the pressure in the double- wall pipe, in the event that the engine is running with pressure in the outer pipe due to a leakage in the inner pipe. The pressure value is shown on the MOP. Oil in the outer pipe is not a normal running situation; therefore only one (1) transducer is present.

Pos. 331
An orifice ø 0.5 mm for above pressure transducer (330), is installed to protect the transducers against pulsations and ensure a steady amount of oil to the transducer (only active in the event of oil pressure in outer pipe, see pos 330 above).

Pos. 332
Mini-mess valve installed in the outer pipewall of the double wall pipe (for connection of portable pressure gauge).

Pos. 333
Ball valve. Normally closed. This valve is used when testing the double wall pipe for leakages, normally during commissioning but also after major repairs of the pipe system.

In the event of a leak from the inner to the outer pipe that cannot be repaired immediately, ball valve pos. 333 is opened and normal running via the outer pipe is maintained.

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).

Pos. 340
Mini-mess valves installed in the main highpressure pipe (P2) for measuring the system pressure. (for connection of portable pressure gauge).

Pos. 345
Line break valve. Normally open. In the event of a leak in the inner main pipe, and the amount of oil lost is so high that the amount of oil needed for normal running

cannot be maintained, this line break valve will close. Running of the engine will be allowed without limitation.

Pos. 346
Line break valve.

Pos. 347
(Only used on large 80 - 98 ME engines).
Orifice. Lubricant connection P2 to double wall pipe sealing. ø=0.6mm.

Pos. 355
Leak indicator. In the event of a leak from the inner pipe, and the amount is so high that the small reservoir is filled, an alarm will be raised. This will not affect the running of the engine, 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 jets 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 raised (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 without interfering 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 run full, and shutdown 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 secures 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

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WARNING !

To protect the accumulators from unnecessary stresses (fast accelleration of the membrane) and oil jets, the valve Pos. 420 must not be opened at pressurised oil system.

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. 430
Double wall Pipe Detection valve. Normally open.

Pos. 431
Double wall Pipe Drain valve. Normally closed.

Pos. 435
Mini-mess valve fitted on the HCU block measuring the oil pressure in case of a possible leak (for connection of portable pressure gauge).

Pos. 440
ELFI Valve or FIVA valve. ELectronic Fuel Injection valve or Fuel Injection Valve 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.

Pos. 445
Electric Linear Motor driving the ELFI valve (proportional type).
Manufacturer: Curtis-Wright.

Pos. 450
Accumulators. Mounted on the HCU block to avoid oil pulsations in the hydraulic system and keeping the oil pressure steady at all engine loads.
Manufacturer: HYDRO LEDUC.

Pos. 455
Mini-mess valve fitted on the HCU block measuring the oil pressure at the inlet to the ELFI 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. ELectronic Exhaust Valve Activation 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 off 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. Raises 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. This is to keep the High Pressure Pipe ‘flooded’ at all times and avoid fluctuations in the oil system (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 ø1.0 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. As 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 to fast (not to mention the 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 is generating high energies 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).

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 Plate 70842, 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 the sealing ring under 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 in Plate 70843, 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 secure 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 secure 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.

1. Monitoring

The aim of monitoring engine bearings, is to avoid extensive damage to the engine, by constantly measuring e.g. the relative wear or the temperature or other. 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. Therefore, monitoring as such is an aid to the engine personel, to base the frequency with which the bearings are opened up for inspection, on actual wear or temperature or other, instead of the traditional time based checking frequency, thus prolonging the opening-up frequency. The systems described in the following are designed to monitor the engine bearings continiously using various techniques.

BWM is a security system monitoring the bearings and giving alarms or slow down depending on the severity of the damage. BWM do not prevent potential damage on the bearings but the intention is that it should prevent consequential damage to the more valuable parts such as the crankshaft and the bed-plate. BWM do not change how often the bearings must be inspected without opening up.

- WIOM (Water In Oil Monitor) is a system intended to prevent certain damage to bearings whom may be linked to to high water content in the lubricating oil.
- SLEM (Shaft-Line Earthing Monitoring) is system intended to prevent certain damage to bearings whom may be linked to spark erosion.
- BWM and BTM is therefore considered as **Engine Protection System.**
- WIOM and SLEM is therefore considered as **Bearing Protection System.**

1.1 Bearing Wear Monitoring (BWM) (for monitoring condition)

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 cross head in bottom dead centre (BDC) (see Plate 70847, principal drawing that shows x-head and BWM sensor on guideplane). 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 specification, the system delivers a relay output signal on three levels, PRE-WARNING, ALARM and SLOW-DOWN in the case of abnormal wear of one or more bearings.

The pre warning signal is not connected to the alarm or safety system. This means that if the BWM system goes into pre warning state, this is shown locally with a yellow LED on each BWM junction box (the way of pre-warning may vary, depending on manufacturer´s design of system). The pre warning state is not a critical state, nonetheless the yellow LED, will draw the attention to the fact that one or more of the cranktrain bearings is/are showing signs of abnormal wear beyond the pre warning limit. If a pre warning signal occours MAN Diesel recommends that the cranktrain bearings in question are checked at next port of call or earliest convinient.

The alarm and slow-down signals are connected to the alarm and safety system. If alarm state is reached, MAN Diesel recommends that an inspection of the cranktrain bearings in question is carried out as soon as possible, given that the conditions for the ship as such is not compromised. Also refer to Guidance Value Automation 701-02.

! *In the case where the BWM system has given a pre warning or an alarm, pointing out that one or more cranktrain bearings are showing wear beyond the limits stated in Guidance Value Automation, refer to the Procedure for the respective bearings in order to take further action on the matter.*

1.2 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. In case of 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 slow down command.

! *In the case where the BTM system has given an alarm, pointing out that one* *or more cranktrain bearings are showing a temperature beyond the alarm limits, refer to the Procedure for the respective bearings in order to take further action on the matter.*

1.3 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 continiously monitoring eventual water contamination of the lubricating oil. For this purpose a Water In Oil Monitoring system is implemented in the engine lub oil system, continiously meassuring 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 alarmsystem.

! *In the case where the WIOM system has given an alarm, pointing out that the humidity of the lubricating oil has risen above the alarm limit, refer to the respective Procedure in order to take further action on the matter.*

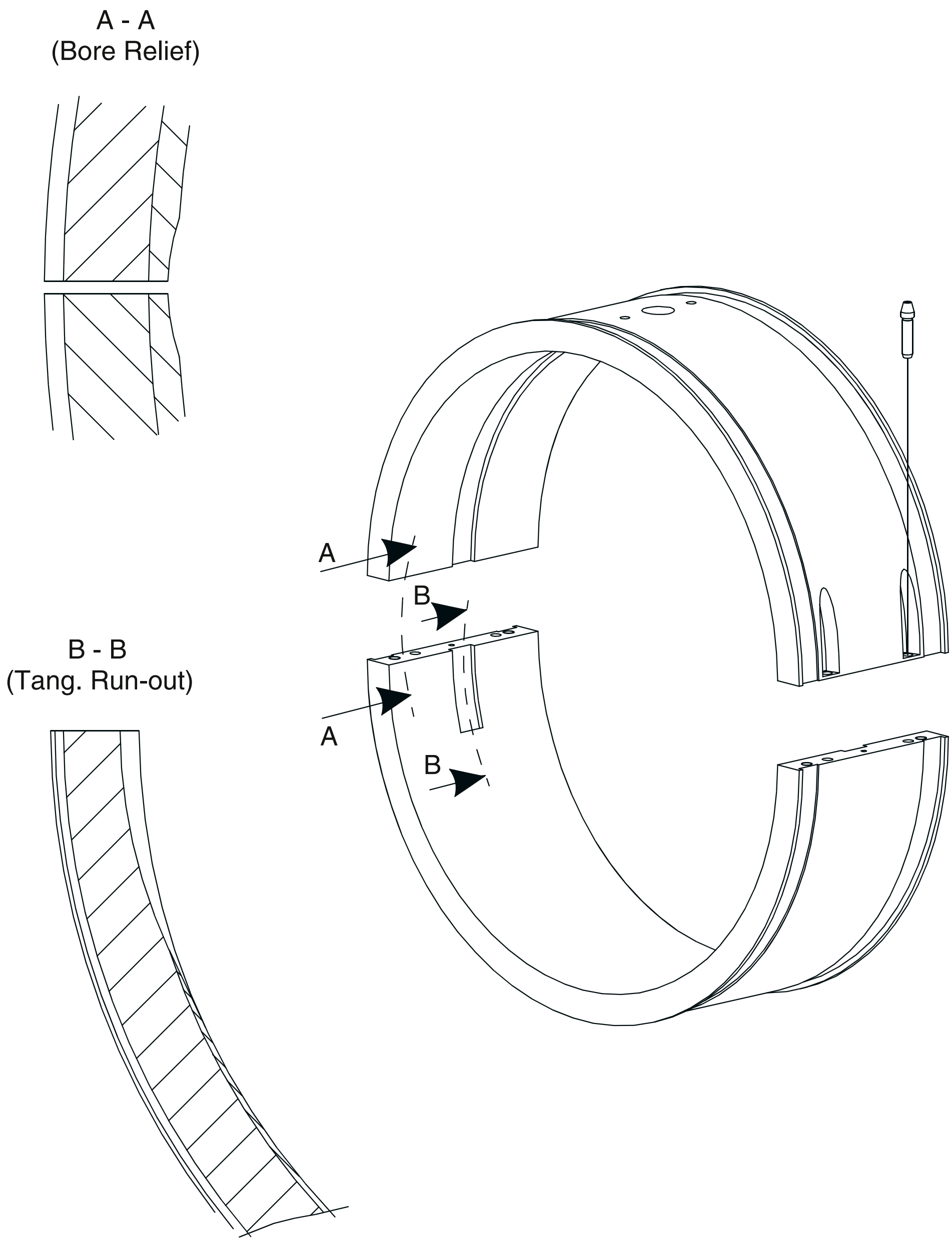
1.4 Propeller Shaft Earthing Device

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 a rest, where a metal to metal contact is made between the shaft and the stern tube liners, or main engine bearings and journals.

However, whilst 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 Plate 70848. 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 brushgear and/or sliprings. The system is connected to the alarm system.



Engine types with thick shell main bearing assemblies:

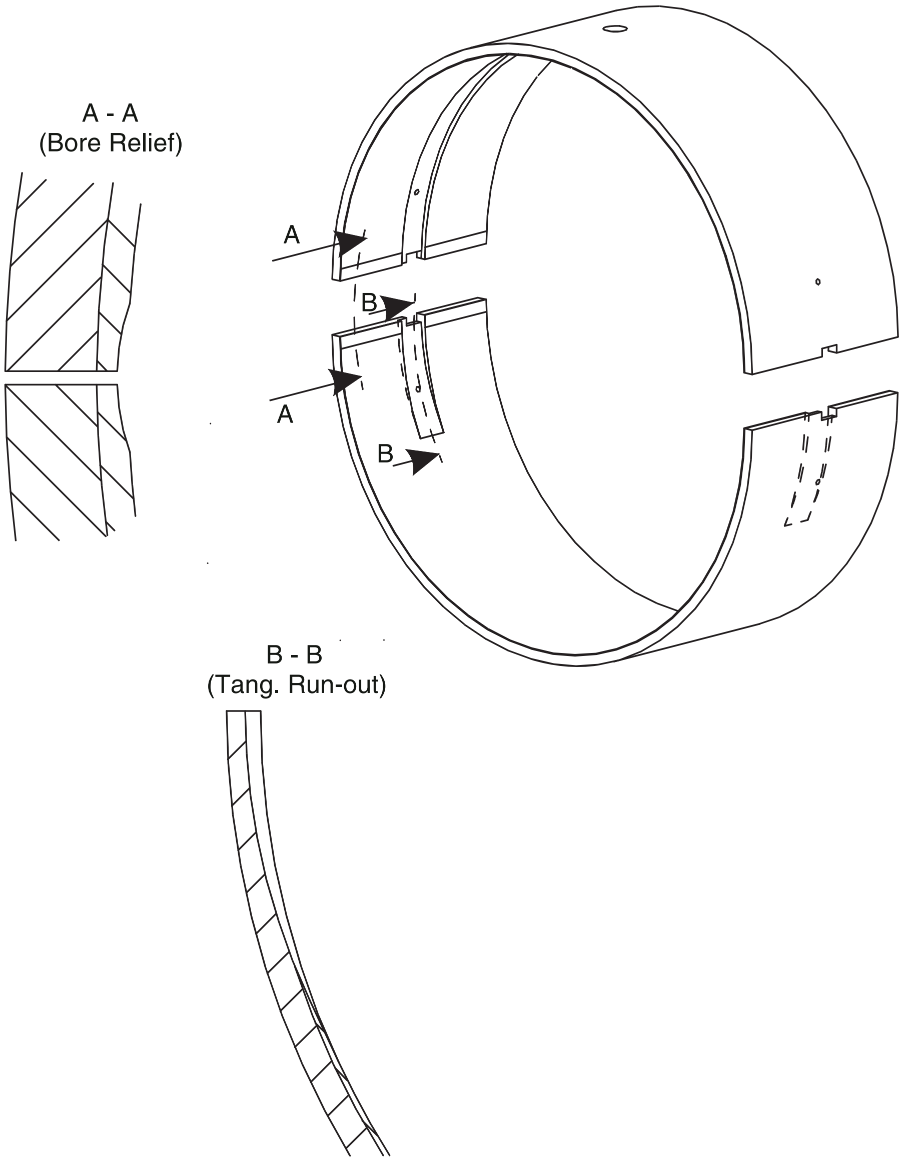
S/K/L50ME/MC

S/K/L60ME/MC

S/K/L70ME/MC

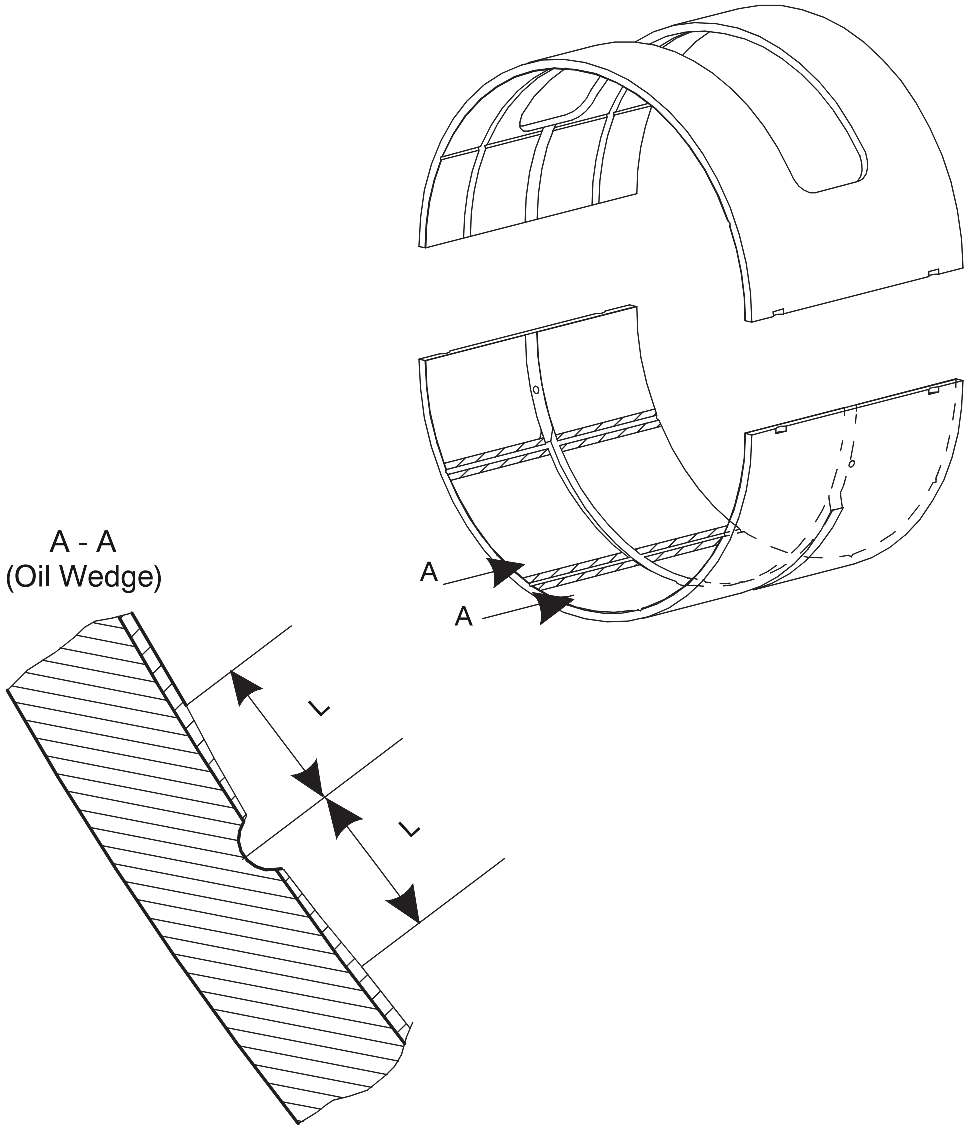
S/K/L80ME/MC

K/L90ME/MC



Engine types with thin shell main bearing assemblies:

S26MC
S35MC
L35MC
S42MC
S46MC-C
S50ME-C/MC-C
S60ME-C/MC-C
S70ME-C/MC-C
S80ME-C/MC-C
S90ME-C/MC-C
K90-98ME-C/MC-C



Extent of oil wedges in crosshead bearing lower shell:

Engine type:	Extent L (mm)*
S26MC	For actual values, refer to Vol II, procedure M90401
S/L35MC	
S42MC	
S46MC-C	
S/K/L50ME/MC	
S50ME-C/MC-C	
S/K/L60ME/MC	
S/K/L70ME/MC	
S/K/L80ME/MC	
K80ME-C/MC-C	
K/L90ME/MC	
K90-98ME-C/MC-C	

‘) On each side of the axial oil groove

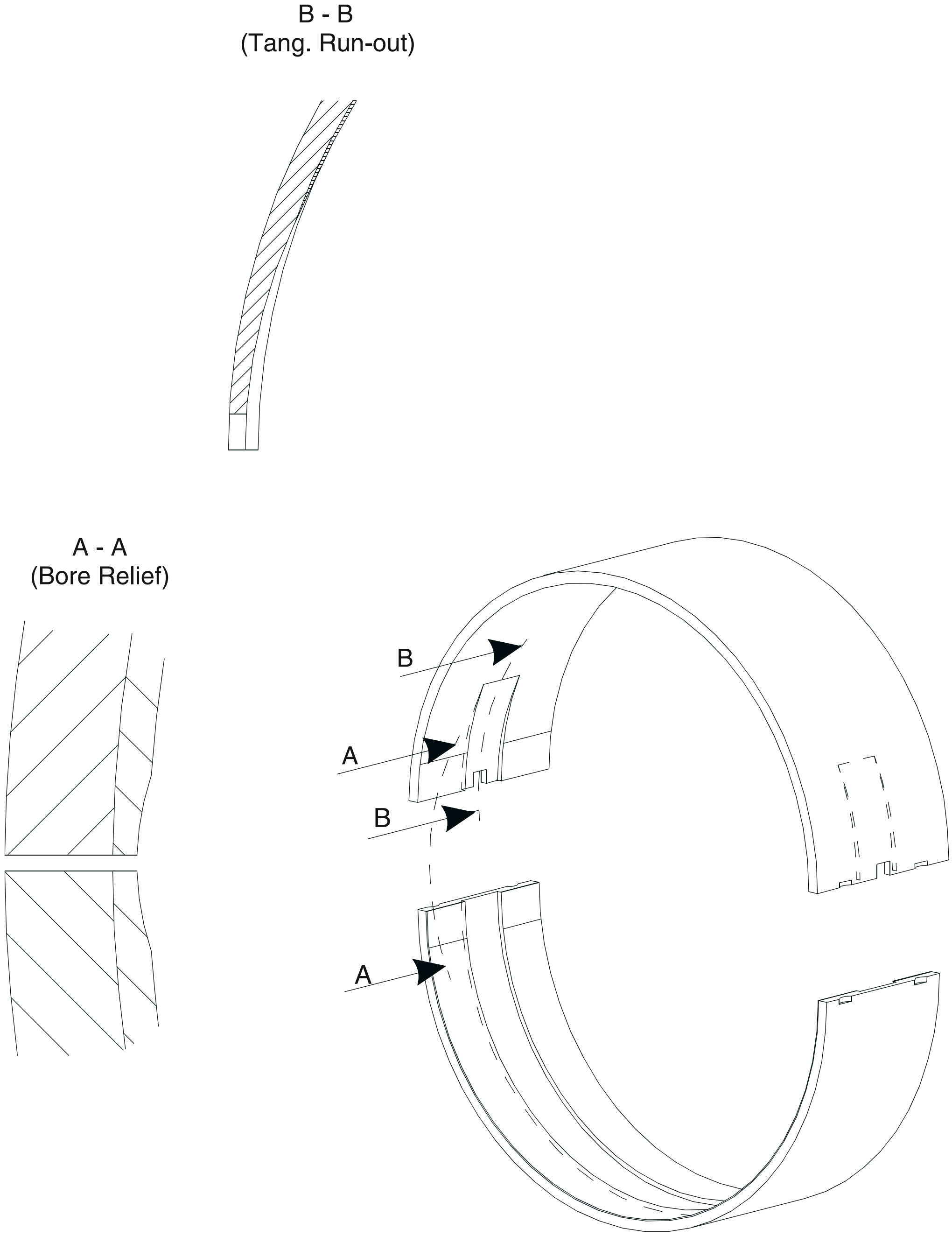
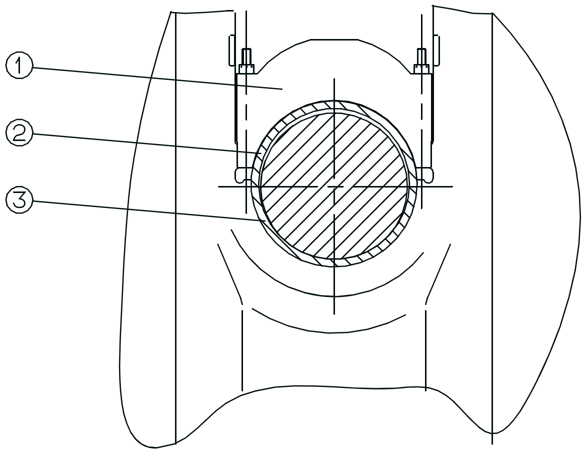

B - B
(Tang. Run-out)
A - A
(Bore Relief)
B
A
B
A

Fig. 1 Thick Shell



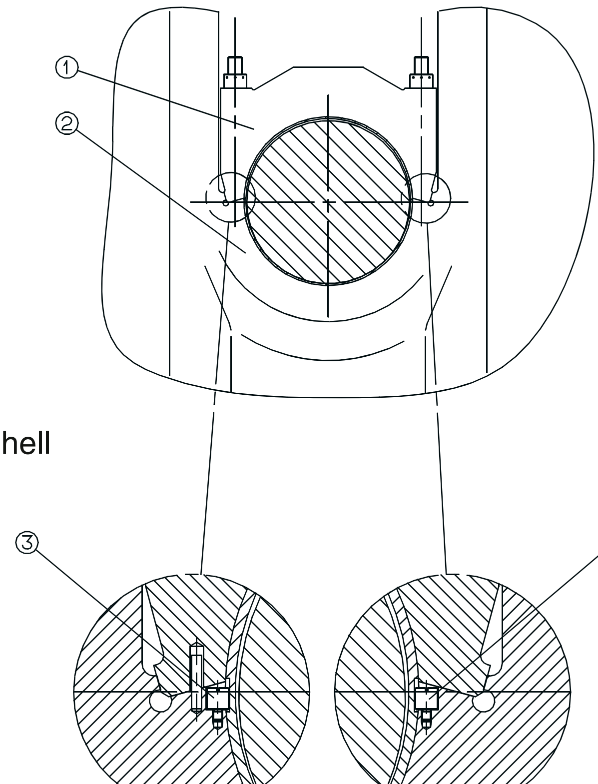
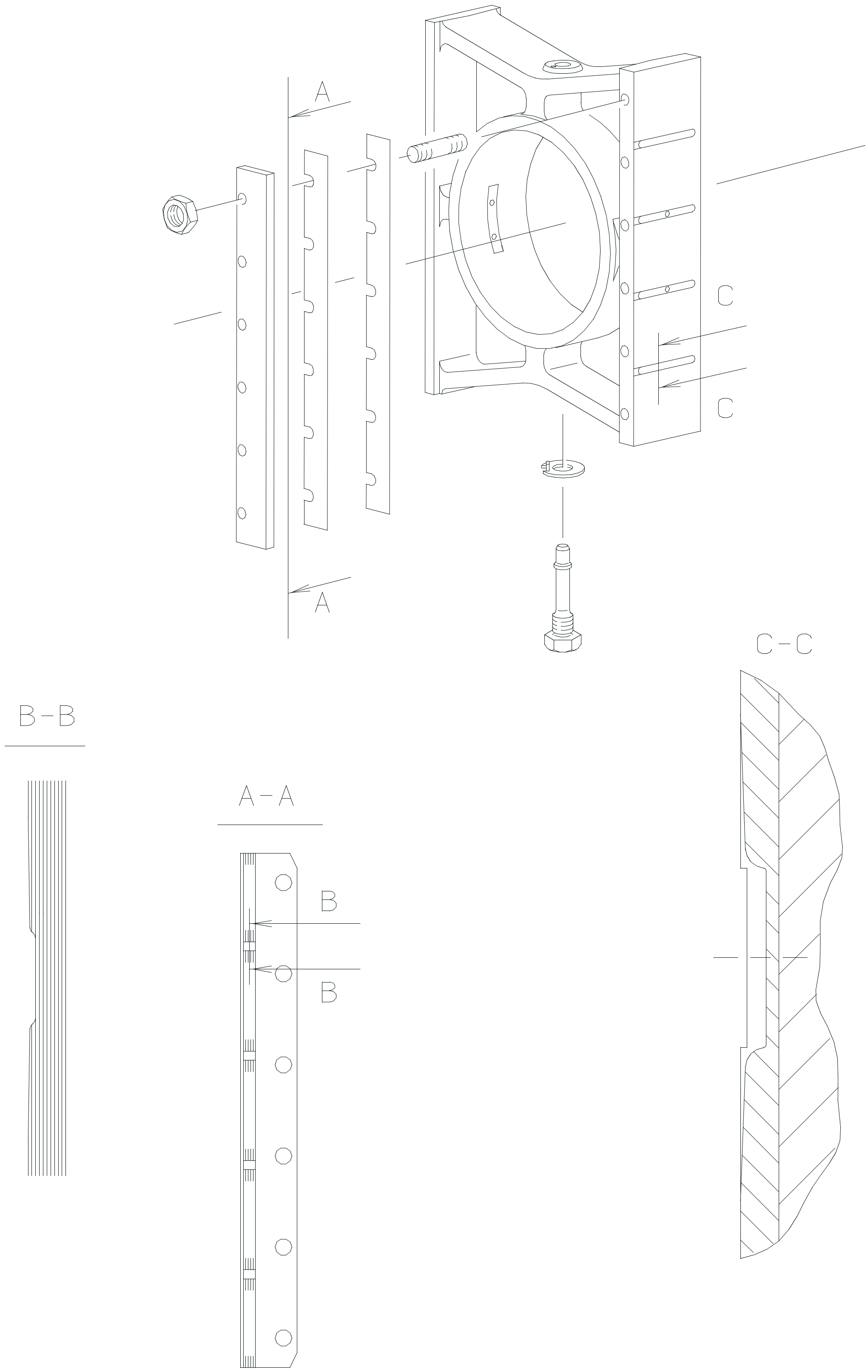
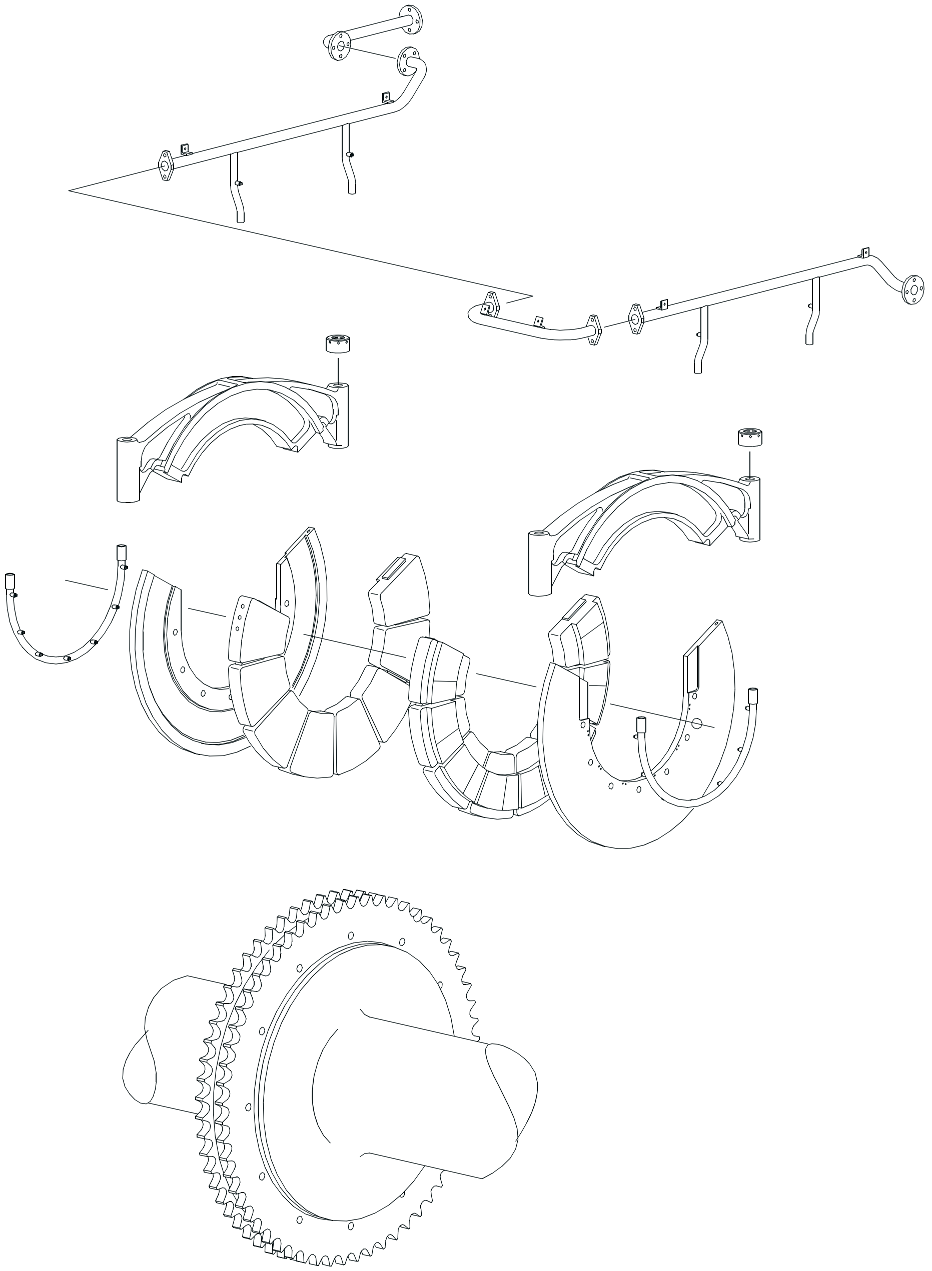


Fig. 2 Thin Shell


A
A
C
C
C-C
B-B
A-A
B
B



References to Volume II, 'Maintenance'		
Bearing Type	**Inspection without Opening-up**	**Open-up Inspection and Overhaul**
Main bearing	905	905
Crankpin bearing	904	904
Crosshead bearing	904	904
Guide shoes	904	–
Crosshead guides	904	–
Thrust bearing	–	905
Camshaft bearing (only MC)	906	906

Recording of Observations

Use the Inspection Sheet, Plate 70814. For help, refer to example, Plate 70813.

A. Inspection without Opening-up

State the following information:

Date / Signature / Engine running hours / Type of inspection / Bearing type (Plate 70809, Table 1) / Bearing number / Observation (Plate 70812, Table 3)/ Remarks / Clearances.

B. Open-up Inspection and Overhaul

State the following information:

Date / Signature / Engine running hours / Type of inspection / Bearing type (Plate 70809, Table 1) / Bearing number / Manufacturer's logo / Damage to (Plate 70809, Table 2) / Observation (Plate 70812, Table 4) / Site and extent of damage (Plate 70810-70811) * / Remarks / Clearances / Hydraulic opening pressure / Roughness.

* The site and extent of the damage is determined by:

1. The approx. 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 aft 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:

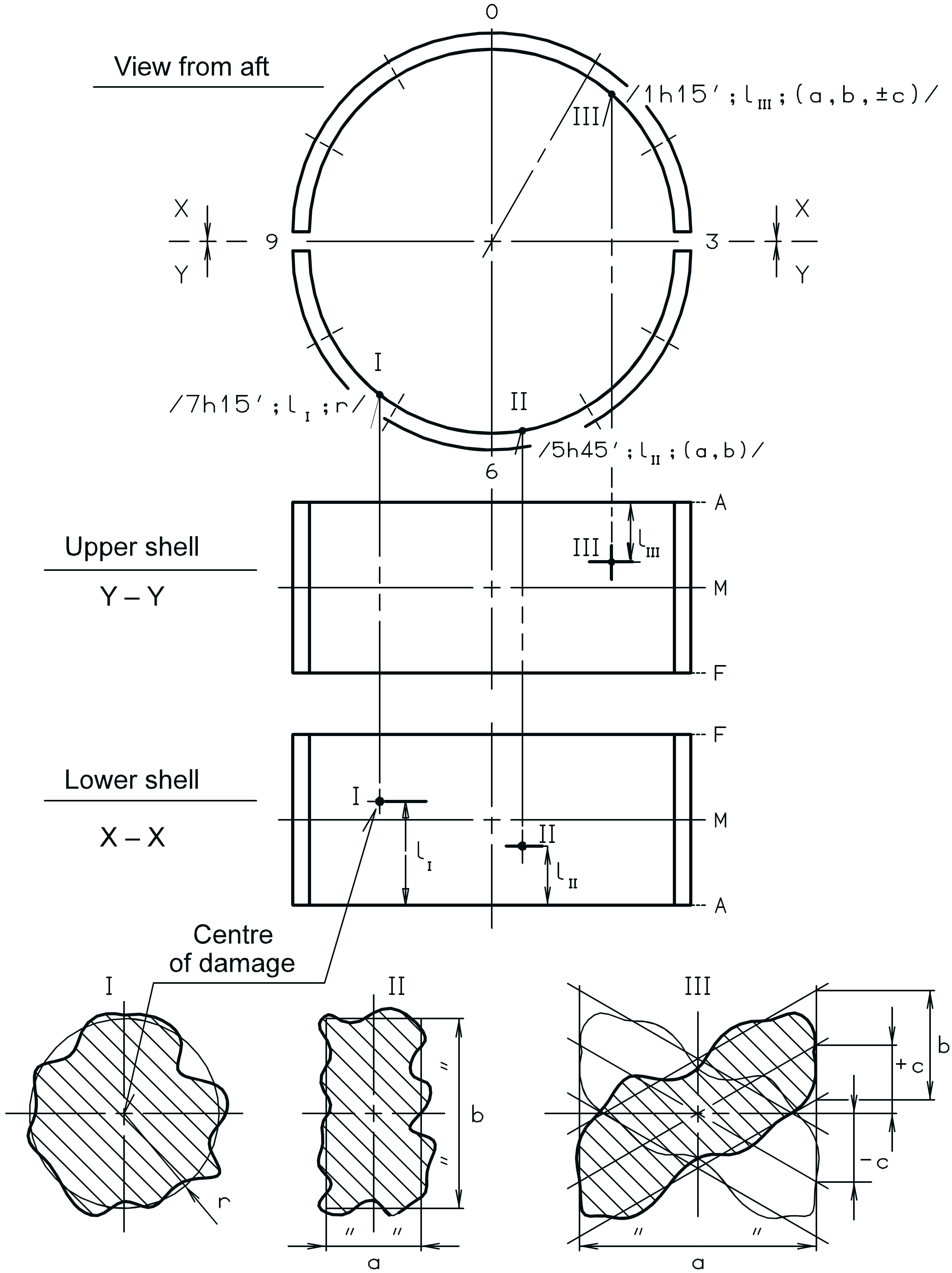
Bearing Type	
Main bearing	MB
Crankpin Bearing	CRB
Crosshead Bearing	CHB
Guide Shoes	GS
Crosshead Guides	CG
Thrust Bearing	TB
Camshaft Bearing (only MC)	CSB

Table 2:

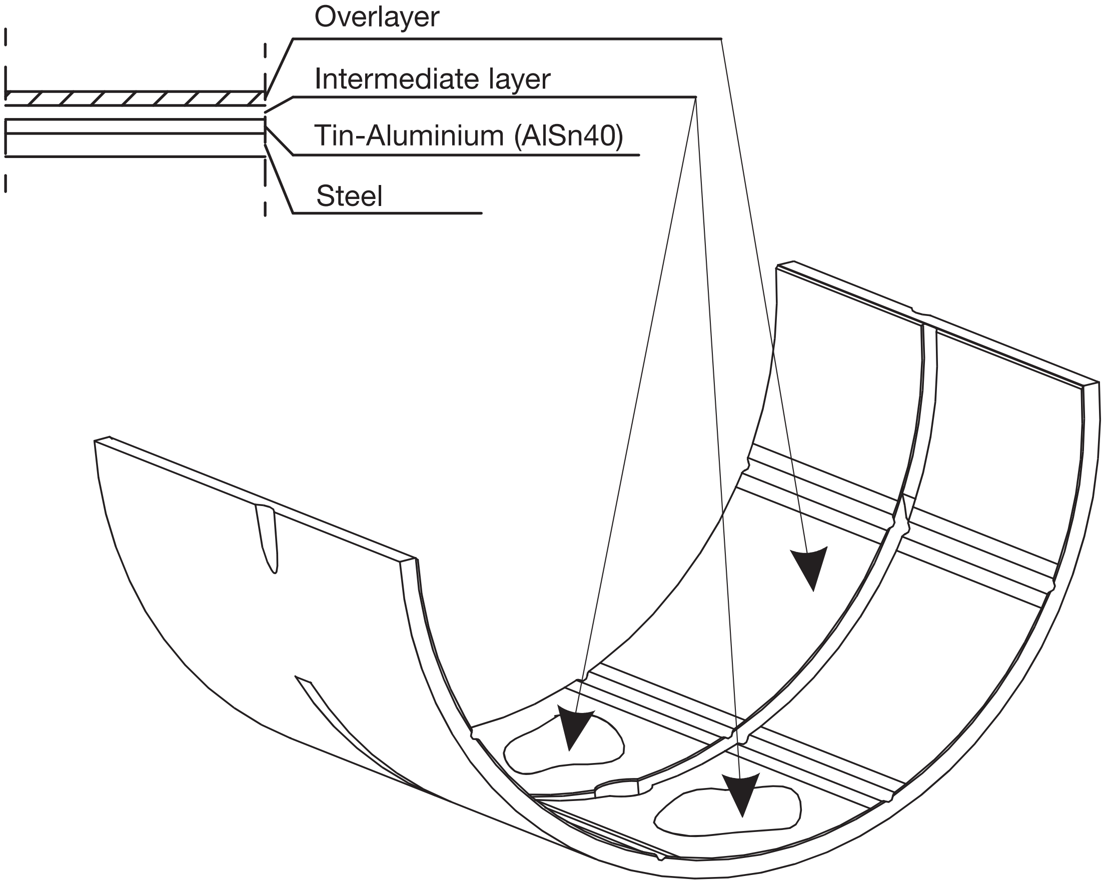
Damage	
Overlayer	OL
White Metal	WM
Journal	J
Pin	P
Transitions:	
Oil Wedge	OW
Bore Relief	BR
Tang. Run-out	TR
Back of Shell	BS

Inspection of bearings

(Location of damage and size)



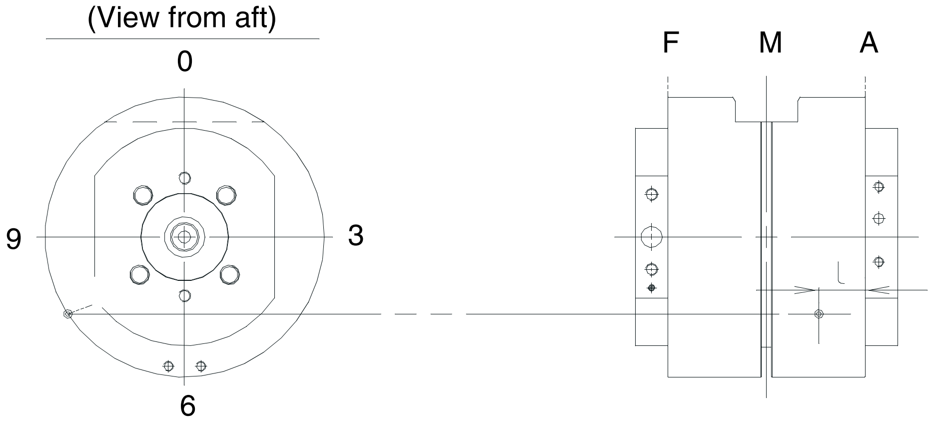
Crosshead Bearing Lower Shells



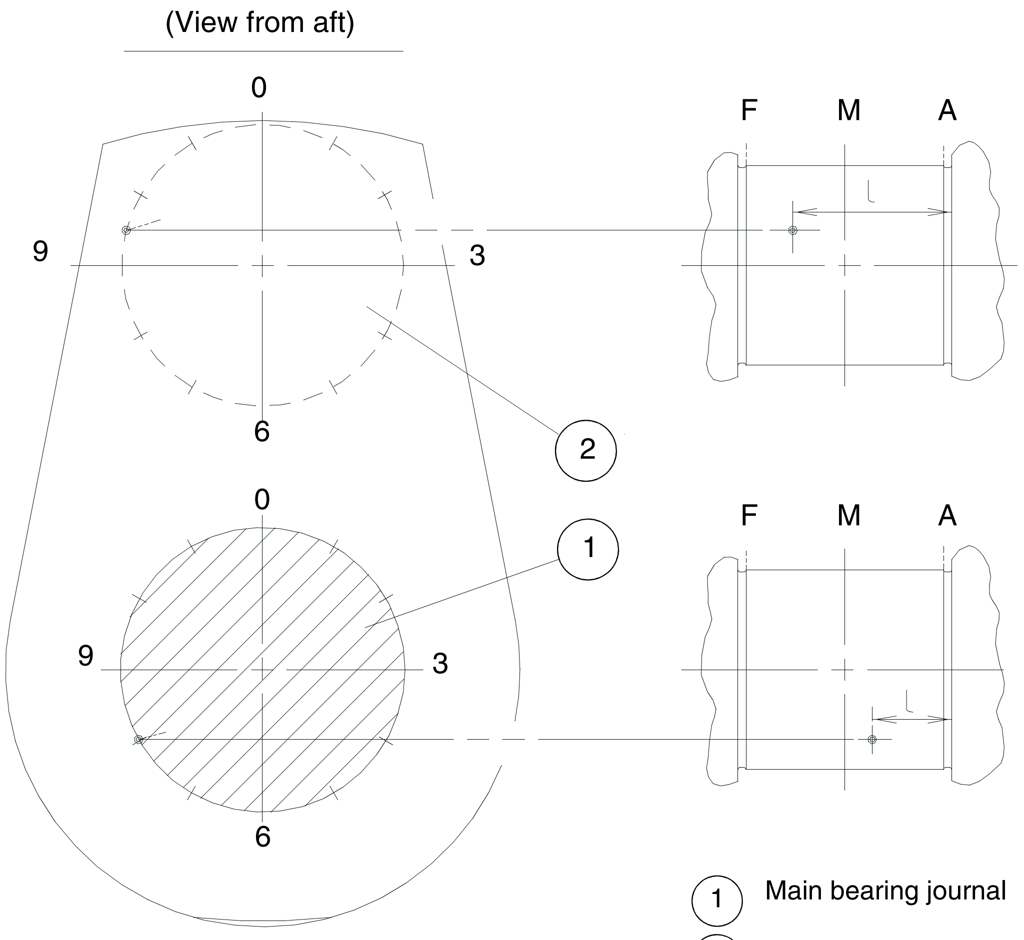
Engine type:	Max. allowed exposure (mm²)
26MC	2900
35MC	4300
42MC	6700
46MC-C	8100
50ME-C/MC-C	9600
60ME-C/MC-C	13100
65ME-C	16100
70ME-C/MC-C	17900

Maximum allowed exposure of the intermediate layer. Values are calculated according to SL05-460/NHN.

Crosshead pin



Main and crank bearing journals



1 Main bearing journal

2 Crank pin bearing journal

Table 3

Inspection without Opening-up (7.1)		
Checks	**Symbol**	**Observations**
Oil flow OF	• U	OK, similarity Uneven
Oil Jets OJ (Crosshead, Guide strips)	• 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.**
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 7.1 7.1 6.2 7.4 B, 6.1
Overlayer OL (Crosshead only)	• TE W	OK Tearing Wiping	7.3 I 7.3 II
Transitions: Oil Wedge OW Bore Relief BR Tang. Run-out TR	• RR W D	OK Ragged Ridges Wiping Disappeared	7.7 7.7 7.10BII
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

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)			N6 (M)	N3 (E)	N6 (E)		
Hydr. open. pressure			880	900	870		
Clearance (mm)	Top	Aft	0,5	0,4	0,4	0,45	
		Fore	0,5	0,4	0,4	0,45	
Description of Condition			MB/4/MBD/WM/CR;L;M;HC/7h15'; λ_I; r//	CHB/5/MBD/WM;OW/W;RR/5h45'; λ_{II}; (a,b)//	CRB/3/MBD/WM/M;W/1h15'; λ_{III}; (a,b,+/-c)//	CHB/6/OF; u/O3; R; TW/WM; SQ//	
Type of inspection 2)			7.2	7.2	7.2	7.1	
Engine running hours			10000	15000	8000	8000	
Checked by			N.N.	N.N.	N.N.	N.N.	
Date			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.

M/V	Engine type: CW / CCW 1)		Running hours Total 4)	Checked by: 4)
Yard:	Builder:	Engine No.:		
No.:	Built year:			Date: 4)

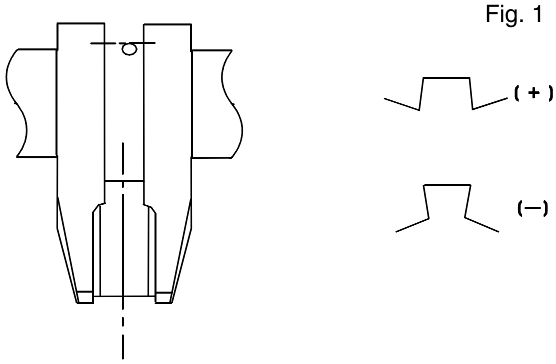
Journal/pin Roughness 3)							
Hydr. open. pressure							
Clearance (mm)	Top	Aft					
		Fore					
Description of Condition							
Type of inspection 2)							
Engine running hours							
Checked by							
Date							

1) Engine direction of rotation, seen from aft, must be underllined; 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.

Report: Crankshaft Deflections
(Autolog)

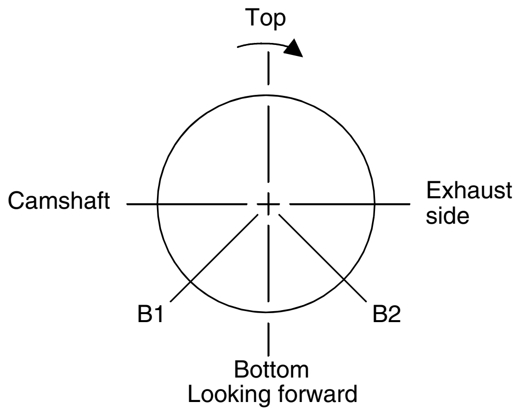
M/V	Engine type:		Total running hours	Checked by:
	Builder:	Engine No.:		
Yard No.:	Built year:			Date:
For comparison of measurements	Ships draught, aft measured (m)		Fully loaded (m)	Ballasted (m)
	Jacket cooling water temp. (°C)		Main lub. oil temp. (°C)	

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, fuel pump side	B_1							
Fuel pump side	C							
Top	T							
Exhaust side *)	E							
Near bottom, exhaust side	B_2							

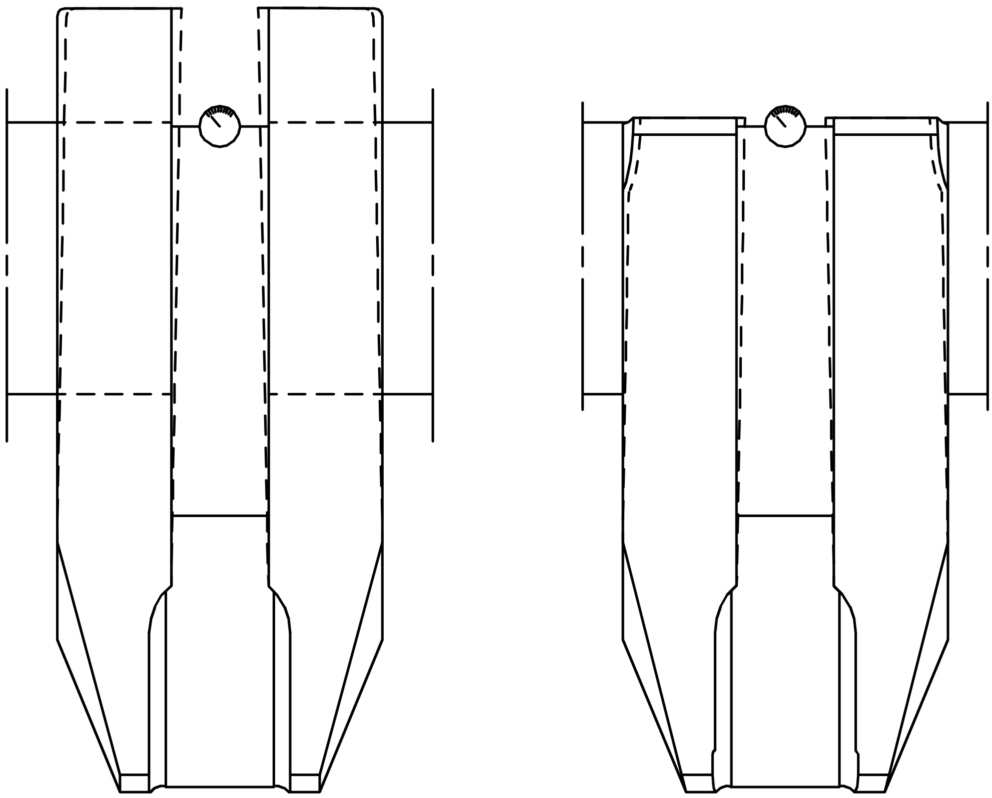
*) Positions C and E are included for reference purposes.

Fig. 4

Bottom $1/2\ (B_1 + B_2)$	= B							

Fig. 5

Vertical Deflections								
Top-bottom or (T-B)	= V							
For permissible deflections, see Plate 70817. See also Item 2.2 ‘Checking the Deflections* earlier in this Chapter.								



Type	Normally obtainable for a new or recently overhauled engine		Realignment recommended		Absolute maximum permissible	
	mm		mm		mm	
	1	2	1	2	1	2
S26MC	0.12	0.23	0.31	0.35	0.46	0.46
L35MC	0.10	0.20	0.27	0.30	0.40	0.40
S35MC	0.17	0.35	0.46	0.52	0.70	0.70
S42MC	0.21	0.43	0.57	0.64	0.86	0.86
S46MC-C	0.23	0.46	0.62	0.69	0.93	0.93
K50ME/MC	0.12	0.25	0.34	0.38	0.51	0.51
L50ME/MC	0.17	0.34	0.45	0.51	0.68	0.68
S50ME/MC	0.23	0.46	0.61	0.69	0.92	0.92
S50ME-C/MC-C	0.23	0.47	0.62	0.70	0.94	0.94
K60ME/MC	0.15	0.31	0.41	0.46	0.62	0.62
L60ME/MC	0.20	0.40	0.54	0.61	0.81	0.81
L60ME-C/MC-C	0.22	0.45	0.59	0.67	0.89	0.89
S60ME/MC	0.27	0.55	0.73	0.82	1.10	1.10
S60ME-C/MC-C	0.28	0.56	0.75	0.84	1.13	1.13
S65ME-C	0.33	0.65	0.87	0.98	1.31	1.31
K70ME/MC	0.18	0.37	0.49	0.55	0.74	0.74
L70ME/MC	0.24	0.48	0.63	0.71	0.95	0.95
L70ME-C/MC-C	0.26	0.53	0.70	0.79	1.05	1.05
S70ME/MC	0.32	0.64	0.85	0.96	1.28	1.28
S70ME-C/MC-C	0.33	0.66	0.88	0.99	1.32	1.32

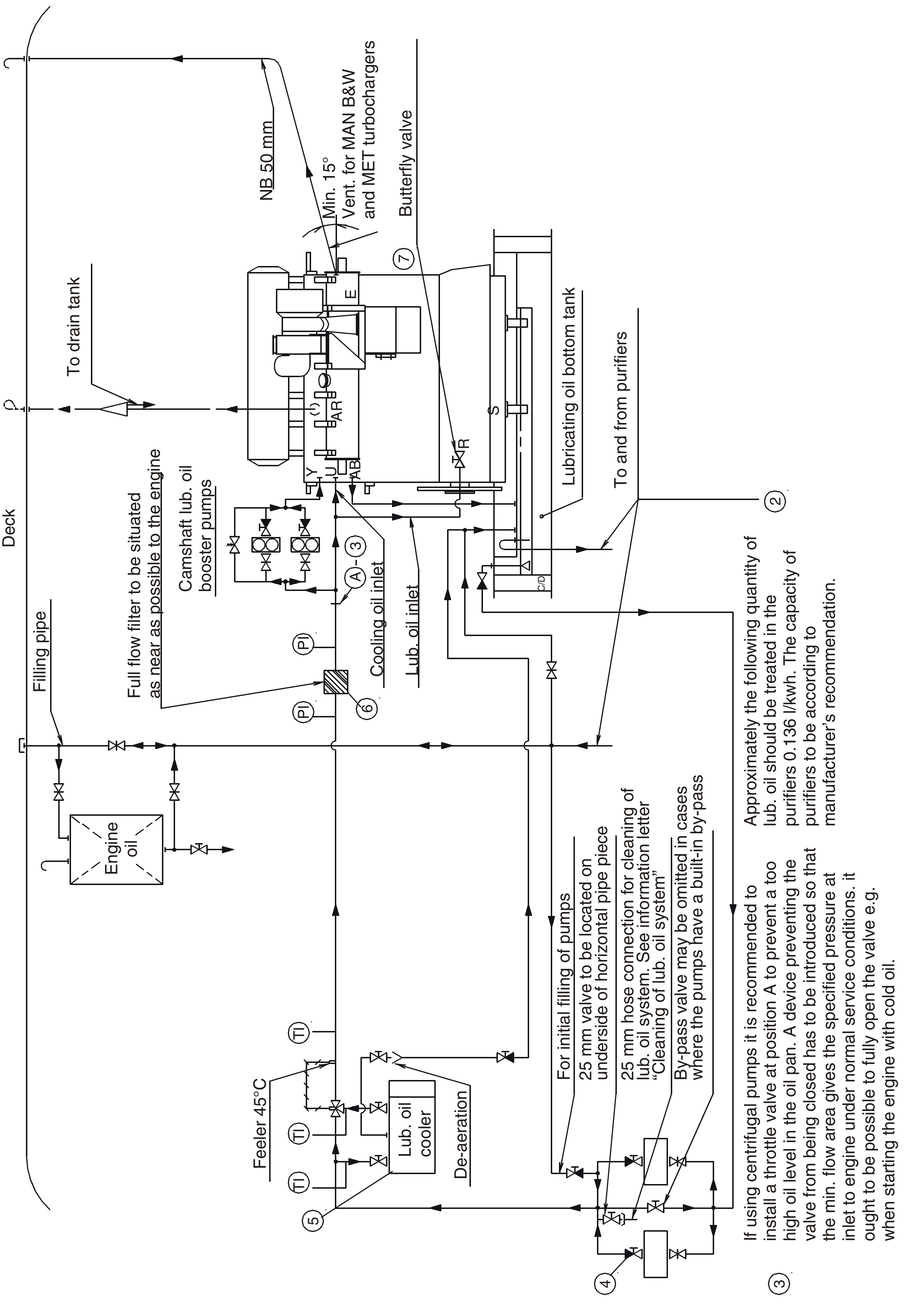
Type	Normally obtainable for a new or recently overhauled engine		Realignment recommended		Absolute maximum permissible	
	mm		mm		mm	
	1	2	1	2	1	2
L80ME/MC	0.27	0.54	0.72	0.81	1.08	1.08
S80ME/MC	0.36	0.73	0.97	1.10	1.46	1.46
S80ME-C/MC-C	0.38	0.75	1.00	1.13	1.50	1.50
K80ME-C/MC-C	0.22	0.44	0.58	0.66	0.88	0.88
L90ME/MC	0.30	0.60	0.81	0.92	1.22	1.22
L90ME-C/MC-C	0.27	0.54	0.72	0.81	1.08	1.08
K90ME/MC	0.25	0.50	0.67	0.75	1.00	1.00
K90ME-C/MC-C	0.20	0.41	0.54	0.61	0.82	0.82
S90ME-C/MC-C	0.36	0.72	0.96	1.08	1.45	1.45
K98ME/MC	0.25	0.49	0.65	0.74	0.98	0.98
K98ME-C/MC-C	0.20	0.41	0.54	0.61	0.81	0.81

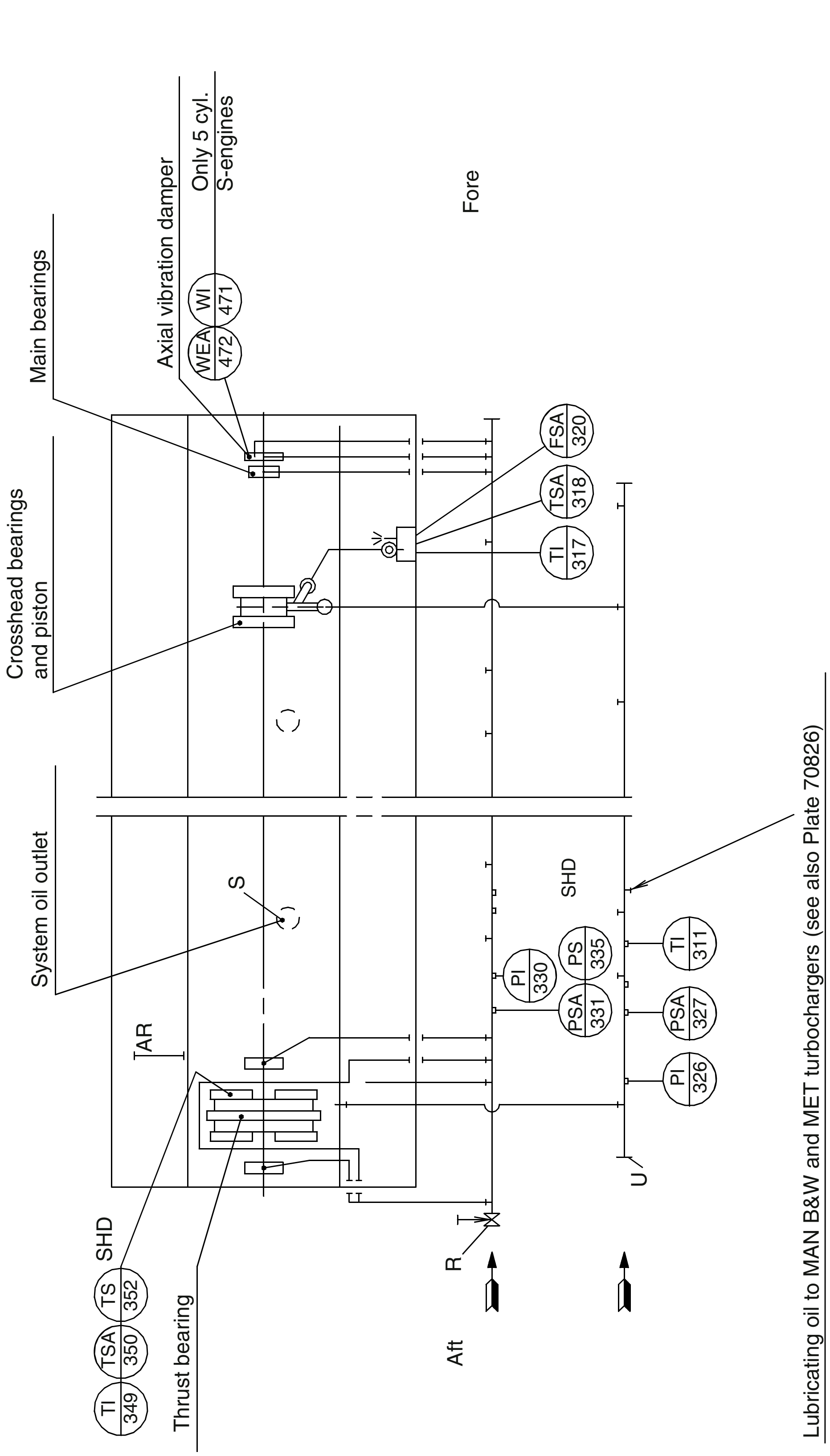
1. Normal for all crank throws.

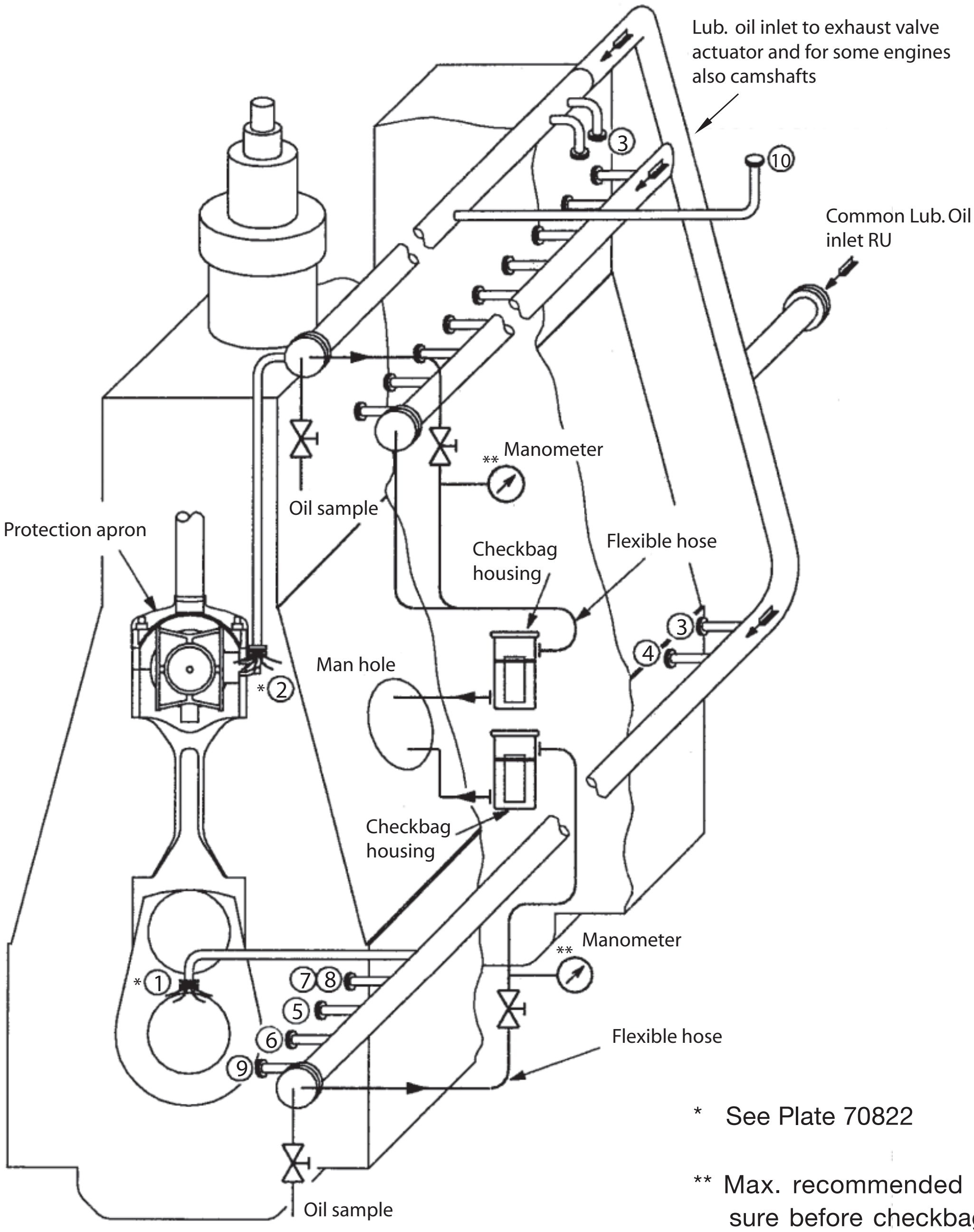
2. Permissible for the foremost crank throw, when the crankshaft fore end is provided with a torsional vibration damper, tuning wheel or directly coupled to a generator rotor. Permissible for the aftmost crank throw, when the crankshaft generator end is provided with a flexible coupling.

When the camshaft chain drive is located in the foremost part of the engine, the crankshaft deflection readings for cyl. 1, are to be measured with untightened chain.

When judging the alignment on the above "limiting-value"' basis, make sure that the crankshaft is actually supported in the adjacent bearings. *(See Section 708-02 'Alignment of Main Bearings' point 2.3 'floating journals').*


Deck
Filling pipe
To drain tank
NB 50 mm
Min. 15°
Vent. for MAN B&W
and MET turbochargers
Butterfly valve
7
E
(¹)
AR
R
S
Y
U
AB
C/D
Lubricating oil bottom tank
To and from purifiers
2
Full flow filter to be situated
as near as possible to the engine
Camshaft lub. oil
booster pumps
A
3
Cooling oil inlet
Lub. oil inlet
PI
6
Engine
oil
TI
Feeler 45°C
Lub. oil
cooler
De-aeration
5
4
For initial filling of pumps
25 mm valve to be located on
underside of horizontal pipe piece
25 mm hose connection for cleaning of
lub. oil system. See information letter
"Cleaning of lub. oil system"
By-pass valve may be omitted in cases
where the pumps have a built-in by-pass
Approximately the following quantity of
lub. oil should be treated in the
purifiers 0.136 l/kwh. The capacity of
purifiers to be according to
manufacturer's recommendation.
3
If using centrifugal pumps it is recommended to
install a throttle valve at position A to prevent a too
high oil level in the oil pan. A device preventing the
valve from being closed has to be introduced so that
the min. flow area gives the specified pressure at
inlet to engine under normal service conditions. it
ought to be possible to fully open the valve e.g.
when starting the engine with cold oil.


Main bearings
Axial vibration damper
Only 5 cyl.
S-engines
Fore
WEA
472
WI
471
FSA
320
TSA
318
TI
317
Crosshead bearings
and piston
System oil outlet
S
AR
SHD
PI
330
PS
335
PSA
331
TI
311
PSA
327
PI
326
U
R
TI
349
TSA
350
TS
352
SHD
Thrust bearing
Aft
Lubricating oil to MAN B&W and MET turbochargers (see also Plate 70826)

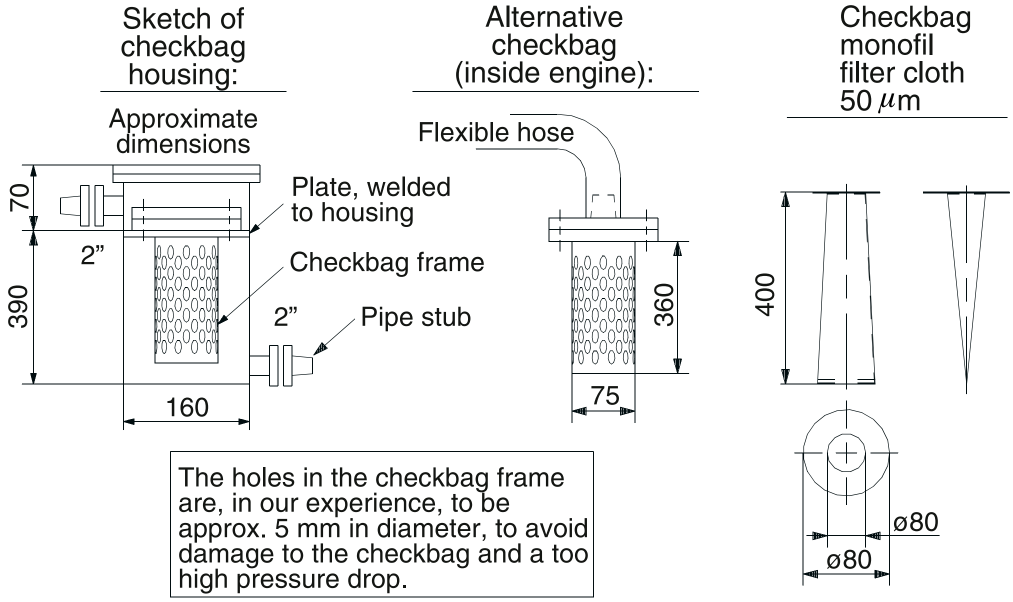


* See Plate 70822

** Max. recommended pressure before checkbag = 1 bar eff. or in accordance with information from the checkbag supplier

<u>Blanking off pipes:</u>

1. Main bearings by-pass blanks
2. Cross head bearings by-pass blanks
3. Blank-off bearings and spray nozzles at main chain
4. Blank-off thrust bearing
5. Blank-off or by-pass axial vibration damper
6. Blank-off torsional vibration damper
7. Blank-off forward moment compensator chain drive (option)
8. Blank-off hydraulic chain tightener
9. Blank-off PTO-PTI power gear
10. Blank-off or by-pass turbocharger

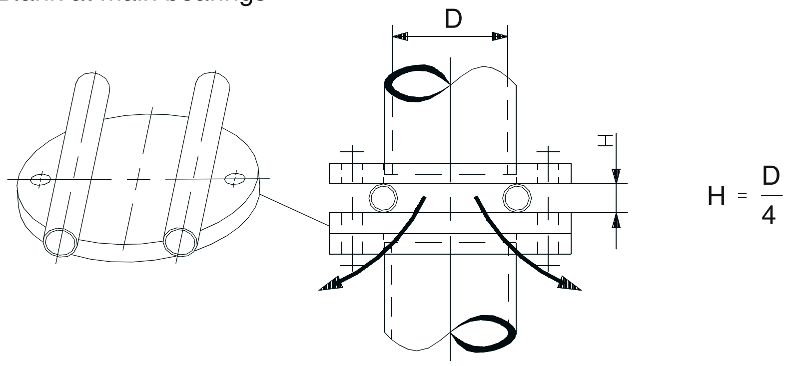


The holes in the checkbag frame are, in our experience, to be approx. 5 mm in diameter, to avoid damage to the checkbag and a too high pressure drop.

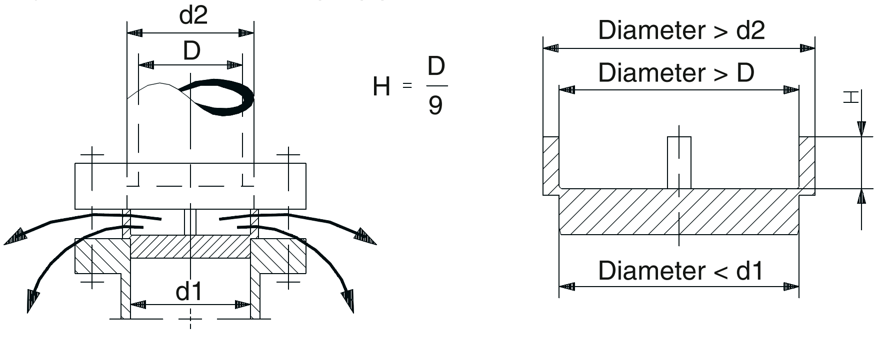
The above filter components can be delivered from MAN B&W Diesel

* Blank flanges for flushing:

A) Blank at main bearings



B) Blank between telescopic pipes and crossheads



M/V	Engine Type:		System		Checked by:
	Builder:	Engine No.:	M.E. Lub. Oil		
Yard No.:	Built year:		Camshaft		Date:

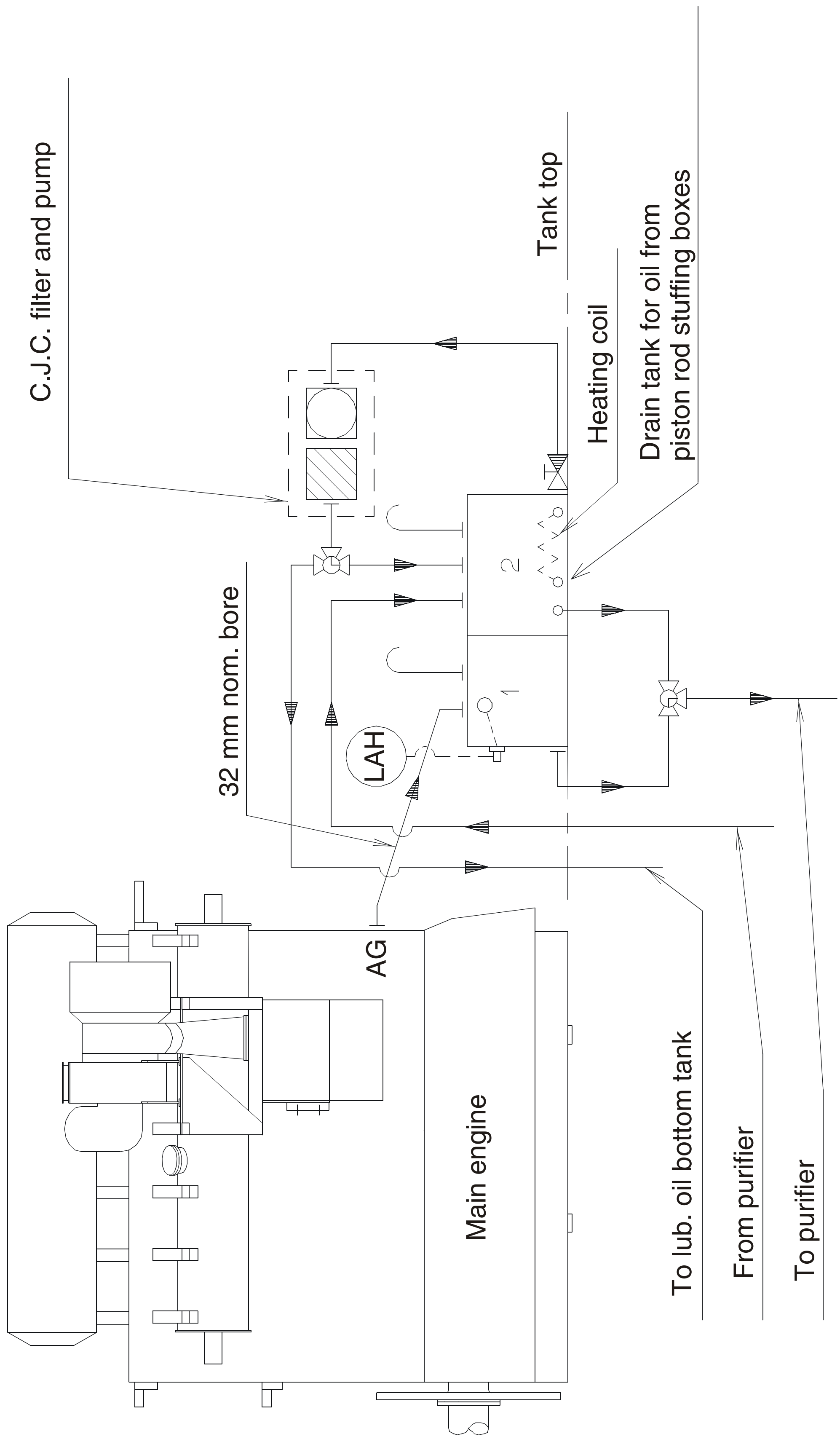
Info				
	Pumps Centrifugal ☐ Screw ☐ Maker: Type: Capacity:	Filters Absolute/fineness Maker : Main : μm Type : By-pass : μm Type :	Centrifuge Maker: Type: Capacity:	Magnet Filter Maker: Type: Other Filters Maker: Type:

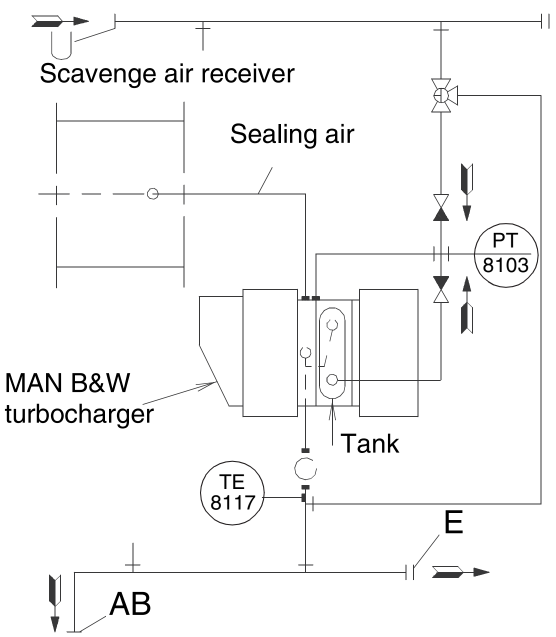
Filter Unit (if used) μm Type: Maker:	L.O. System							
Inspection of / Checked by / Date Pipes: Tanks:	Temp. [C]	Press. [bar] at pump & M.E.	Pump 1-2: Time start & stop	Pump 1-2: Running hours per day	Pump 1-2: Running hours total	Purifier: Start/stop running hours	Filter Unit: Start/stop running hours	Check No. & ISO Code

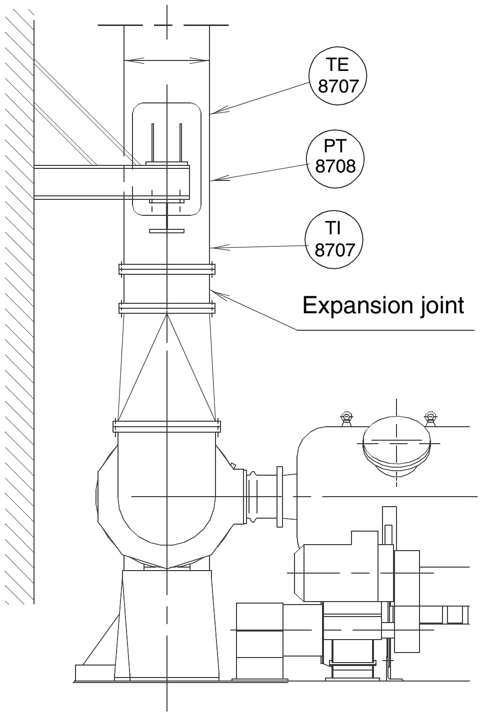
Date:	Remarks								

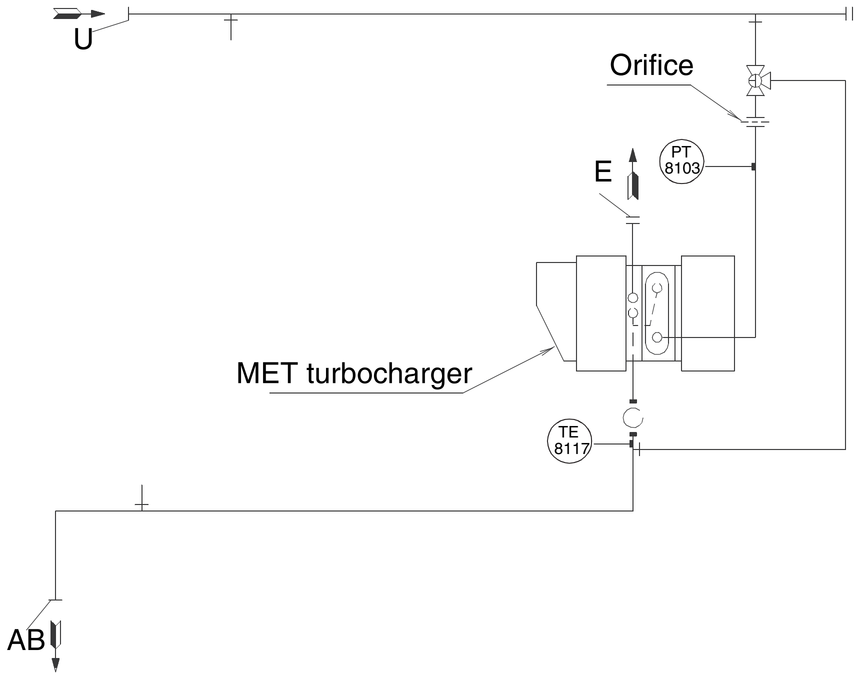
Sign.	Inspector:	Yard/Engine builder	Total flushing hrs.:	Final cleanliness: Check bags ________ ISO 4406 Code ________

Recording of pump running hrs. with ½hr.
Cleaning and replacement of filters to be recorded under remarks.
Accepted flushing cleanliness level: Clean check bags after 2 hrs. (ISO 4406 Code $\leq$ 19/15)


C.J.C. filter and pump
Tank top
Heating coil
Drain tank for oil from piston rod stuffing boxes
32 mm nom. bore
LAH
1
2
AG
Main engine
To lub. oil bottom tank
From purifier
To purifier

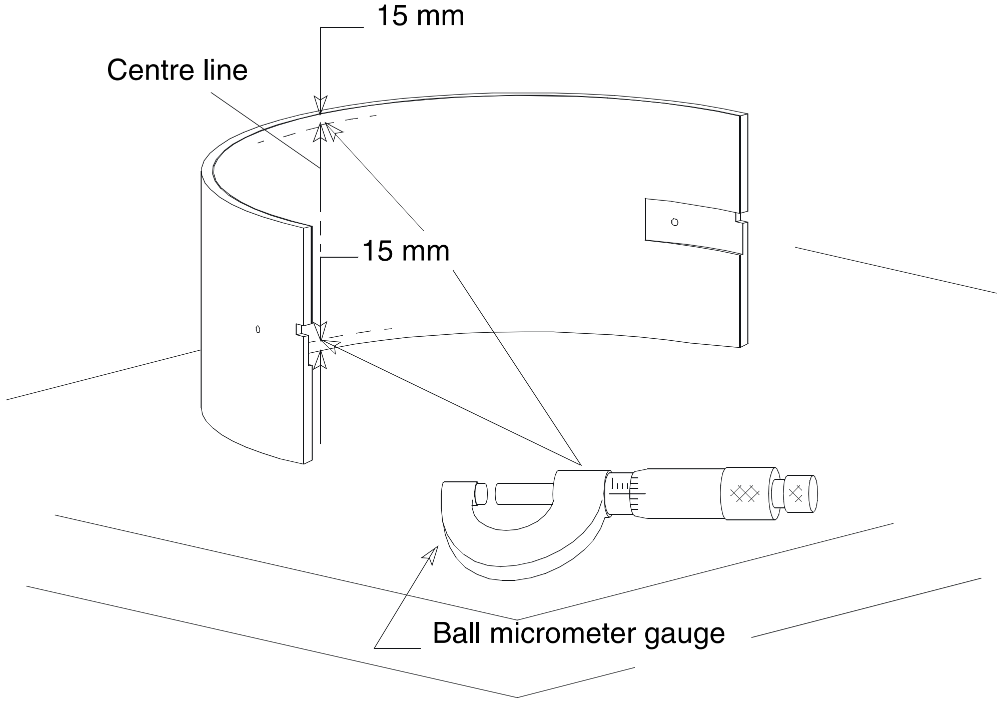

Scavenge air receiver
Sealing air
PT
8103
MAN B&W
turbocharger
Tank
TE
8117
E
AB

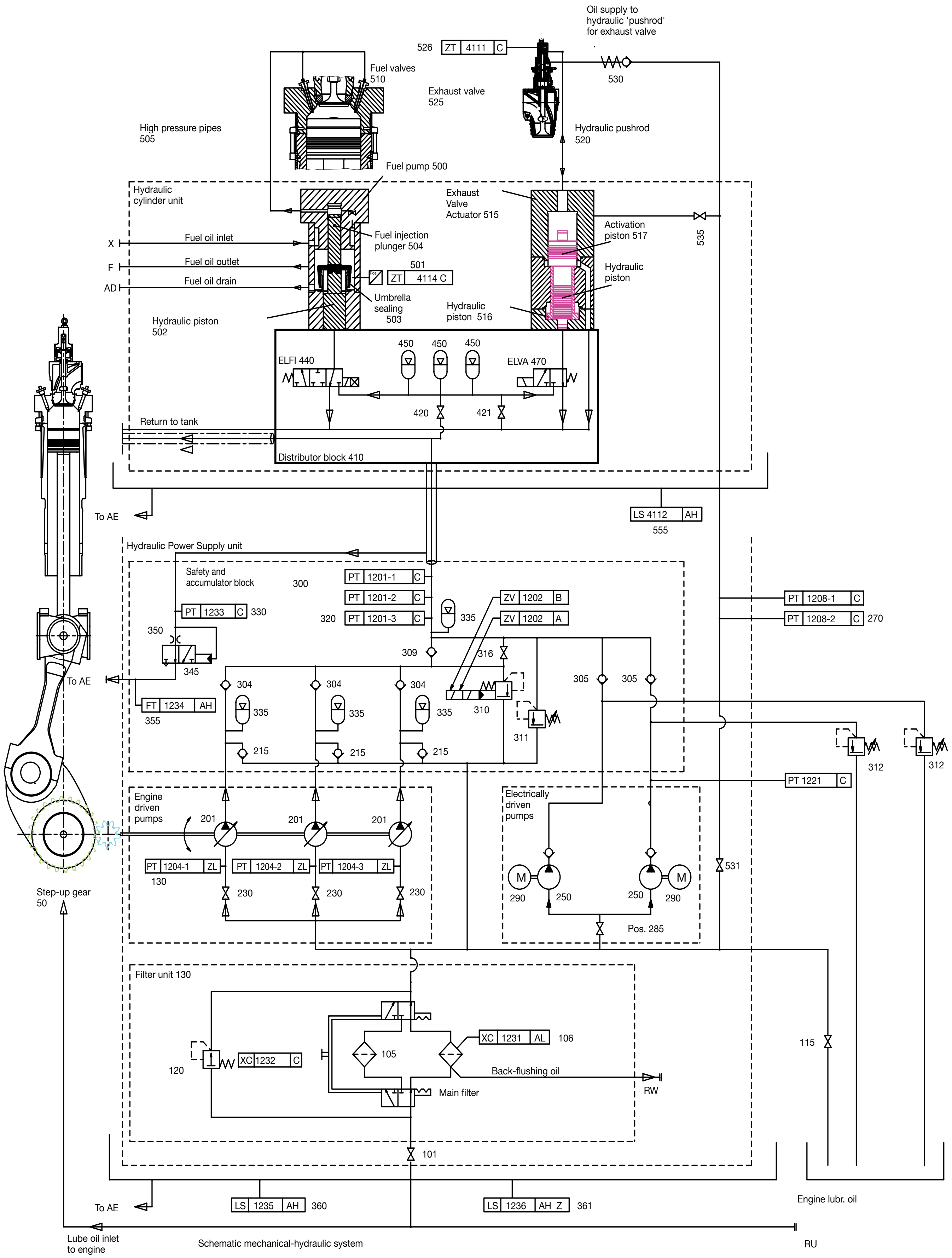

TE
8707
PT
8708
TI
8707
Expansion joint

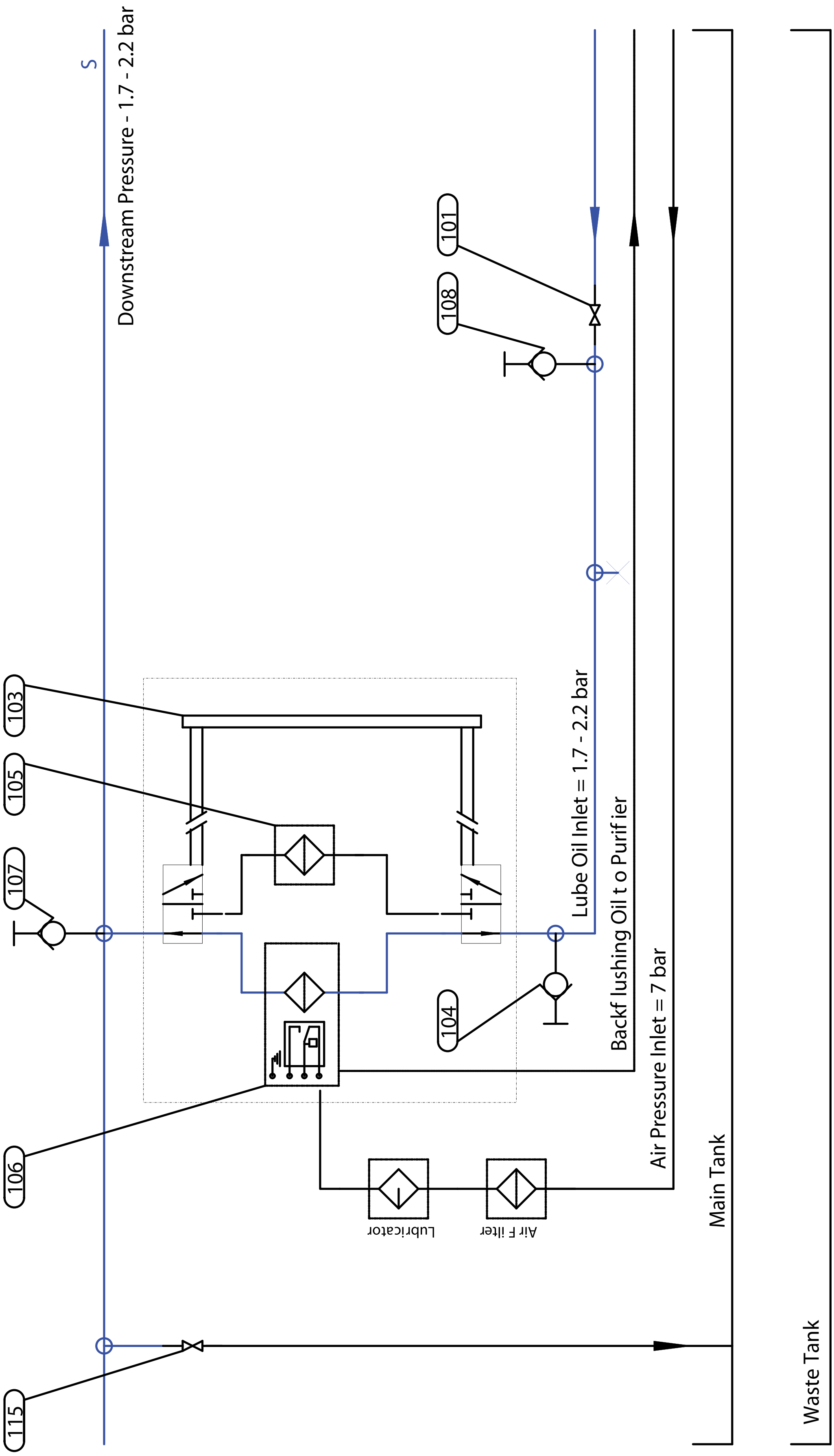

U
Orifice
PT
8103
E
MET turbocharger
TE
8117
AB

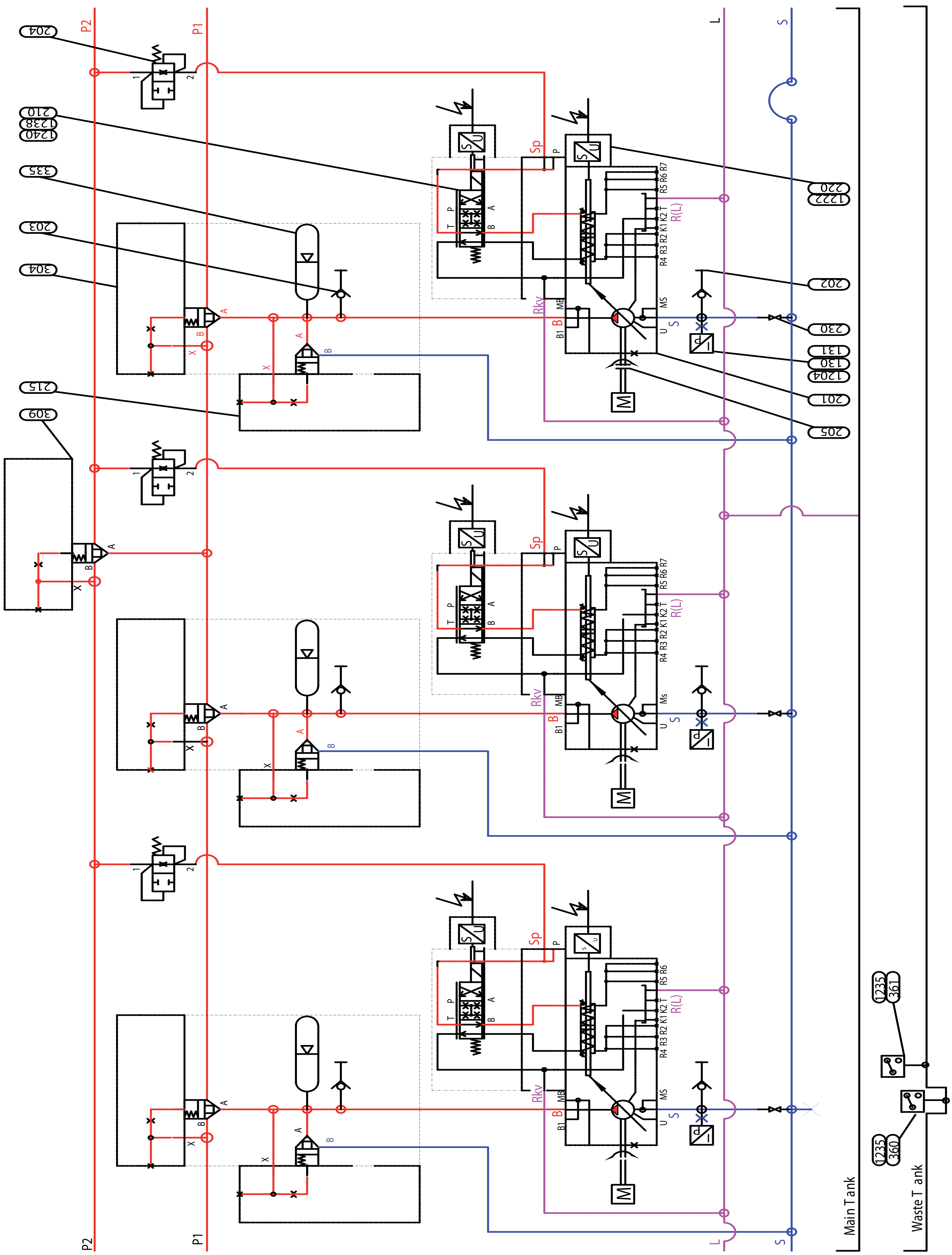
See also 'Check of Bearings before Installation'

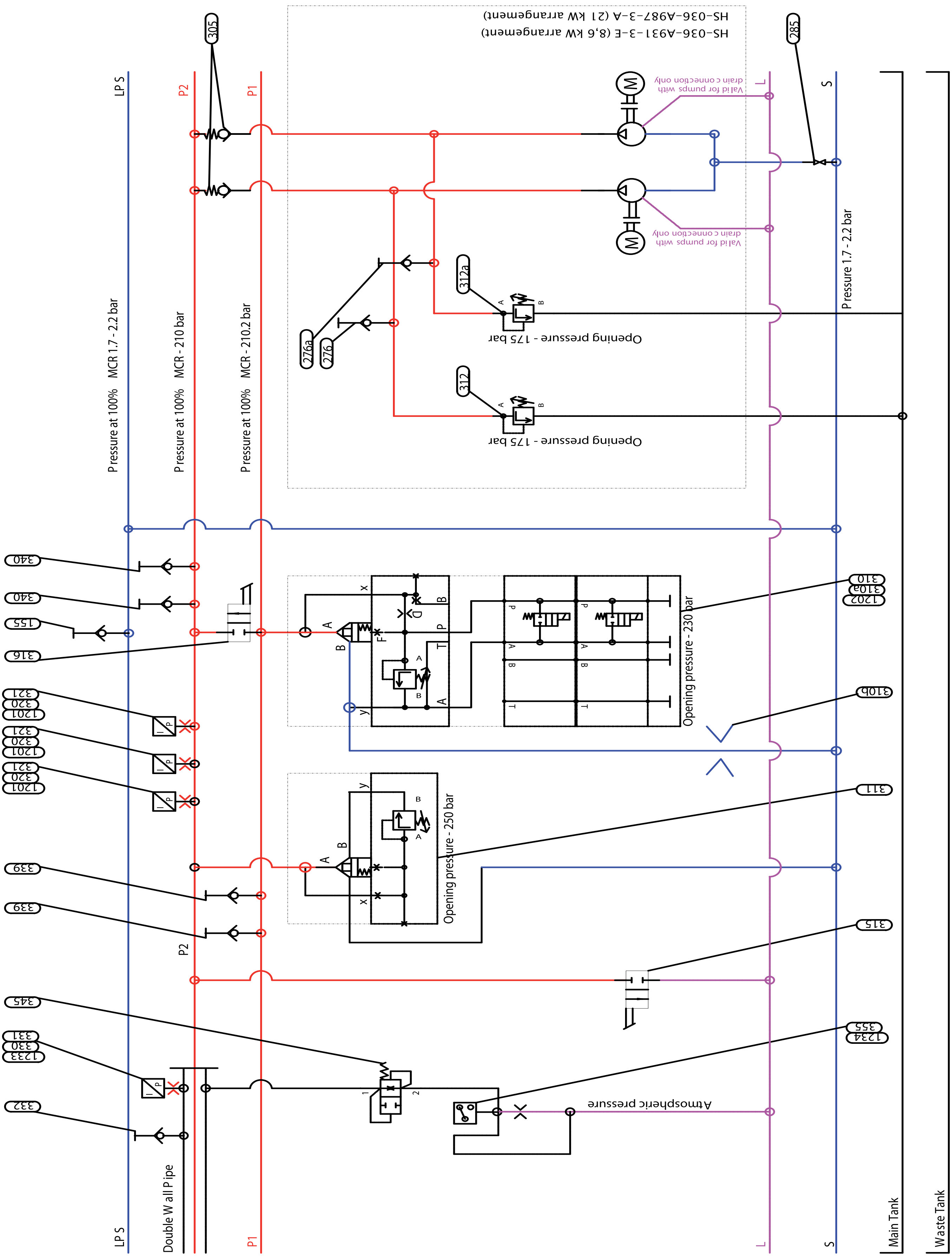
Fig. 1 - Measuring of crown thickness.

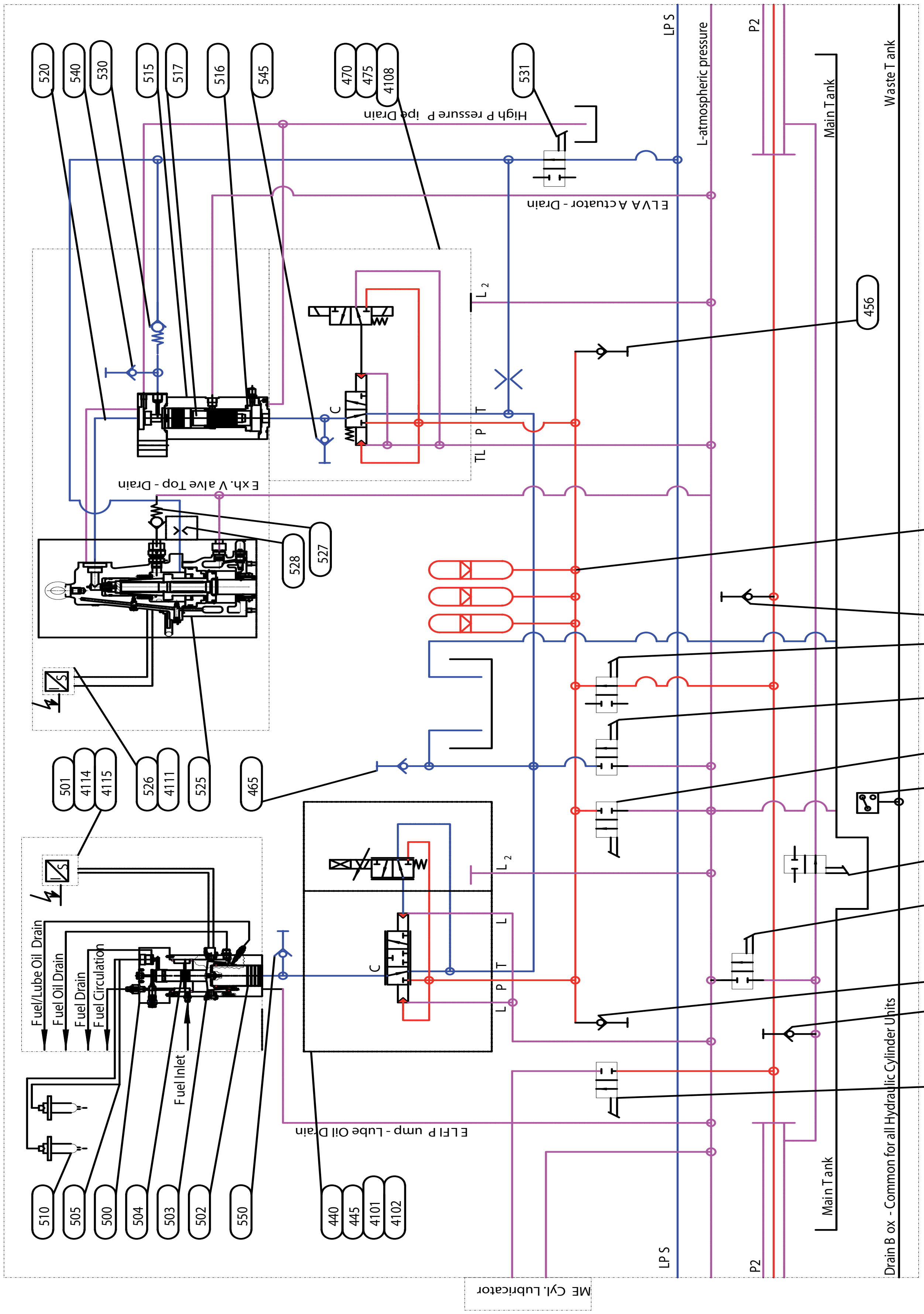


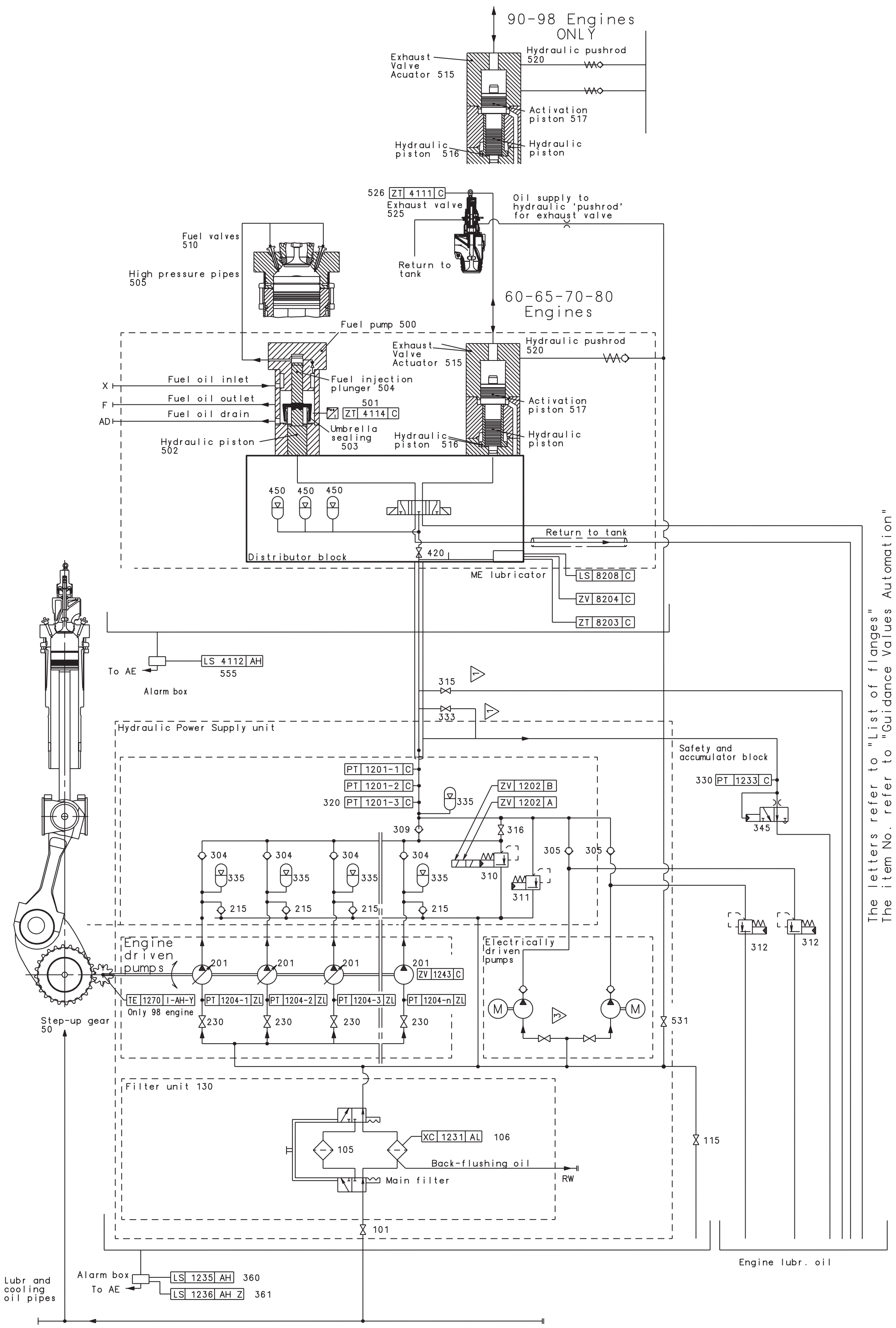

Oil supply to
hydraulic 'pushrod'
for exhaust valve
526
ZT 4111 C
530
Fuel valves
510
Exhaust valve
525
High pressure pipes
505
Hydraulic pushrod
520
Fuel pump 500
Hydraulic
cylinder unit
Exhaust
Valve
Actuator 515
Activation
piston 517
535
X
Fuel oil inlet
Fuel injection
plunger 504
F
Fuel oil outlet
501
ZT 4114 C
Hydraulic
piston
AD
Fuel oil drain
Umbrella
sealing
503
Hydraulic piston
502
Hydraulic
piston 516
450
450
450
ELFI 440
ELVA 470
420
421
Return to tank
Distributor block 410
To AE
LS 4112 AH
555
Hydraulic Power Supply unit
Safety and
accumulator block
300
PT 1201-1 C
PT 1201-2 C
PT 1201-3 C
320
335
ZV 1202 B
ZV 1202 A
PT 1208-1 C
PT 1208-2 C
270
PT 1233 C
330
350
309
316
345
To AE
304
304
304
305
305
FT 1234 AH
355
335
335
335
310
311
215
215
215
312
312
PT 1221 C
Engine
driven
pumps
201
201
201
Electrically
driven
pumps
PT 1204-1 ZL
PT 1204-2 ZL
PT 1204-3 ZL
130
230
230
230
M
M
290
250
250
290
531
Step-up gear
50
Pos. 285
Filter unit 130
XC 1231 AL
106
115
105
XC 1232 C
120
Back-flushing oil
RW
Main filter
101
Engine lubr. oil
To AE
LS 1235 AH
360
LS 1236 AH Z
361
Lube oil inlet
to engine
Schematic mechanical-hydraulic system
RU


S
Downstream Pressure - 1.7 - 2.2 bar
101
108
103
105
107
104
106
115
Lube Oil Inlet = 1.7 - 2.2 bar
Backf lushing Oil t o Purif ier
Air Pressure Inlet = 7 bar
Main Tank
Waste Tank
Lubricator
Air F ilter

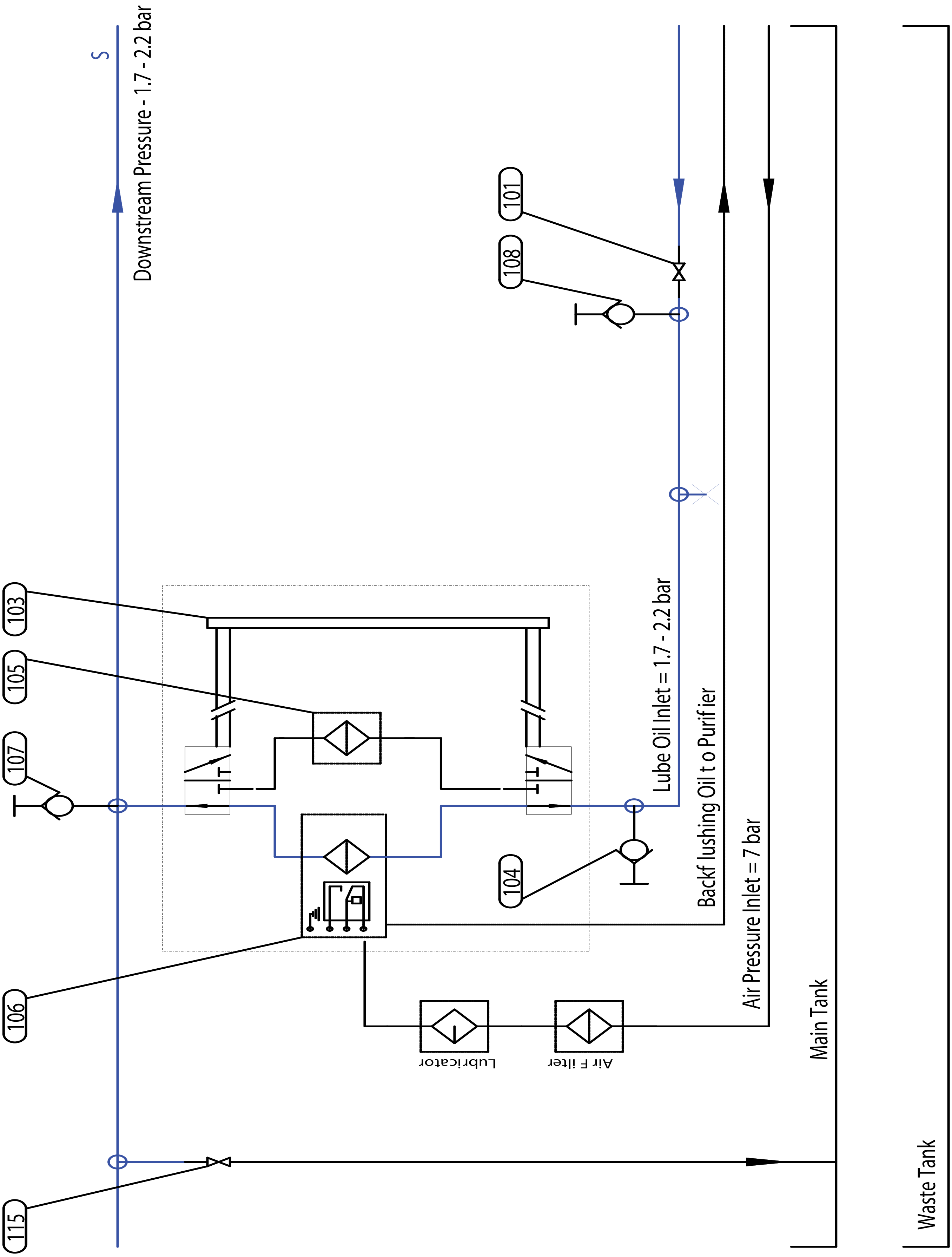

P1
P2
Main Tank
Waste Tank

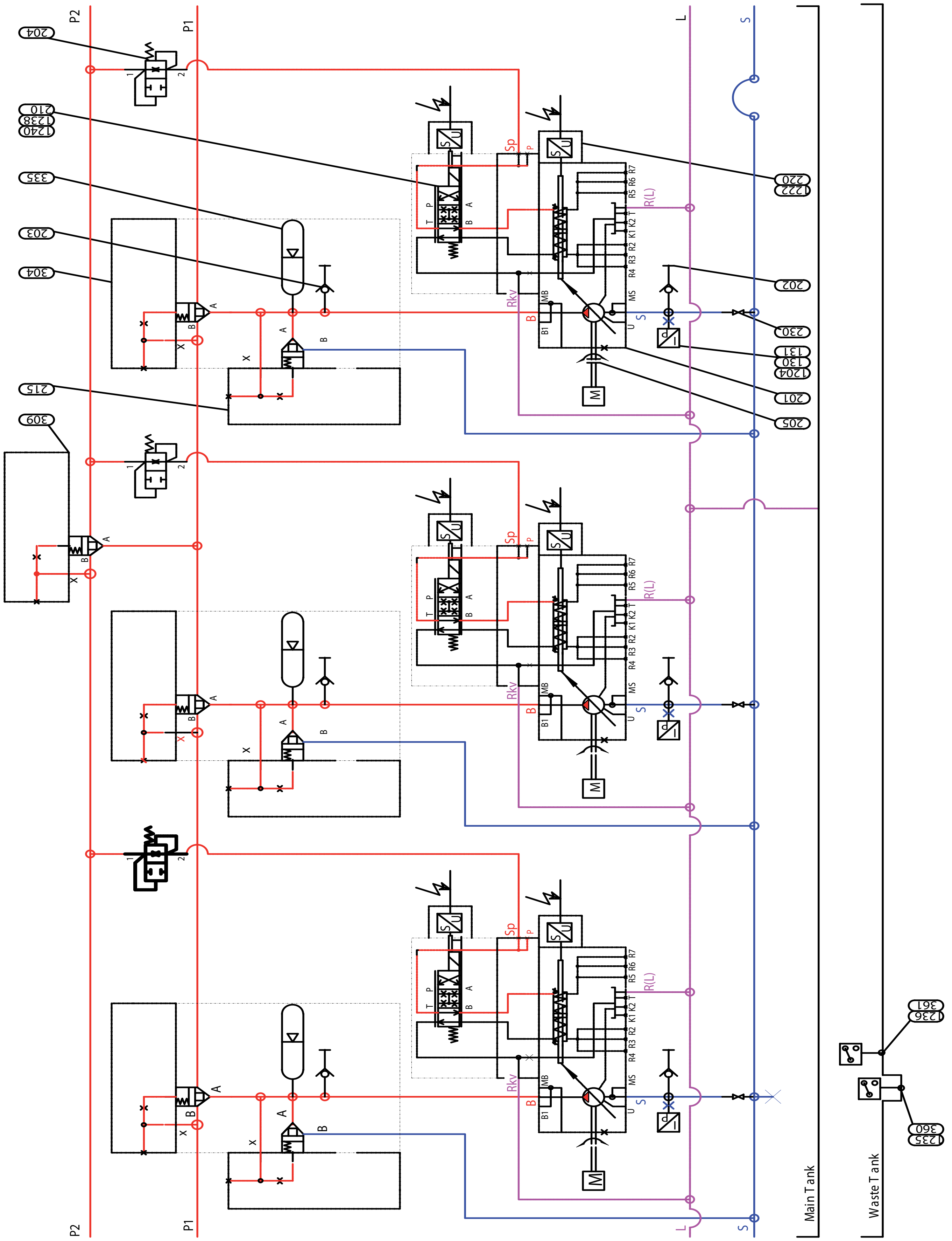

LP S
P2
P1
Pressure at 100% MCR 1.7 - 2.2 bar
Pressure at 100% MCR - 210 bar
Pressure at 100% MCR - 210.2 bar
HS-036-A987-3-A (21 kW arrangement)
HS-036-A931-3-E (8,6 kW arrangement)
Valid for pumps with drain connection only
Valid for pumps with drain connection only
Opening pressure - 175 bar
Opening pressure - 175 bar
Pressure 1.7 - 2.2 bar
Opening pressure - 230 bar
Opening pressure - 250 bar
Atmospheric pressure
Double Wall Pipe
L
S
Main Tank
Waste Tank
305
285
312a
312
276a
276
340
340
155
316
321
320
1201
339
339
345
331
330
1233
332
310
310a
1202
310b
311
315
355
1234


520
540
530
515
517
516
545
470
475
4108
531
High Pressure Pipe Drain
ELVA Actuator - Drain
LPS
L-atmospheric pressure
P2
Main Tank
Waste Tank
L2
C
T
P
TL
456
Exh. Valve Top - Drain
528
527
450
425
420
405
421
4112
555
430
431
455
435
560
501
4114
4115
526
4111
525
465
L
Fuel/Lube Oil Drain
Fuel Oil Drain
Fuel Drain
Fuel Circulation
Fuel Inlet
ELFI Pump - Lube Oil Drain
510
505
500
504
503
502
550
440
445
4101
4102
Main Tank
Drain Box - Common for all Hydraulic Cylinder Units
LPS
P2
ME Cyl. Lubricator

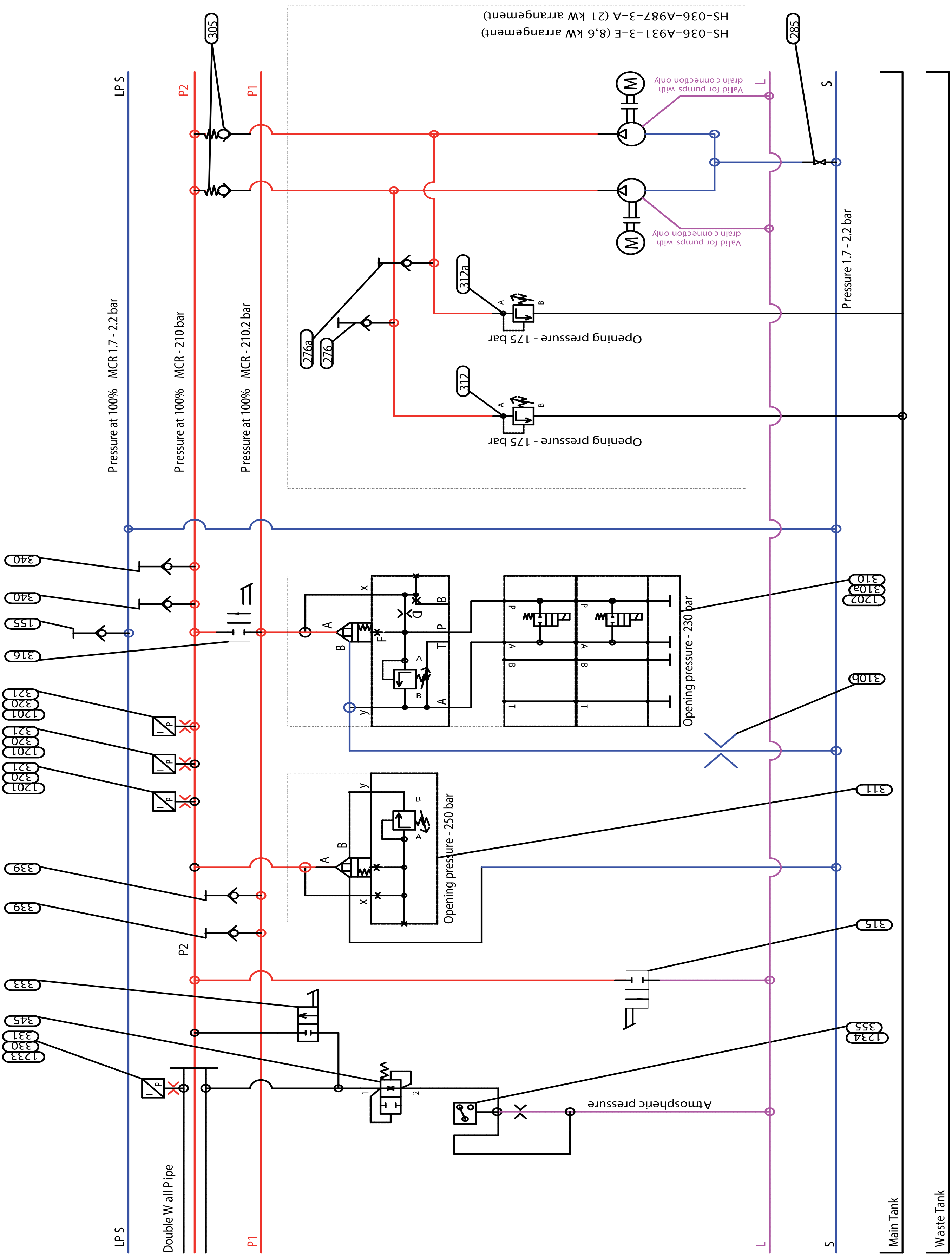


Schematic mechanical-hydraulic system

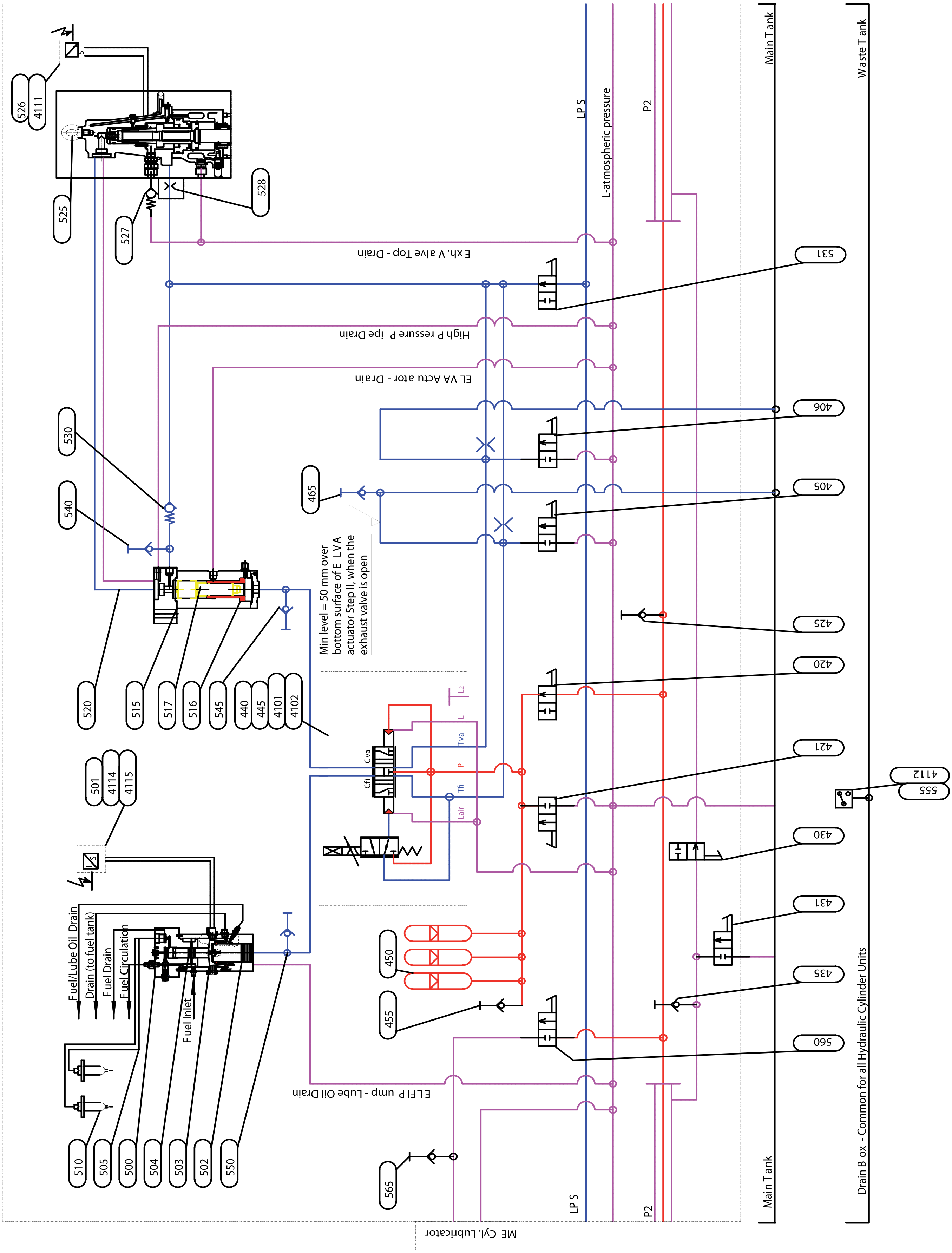

S
Downstream Pressure - 1.7 - 2.2 bar
101
108
103
105
107
104
106
115
Lube Oil Inlet = 1.7 - 2.2 bar
Backflushing Oil to Purifier
Air Pressure Inlet = 7 bar
Main Tank
Waste Tank
Lubricator
Air Filter

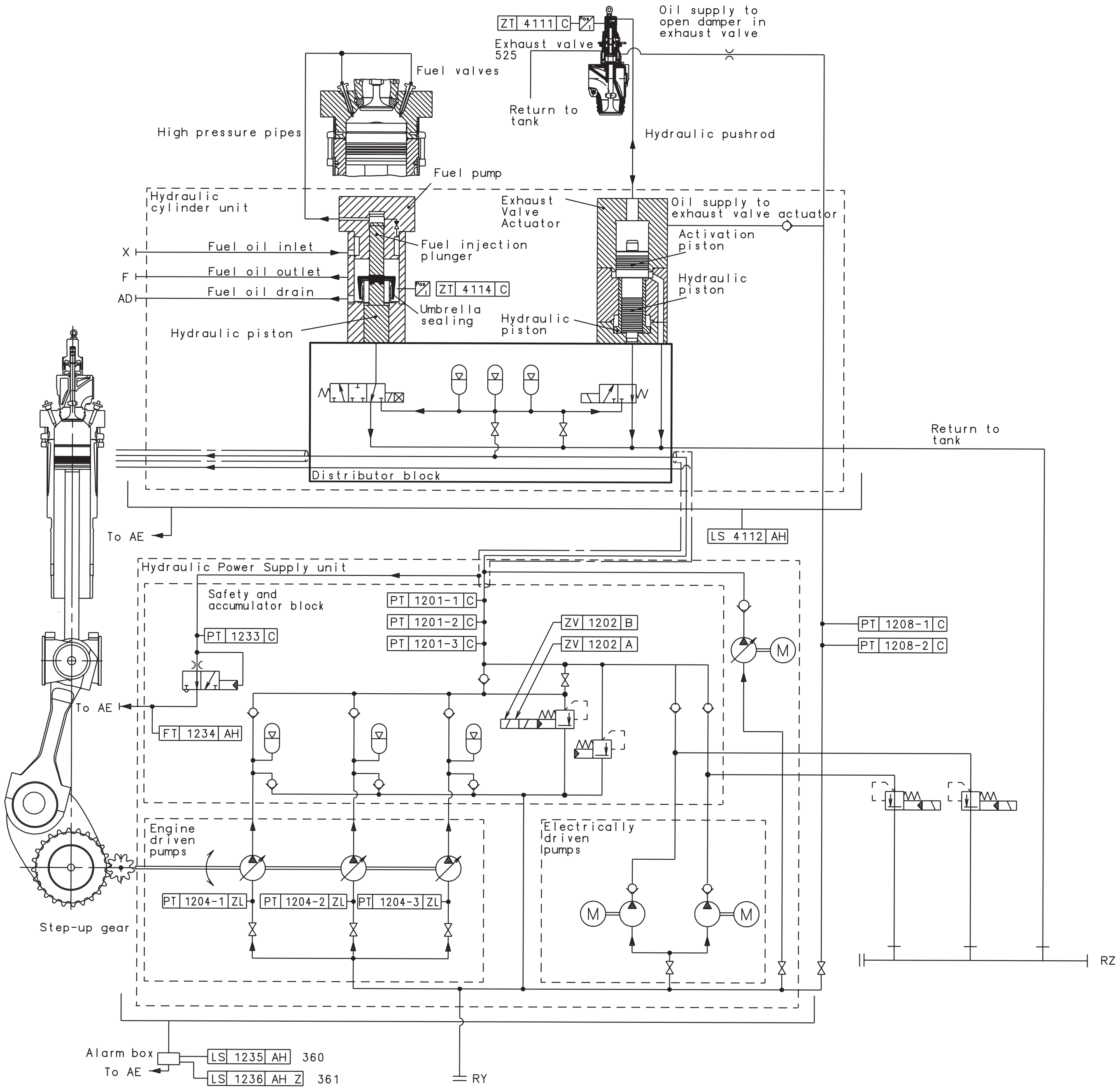

P2
P1
L
S
204
210
1238
1240
335
203
304
215
309
220
1222
202
230
131
130
1204
201
205
361
1236
360
1235
Main Tank
Waste Tank

Gear Driven HPS and FIVA

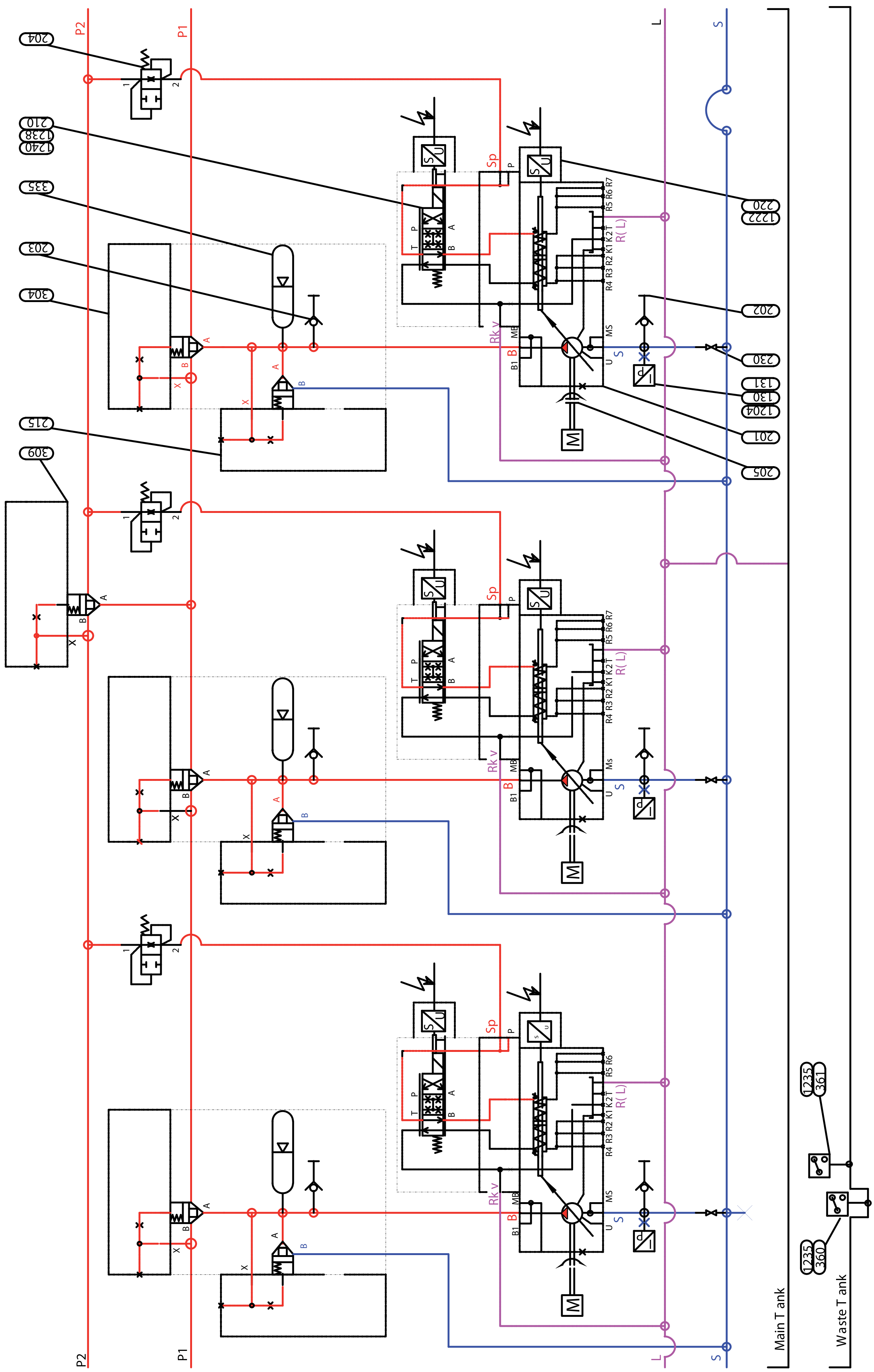


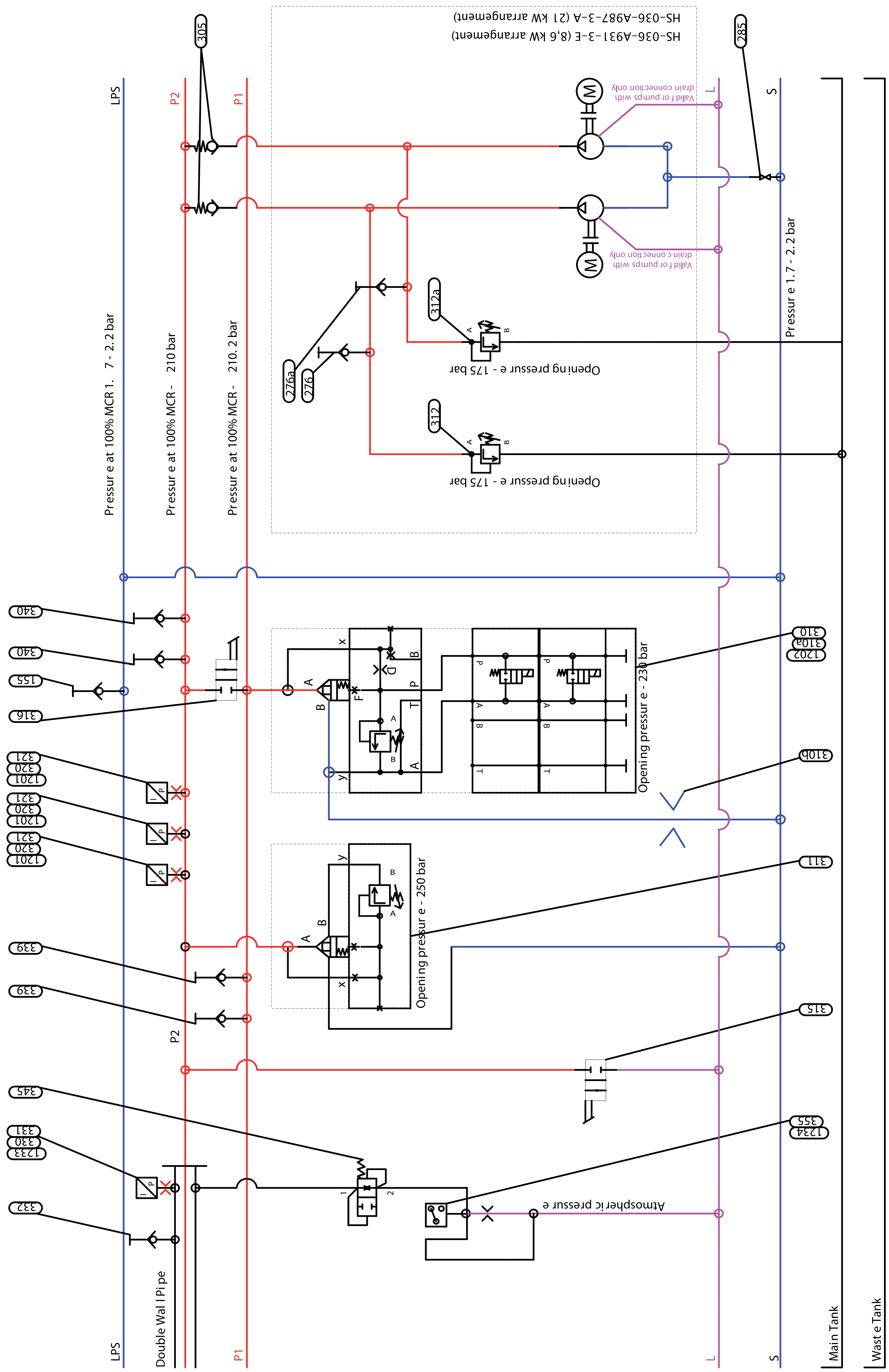
Gear Driven HPS and FIVA

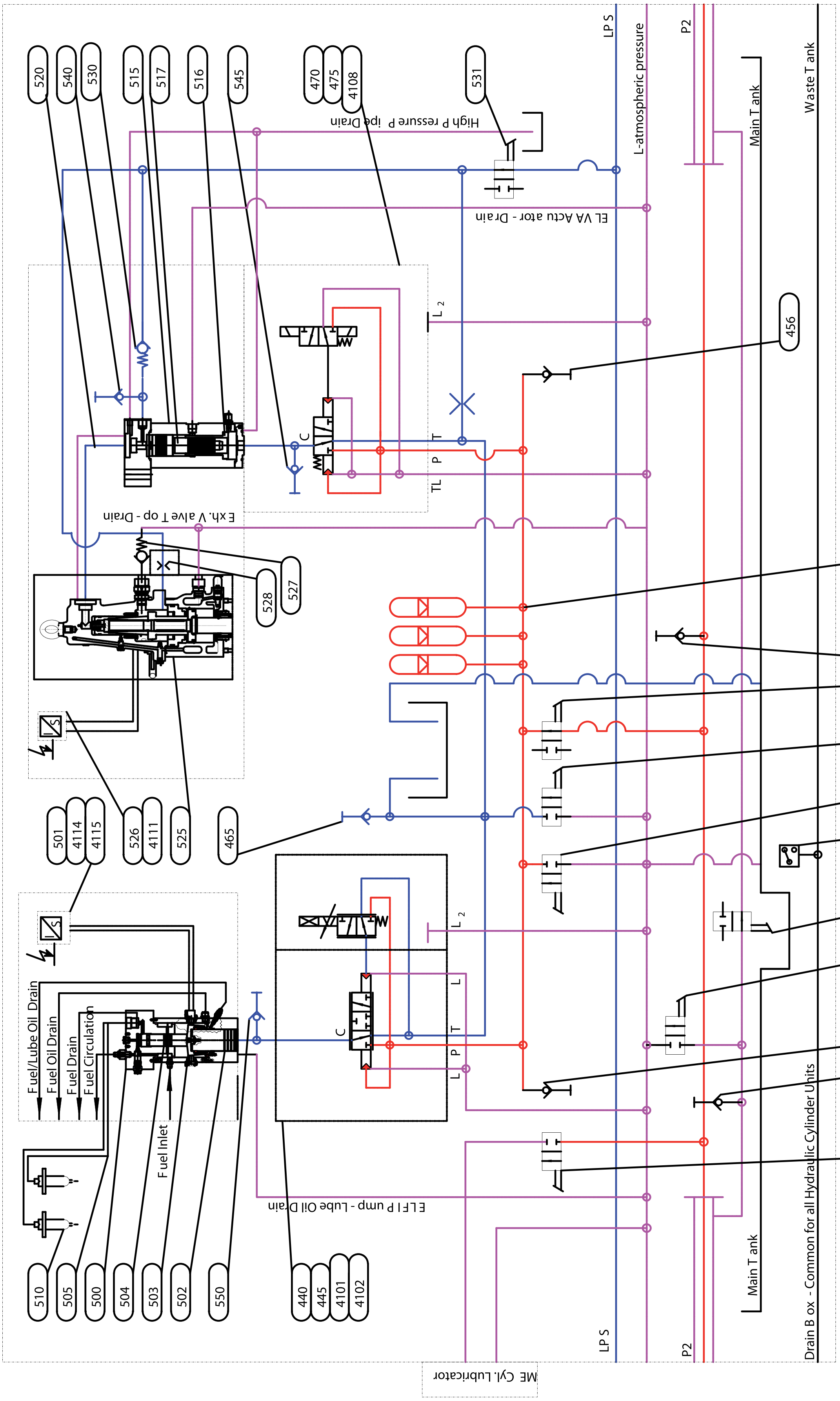



ZT 4111 C
Exhaust valve 525
Oil supply to open damper in exhaust valve
Fuel valves
Return to tank
High pressure pipes
Hydraulic pushrod
Fuel pump
Hydraulic cylinder unit
Exhaust Valve Actuator
Oil supply to exhaust valve actuator
Activation piston
Fuel oil inlet
Fuel injection plunger
X
Fuel oil outlet
F
Fuel oil drain
AD
ZT 4114 C
Hydraulic piston
Umbrella sealing
Hydraulic piston
Hydraulic piston
Return to tank
Distributor block
To AE
LS 4112 AH
Hydraulic Power Supply unit
Safety and accumulator block
PT 1201-1 C
PT 1201-2 C
PT 1201-3 C
ZV 1202 B
ZV 1202 A
PT 1208-1 C
PT 1208-2 C
PT 1233 C
To AE
FT 1234 AH
Engine driven pumps
Electrically driven pumps
PT 1204-1 ZL
PT 1204-2 ZL
PT 1204-3 ZL
Step-up gear
RZ
Alarm box
To AE
LS 1235 AH 360
LS 1236 AH Z 361
RY

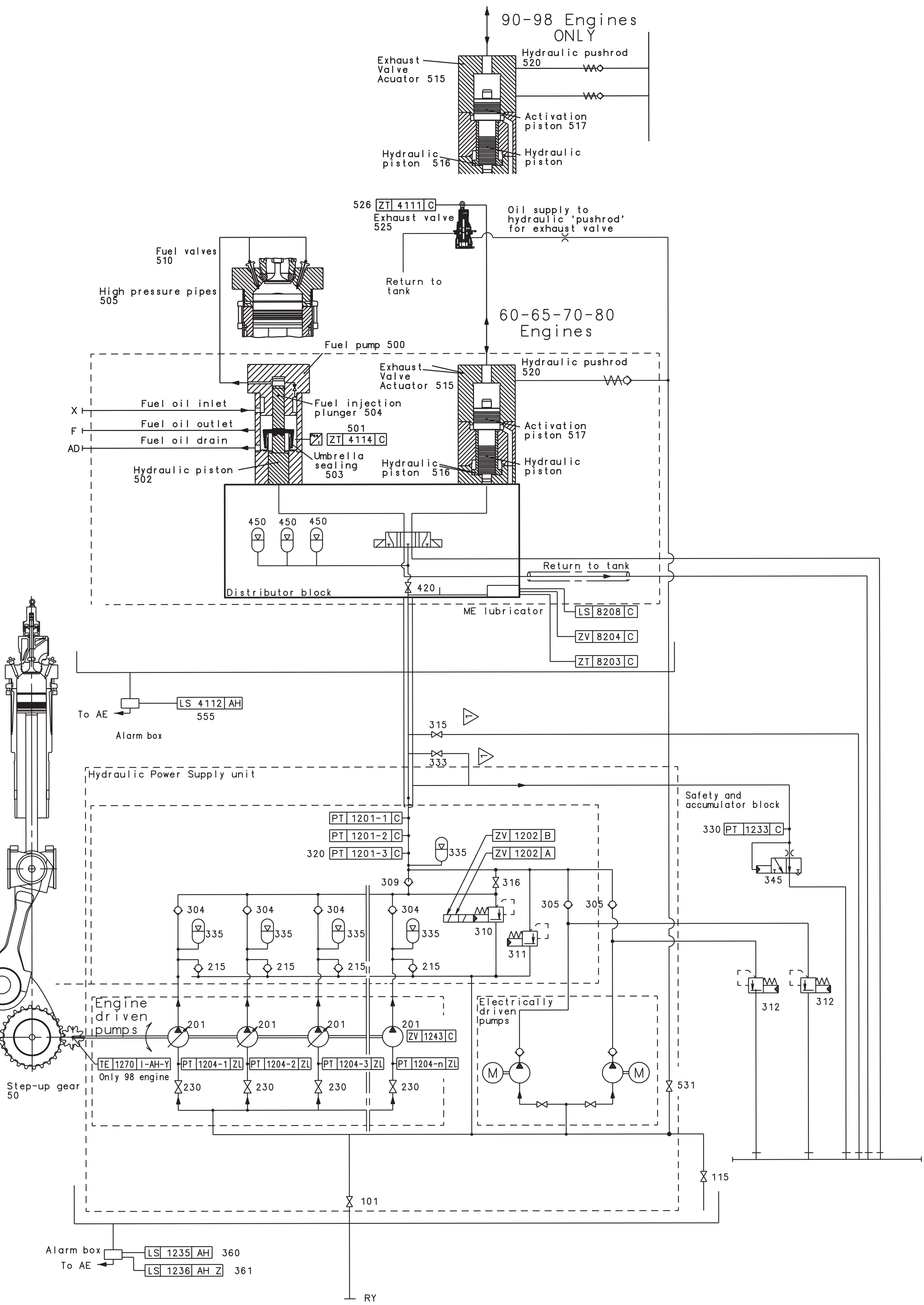
Gear Driven HPS,ELFI and ELVA, Separate LPS

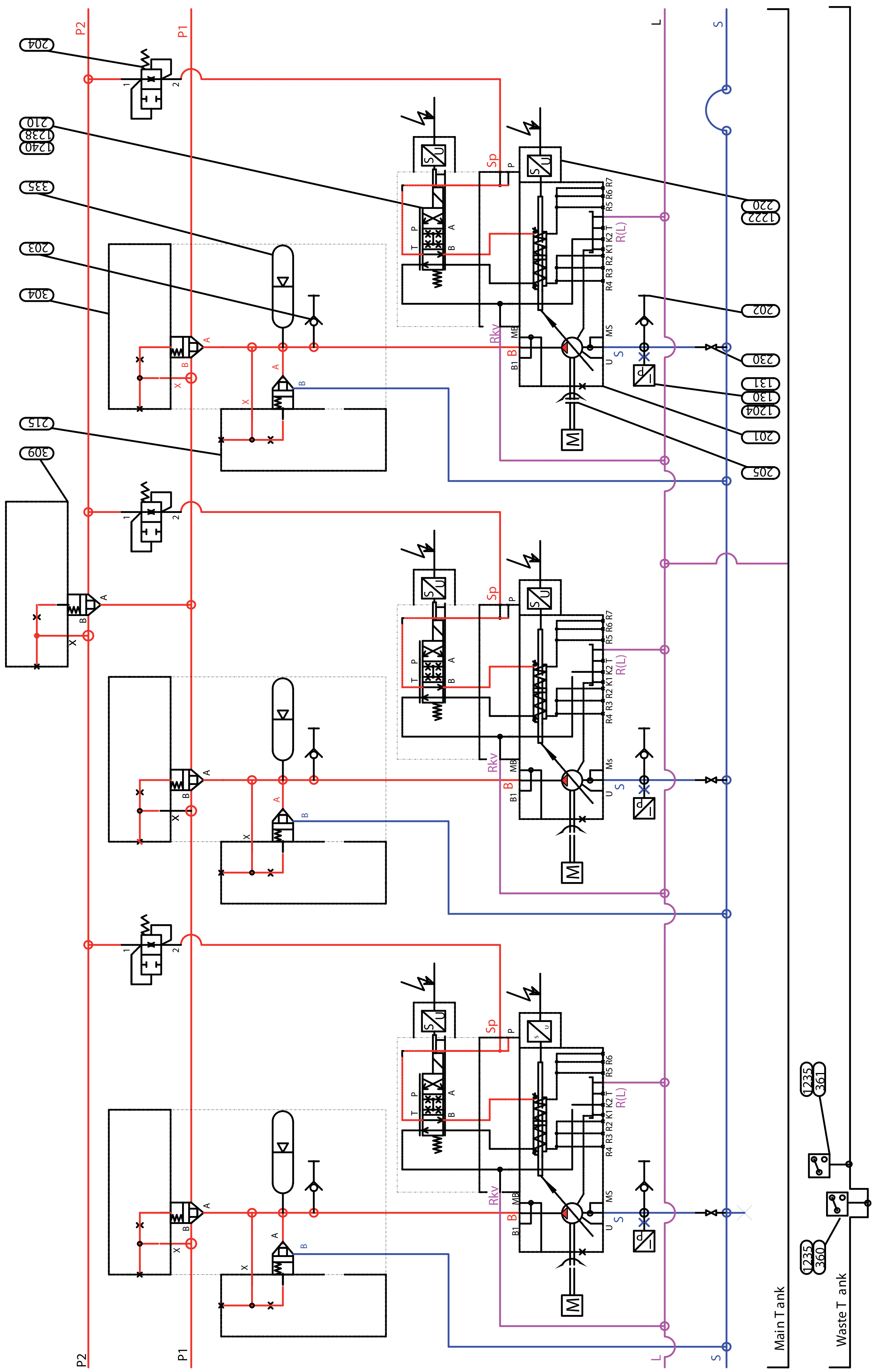



LPS
P2
P1
L
S
305
285
HS-036-A931-3-E (8,6 kW arrangement)
HS-036-A987-3-A (21 kW arrangement)
Valid for pumps with drain connection only
Pressure e at 100% MCR 1. 7 - 2.2 bar
Pressure e at 100% MCR - 210 bar
Pressure e at 100% MCR - 210. 2 bar
Pressur e 1.7 - 2.2 bar
Opening pressur e - 175 bar
312a
312
276a
276
340
155
316
321
320
1201
310
310a
1202
310b
Opening pressur e - 230 bar
339
311
Opening pressur e - 250 bar
315
345
331
330
1233
332
355
1234
Atmospheric pressur e
Double Wal l Pi pe
Main Tank
Wast e Tank

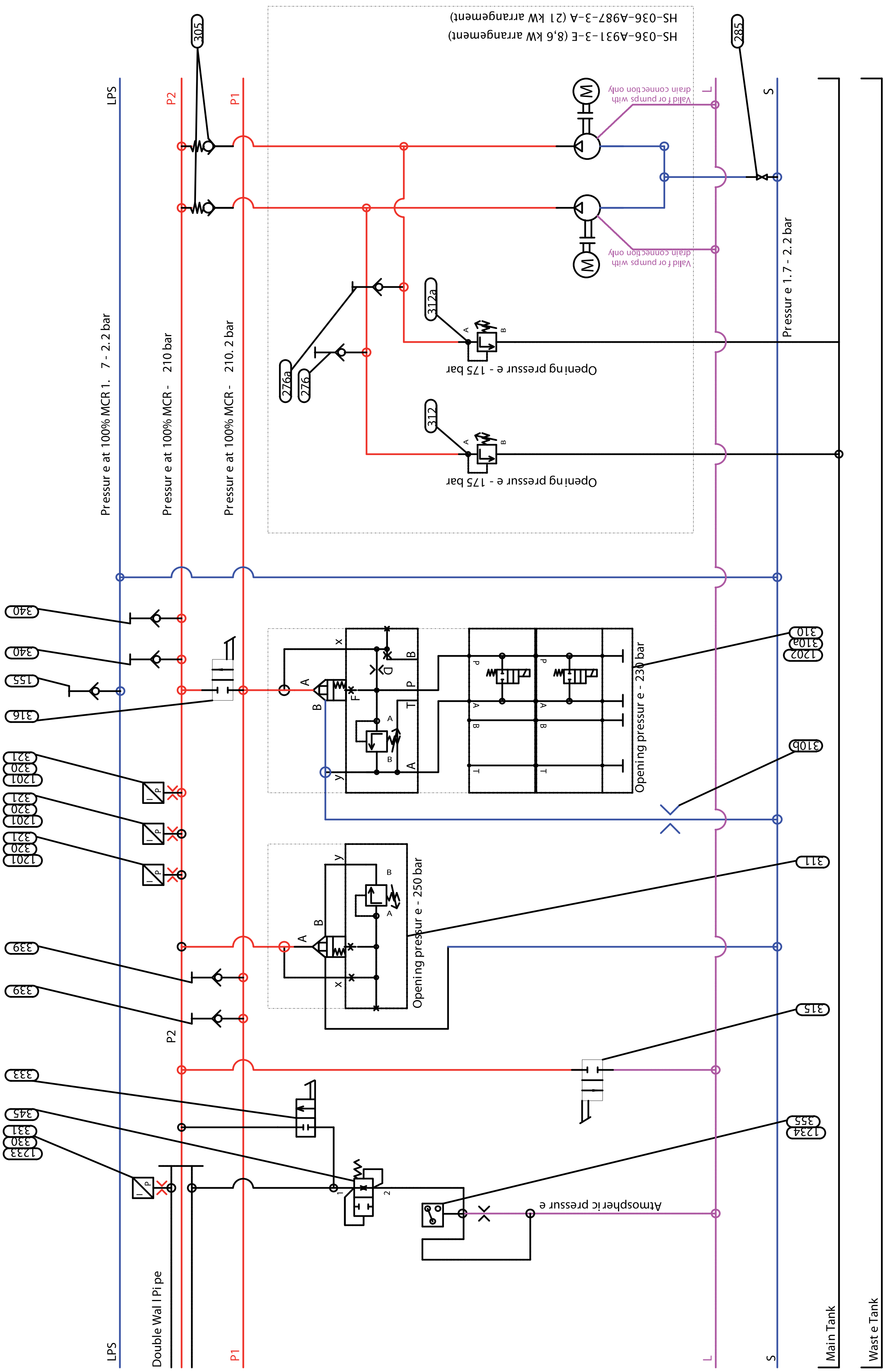

LPS
L-atmospheric pressure
P2
Main Tank
Waste Tank
High Pressure Pipe Drain
ELVA Actuator - Drain
Exh. Valve Top - Drain
ELFI Pump - Lube Oil Drain
Fuel/Lube Oil Drain
Fuel Oil Drain
Fuel Drain
Fuel Circulation
Fuel Inlet
Drain Box - Common for all Hydraulic Cylinder Units
ME Cyl. Lubricator
520
540
530
515
517
516
545
470
475
4108
531
456
450
425
420
405
421
4112
555
430
431
455
435
560
528
527
501
4114
4115
526
4111
525
465
510
505
500
504
503
502
550
440
445
4101
4102

Gear Driven HPS and FIVA, Separate LPS

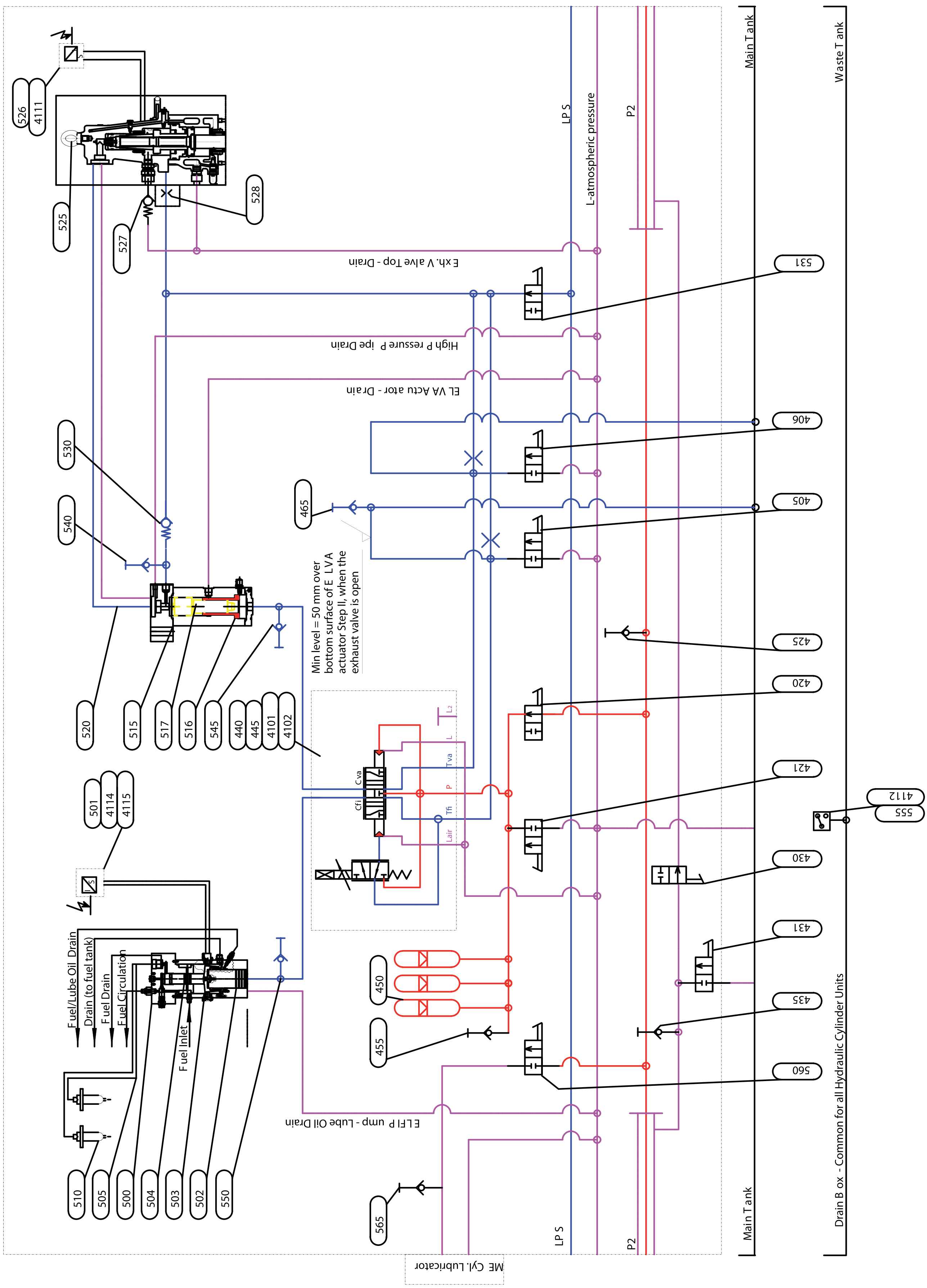



P2
P1
L
S
204
210
1238
1240
335
203
304
215
309
220
1222
202
230
131
130
1204
201
205
Sp
Rkv
R(L)
1235
361
1235
360
Main Tank
Waste Tank

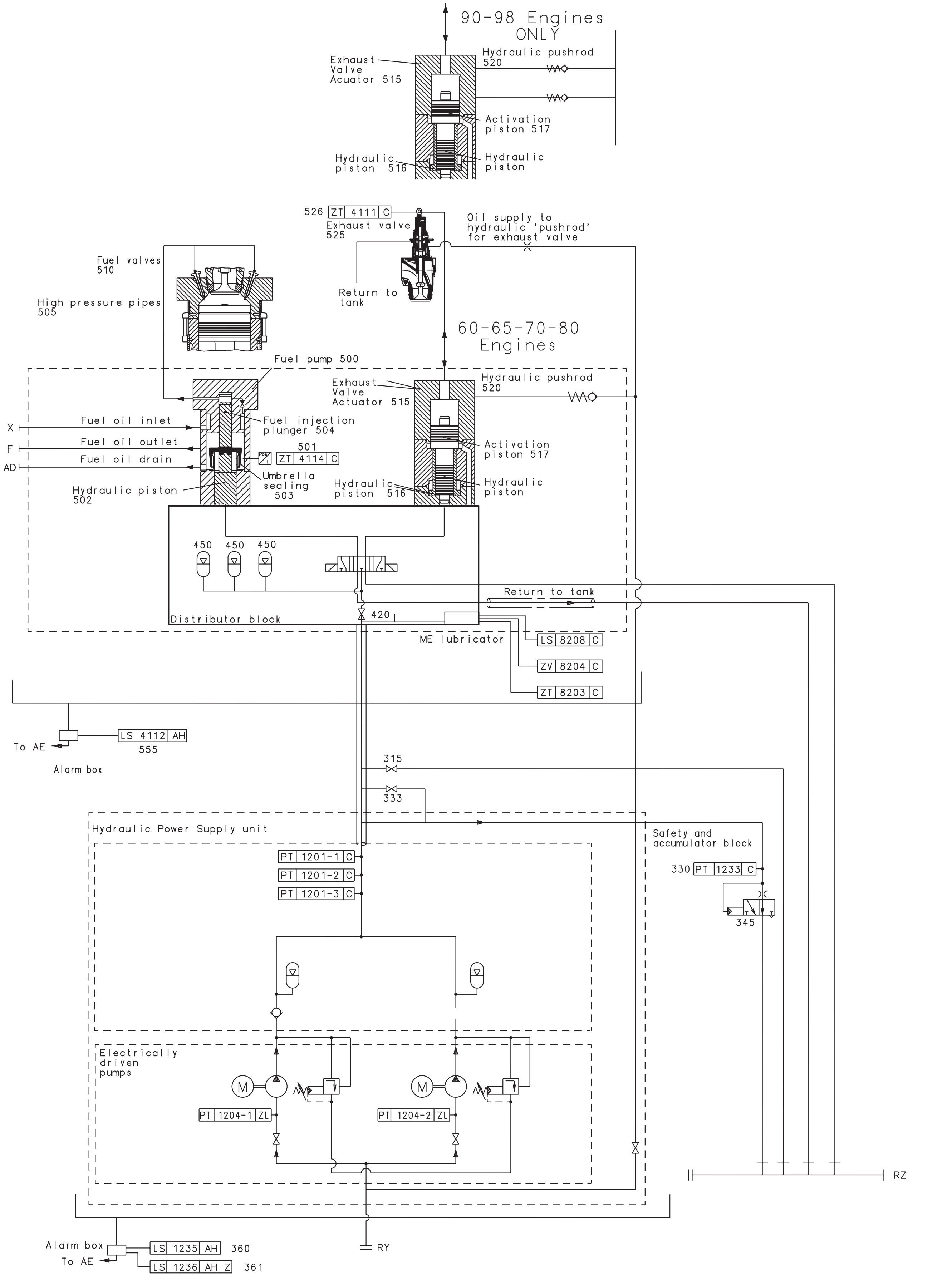
Gear Driven HPS and FIVA, Separate LPS



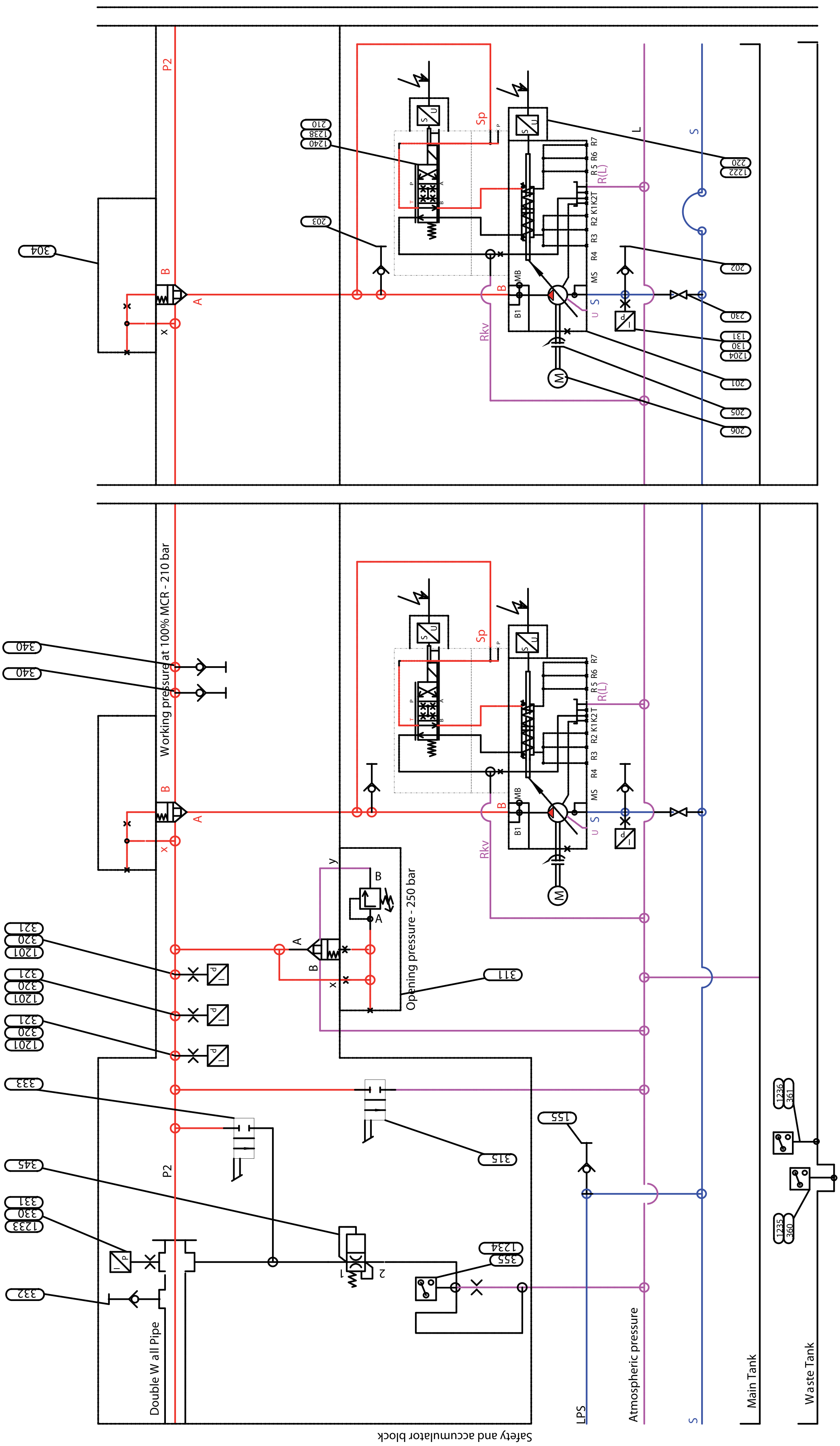
Gear Driven HPS and FIVA, Separate LPS

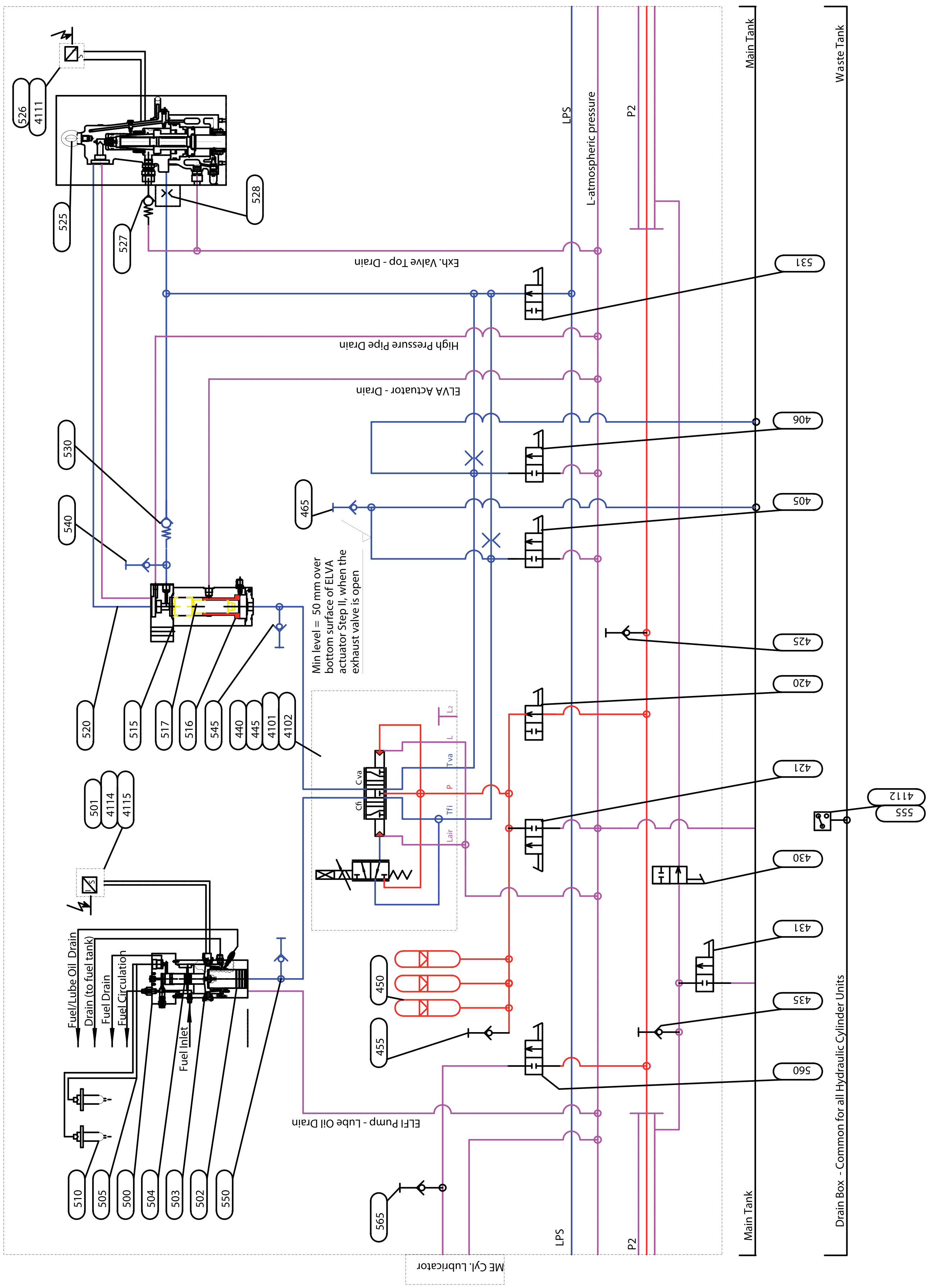


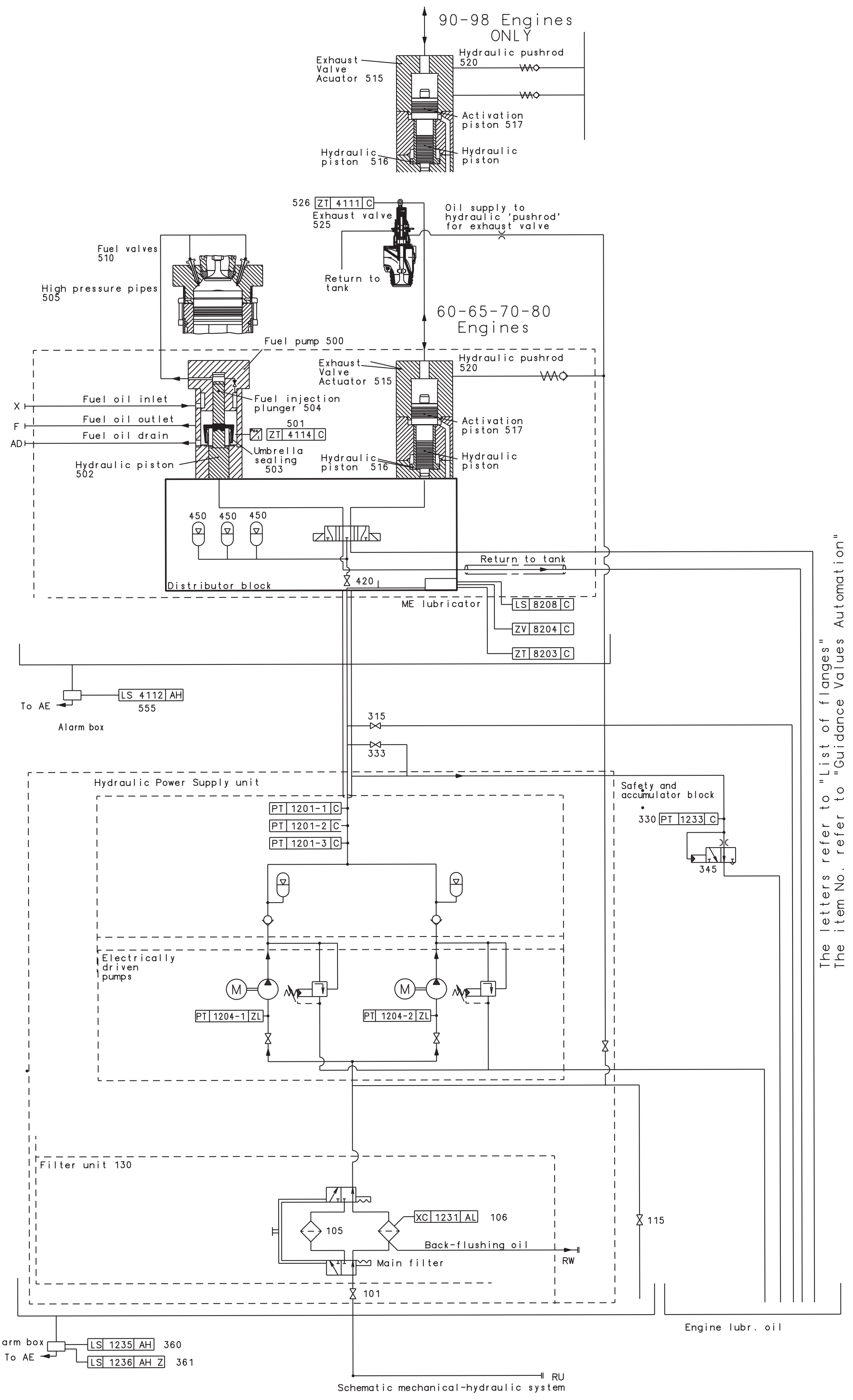
El Driven HPS and FIVA, Separate LPS

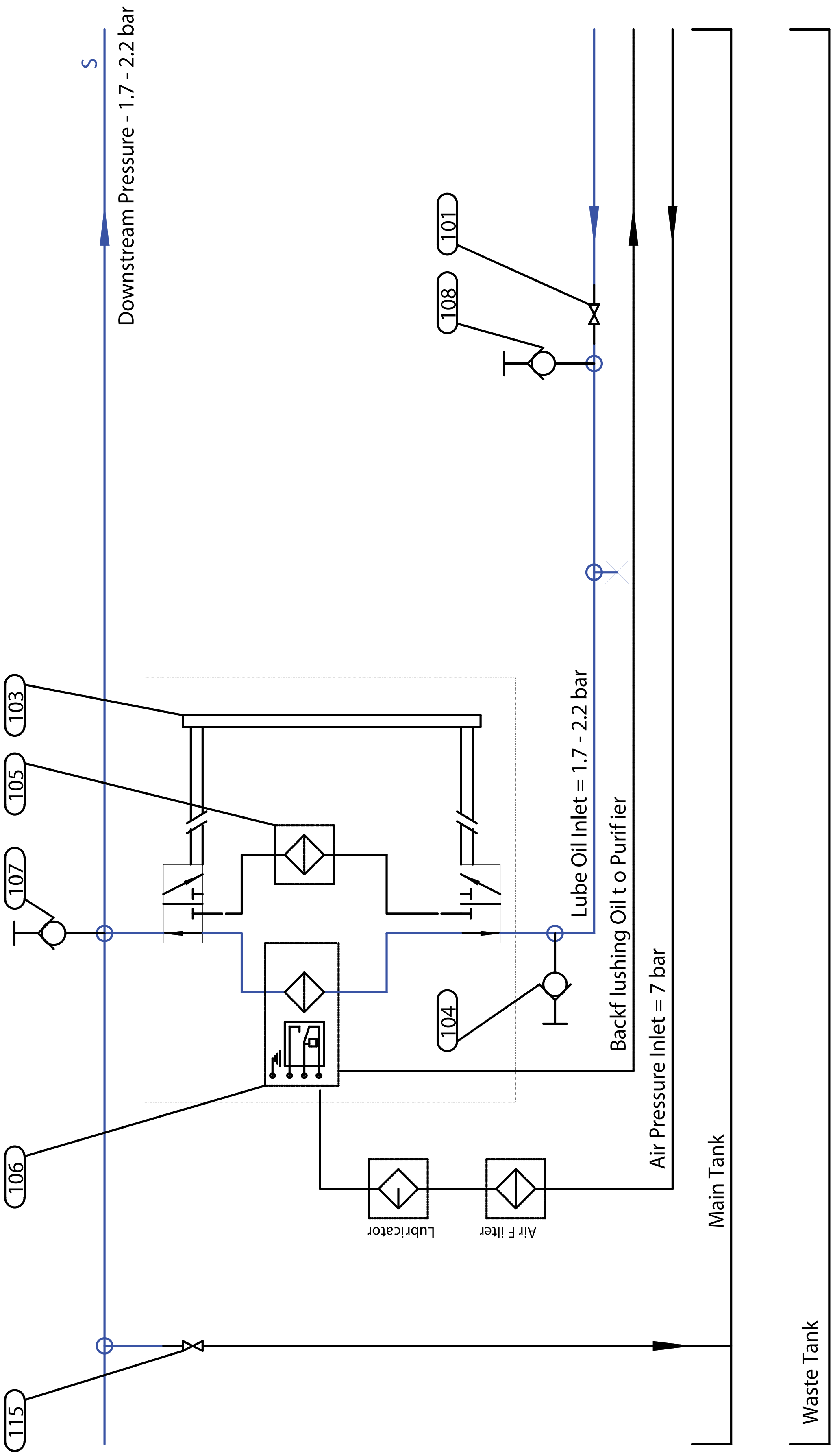


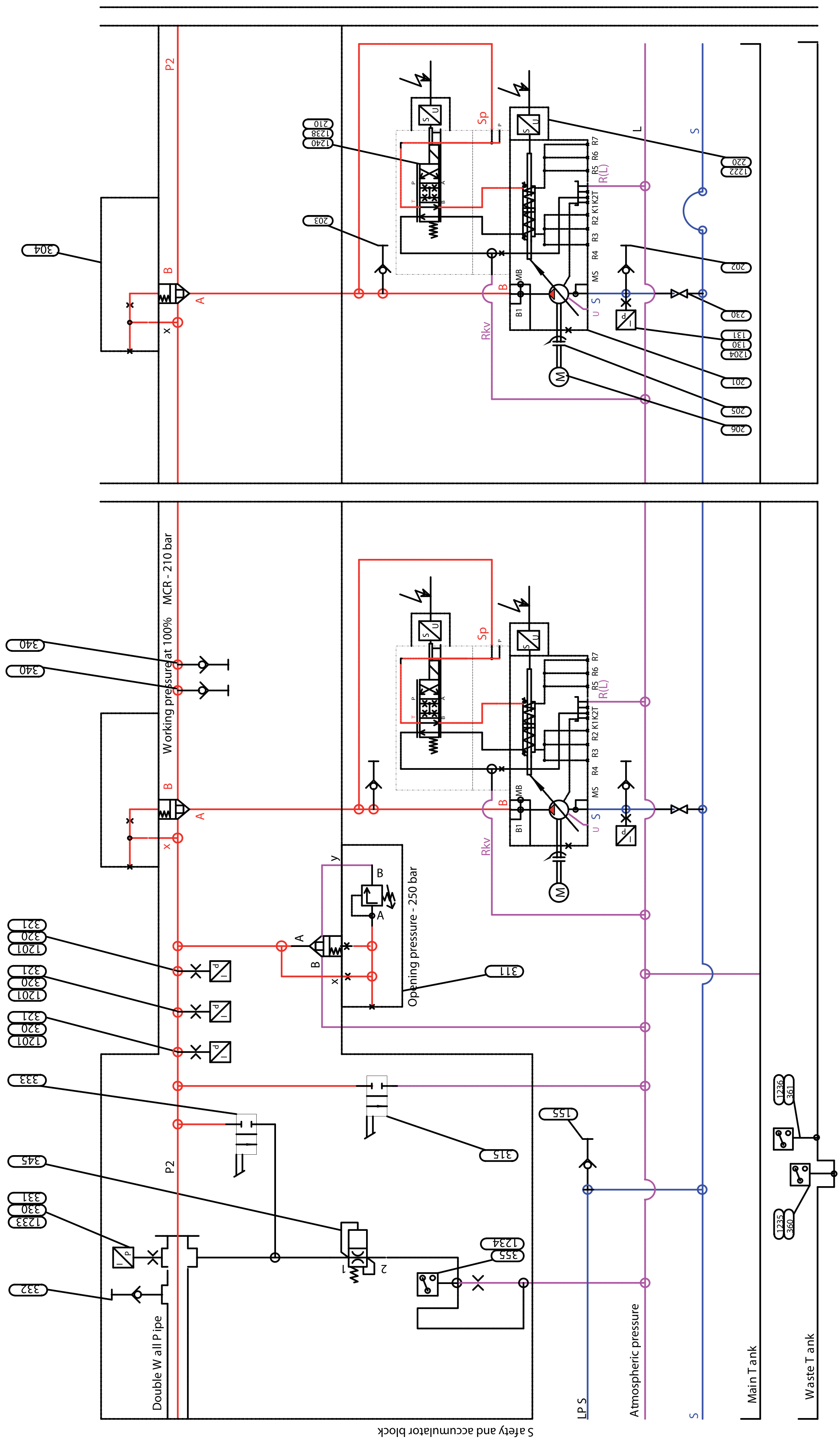
El Driven HPS and FIVA, Separate LPS

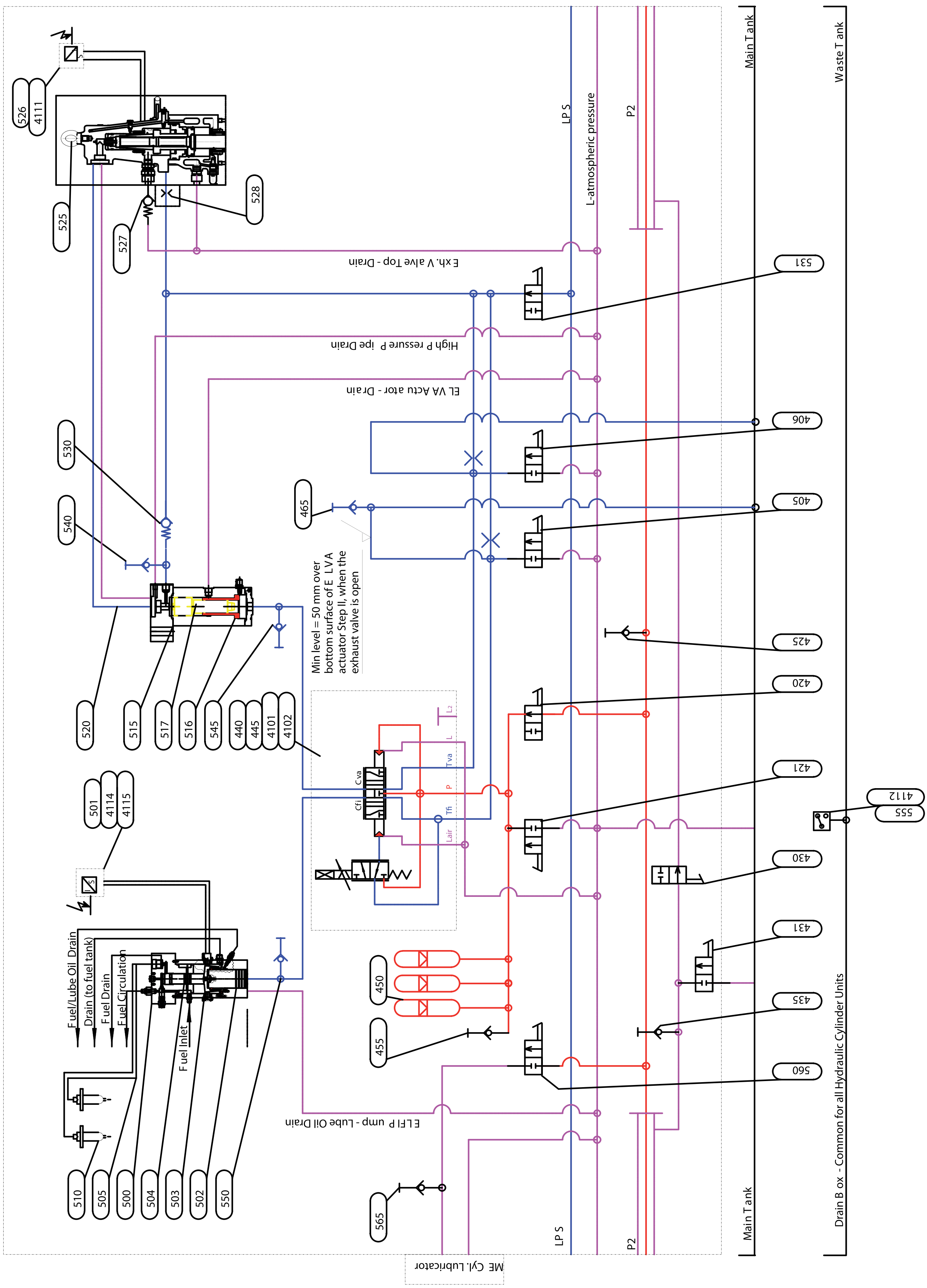


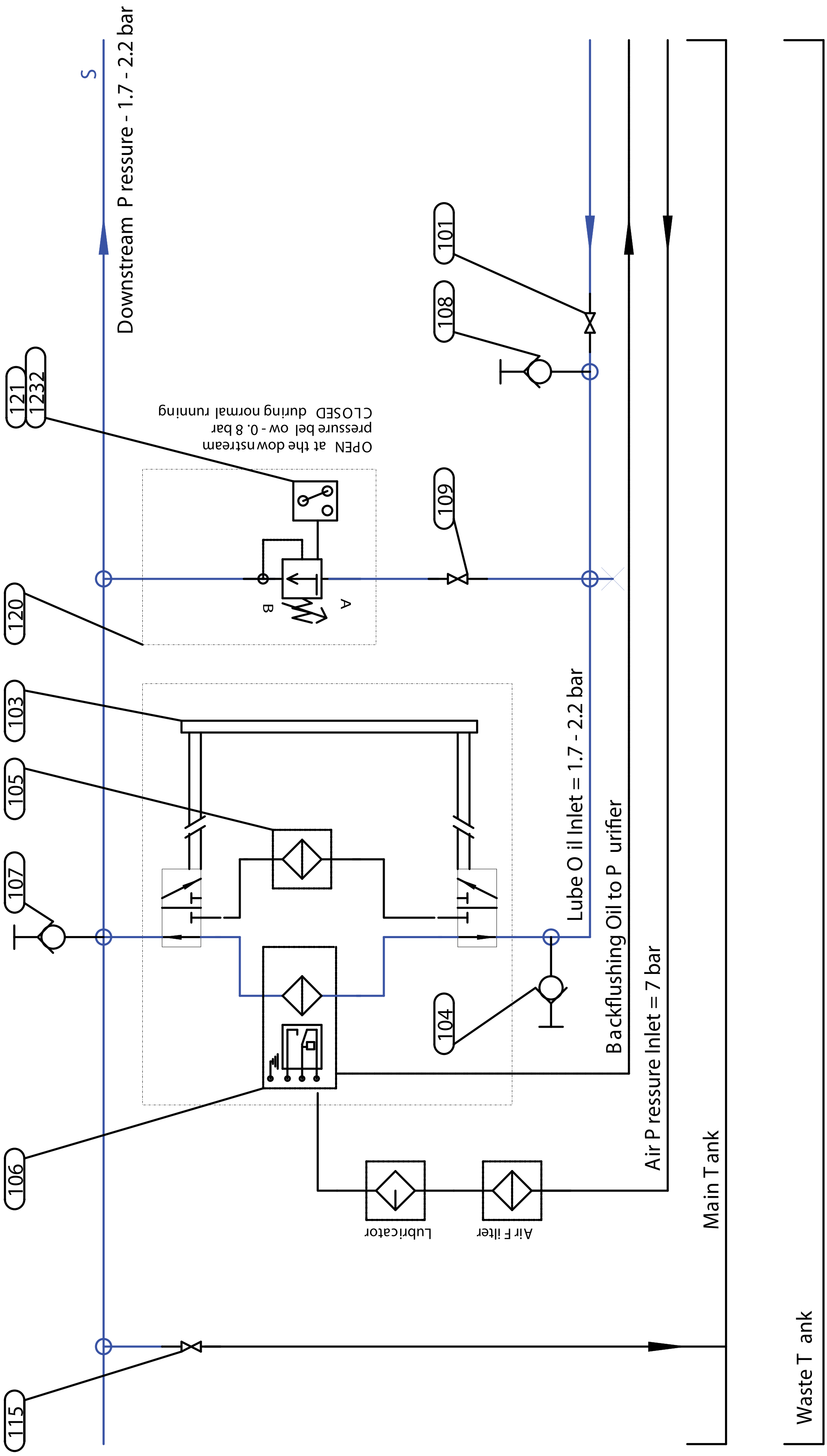

Main Tank
Waste Tank
LPS
L-atmospheric pressure
P2
Exh. Valve Top - Drain
High Pressure Pipe Drain
ELVA Actuator - Drain
Min level = 50 mm over bottom surface of ELVA actuator Step II, when the exhaust valve is open
ELFI Pump - Lube Oil Drain
ME Cyl. Lubricator
Drain Box - Common for all Hydraulic Cylinder Units
Fuel/Lube Oil Drain
Drain (to fuel tank)
Fuel Drain
Fuel Circulation
Fuel Inlet
526
4111
525
527
528
530
540
465
520
515
517
516
545
440
445
4101
4102
501
4114
4115
510
505
500
504
503
502
550
450
455
565
531
406
405
425
420
421
430
431
435
560
4112
555
Cva
Cfi
Tva
Tfi
Lair


90-98 Engines ONLY
Exhaust Valve Acuator 515
Hydraulic pushrod 520
Activation piston 517
Hydraulic piston 516
Hydraulic piston
526 ZT 4111 C
Exhaust valve 525
Oil supply to hydraulic 'pushrod' for exhaust valve
Return to tank
Fuel valves 510
High pressure pipes 505
60-65-70-80 Engines
Fuel pump 500
Fuel oil inlet
Fuel oil outlet
Fuel oil drain
Fuel injection plunger 504
501
ZT 4114 C
Umbrella sealing 503
Hydraulic piston 502
X
F
AD
450
Return to tank
420
Distributor block
ME lubricator
LS 8208 C
ZV 8204 C
ZT 8203 C
To AE
LS 4112 AH
555
Alarm box
315
333
Hydraulic Power Supply unit
Safety and accumulator block
330 PT 1233 C
345
PT 1201-1 C
PT 1201-2 C
PT 1201-3 C
Electrically driven pumps
M
PT 1204-1 ZL
PT 1204-2 ZL
Filter unit 130
XC 1231 AL
106
105
Back-flushing oil
Main filter
RW
115
101
Engine lubr. oil
Alarm box
To AE
LS 1235 AH
360
LS 1236 AH Z
361
RU
Schematic mechanical-hydraulic system
The letters refer to "List of flanges"
The item No. refer to "Guidance Values Automation"

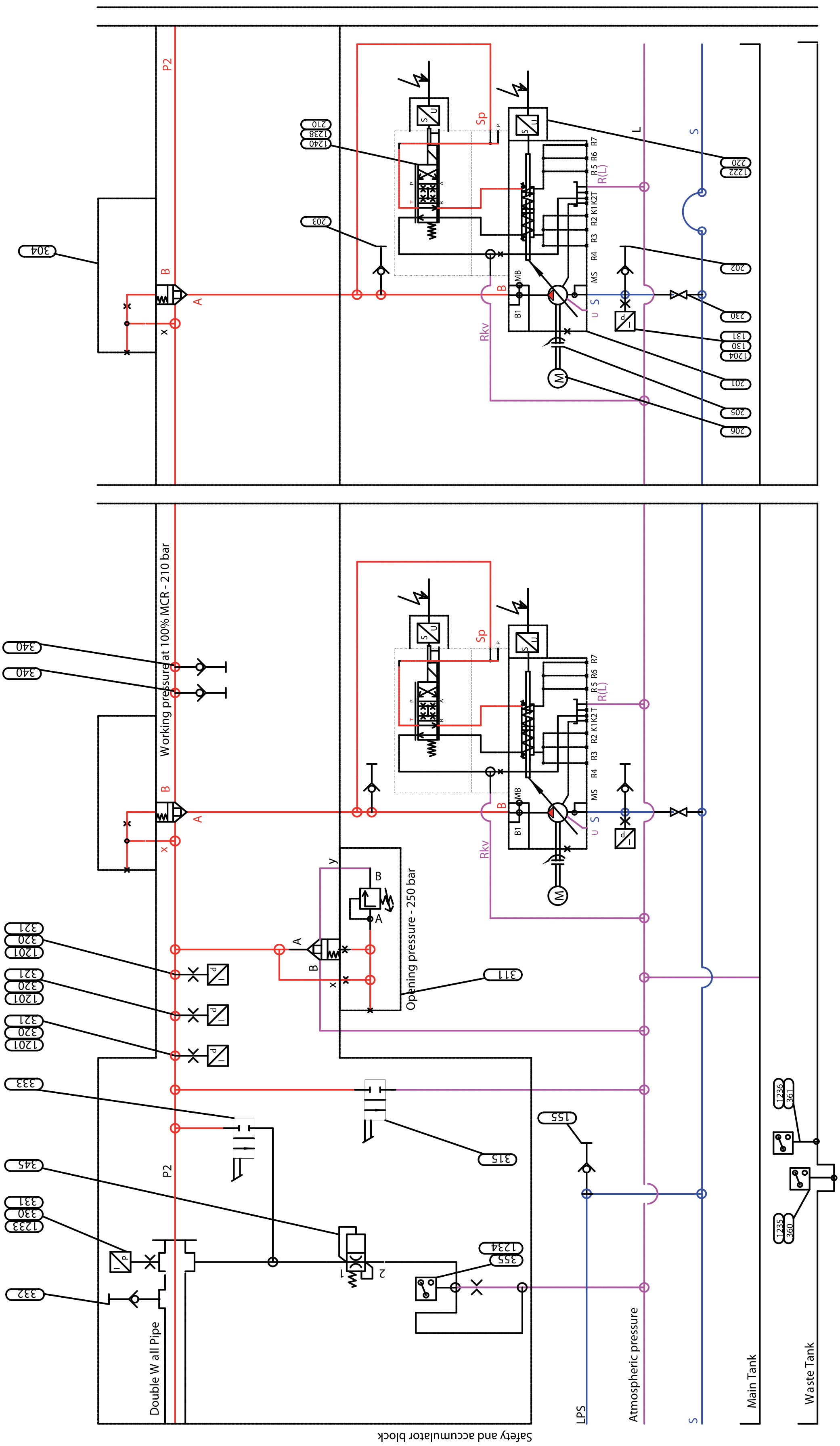

S
Downstream Pressure - 1.7 - 2.2 bar
101
108
103
105
107
104
106
115
Lube Oil Inlet = 1.7 - 2.2 bar
Backflushing Oil to Purifier
Air Pressure Inlet = 7 bar
Main Tank
Waste Tank
Lubricator
Air Filter

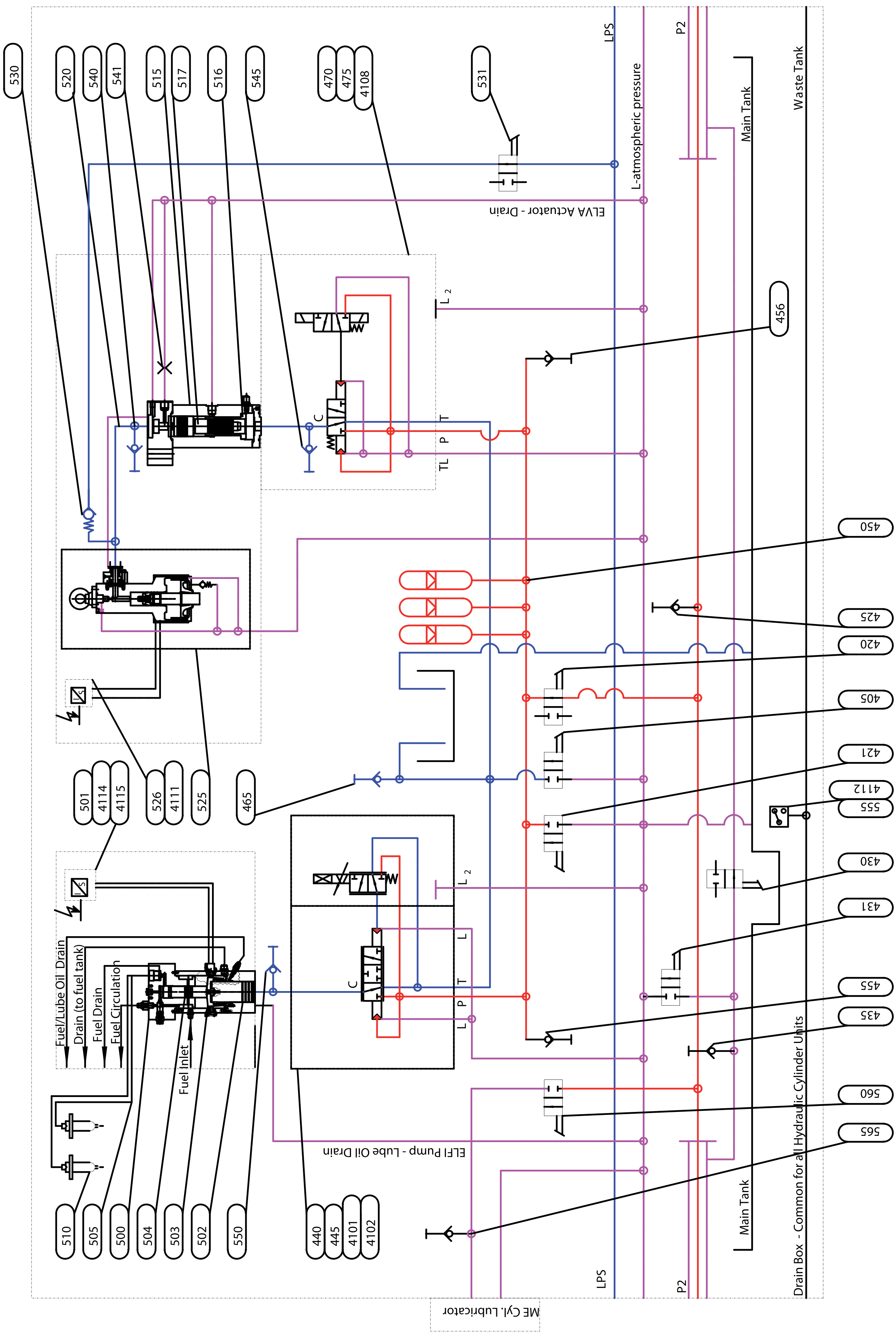

Working pressure at 100% MCR - 210 bar
Opening pressure - 250 bar
Double Wall Pipe
Atmospheric pressure
Main Tank
Waste Tank
Safety and accumulator block
LPS


Main Tank
Waste Tank
LP S
L-atmospheric pressure
P2
Exh. Valve Top - Drain
High Pressure Pipe Drain
ELVA Actuator - Drain
ELFI Pump - Lube Oil Drain
Min level = 50 mm over bottom surface of ELVA actuator Step II, when the exhaust valve is open
Fuel/Lube Oil Drain
Drain (to fuel tank)
Fuel Drain
Fuel Circulation
Fuel Inlet
Drain Box - Common for all Hydraulic Cylinder Units
ME Cyl. Lubricator
Cva
Cfi
Tva
Tfi
Lair
526
4111
525
527
528
530
540
465
520
515
517
516
545
440
445
4101
4102
501
4114
4115
510
505
500
504
503
502
550
450
455
565
531
406
405
425
420
421
4112
555
430
431
435
560

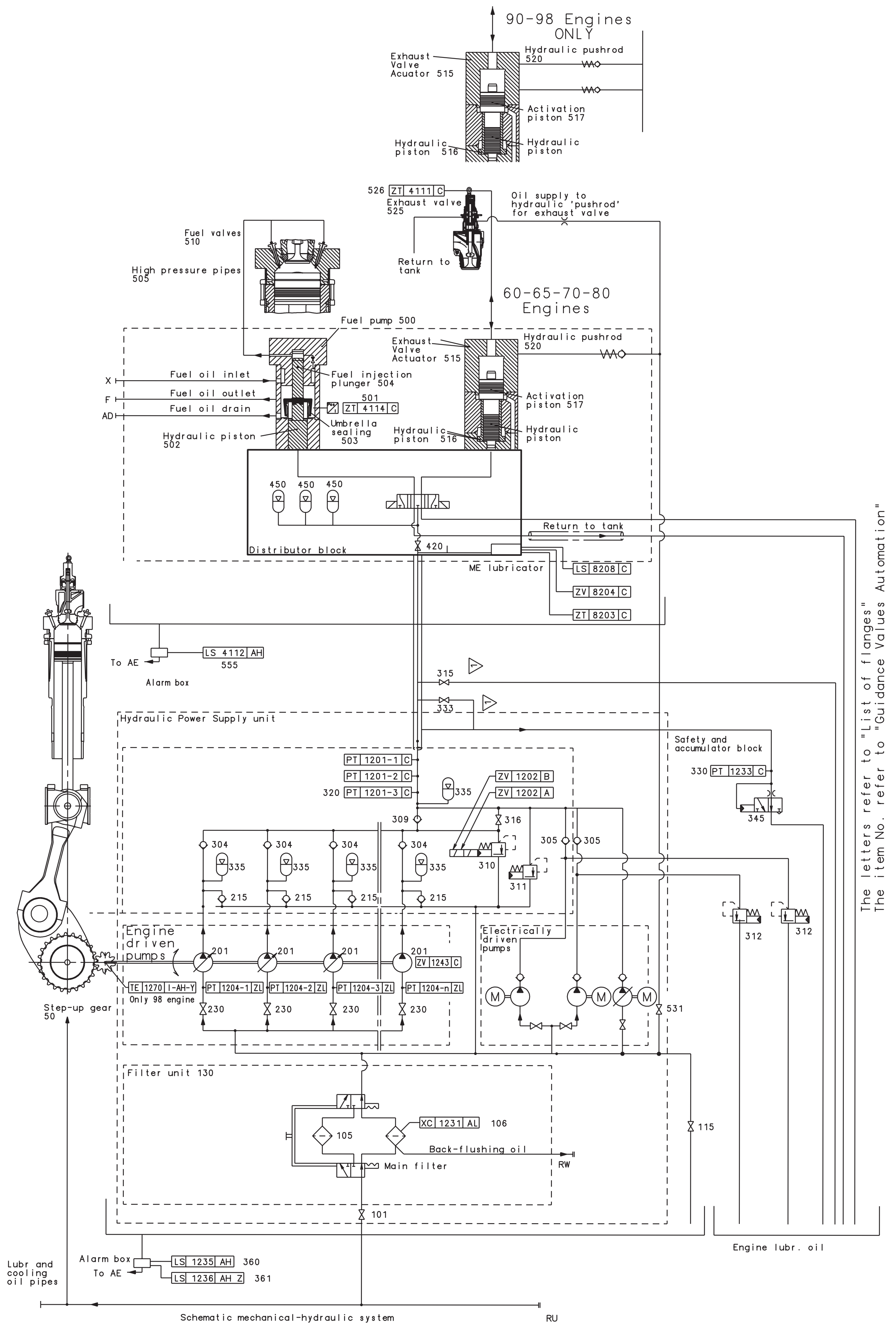


Downstream Pressure - 1.7 - 2.2 bar
S
OPEN at the downstream pressure below - 0.8 bar
CLOSED during normal running
A
B
Lube Oil Inlet = 1.7 - 2.2 bar
Backflushing Oil to Purifier
Air Pressure Inlet = 7 bar
Main Tank
Waste Tank
Lubricator
Air Filter
101
108
109
104
121
1232
120
103
105
107
106
115

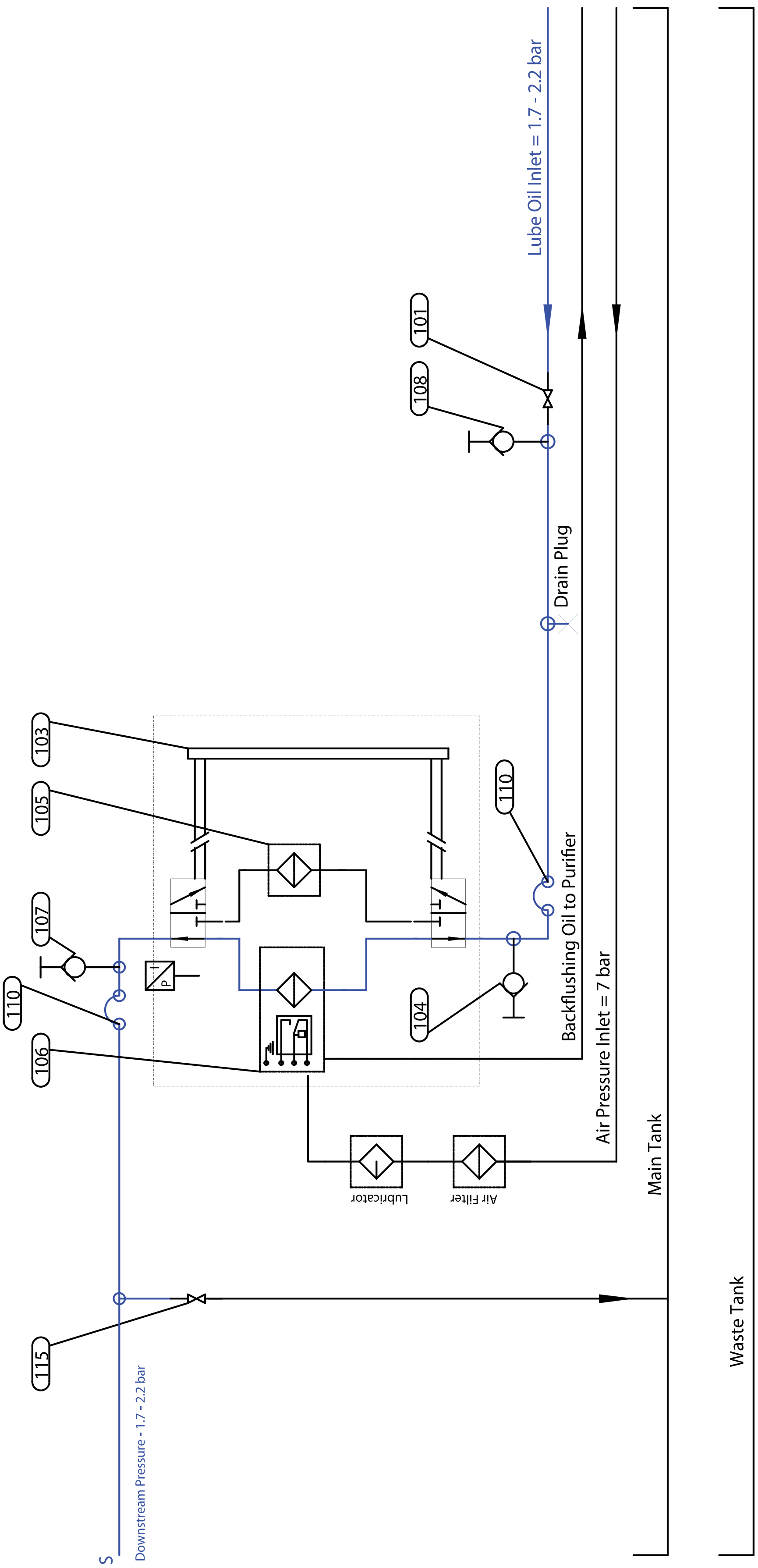

Working pressure at 100% MCR - 210 bar
Opening pressure - 250 bar
Double Wall Pipe
Safety and accumulator block
LPS
Atmospheric pressure
Main Tank
Waste Tank

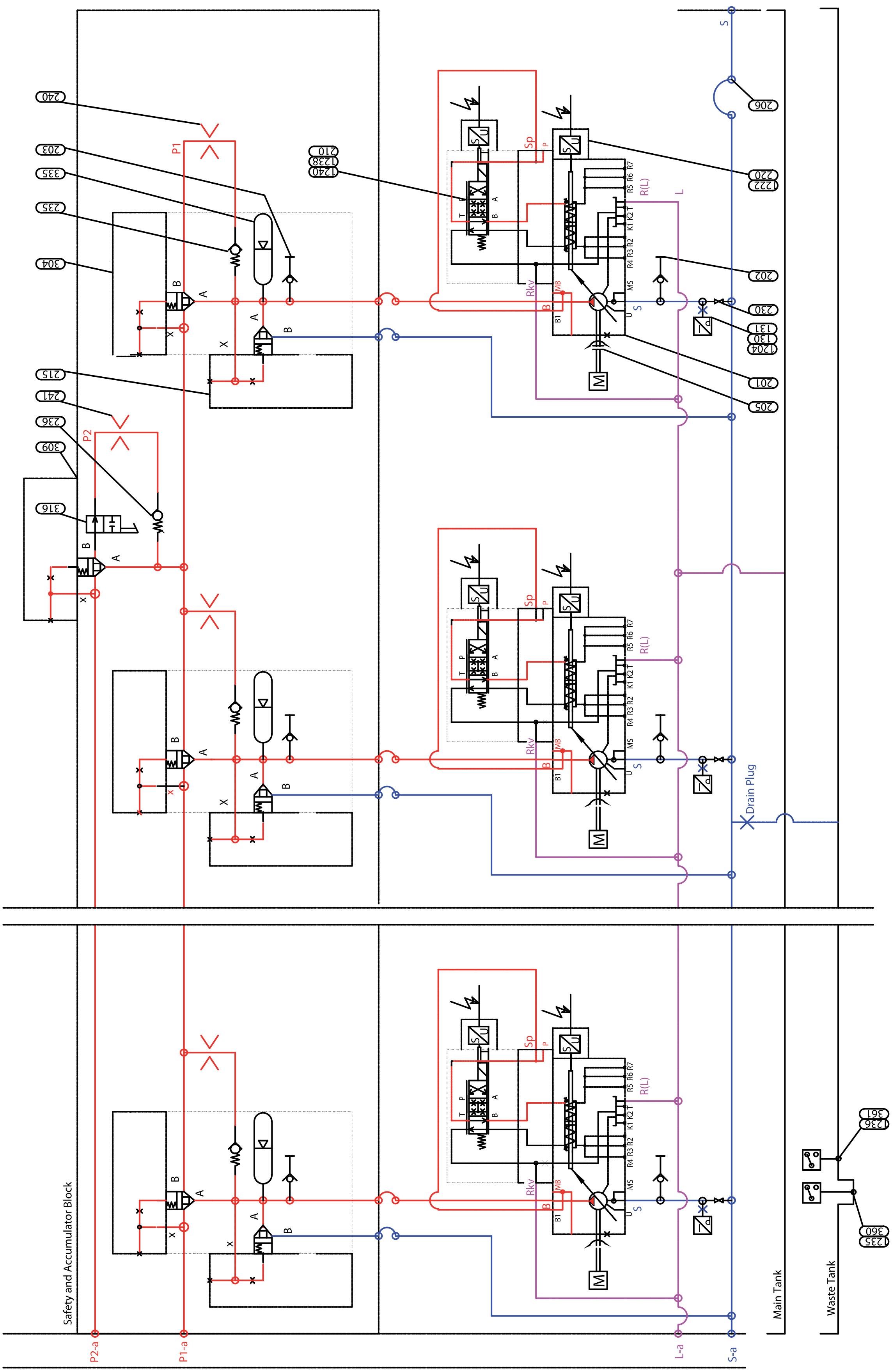


530
520
540
541
515
517
516
545
470
475
4108
531
LPS
L-atmospheric pressure
P2
Main Tank
Waste Tank
ELVA Actuator - Drain
456
450
425
420
405
421
4112
555
430
431
455
435
560
565
501
4114
4115
526
4111
525
465
Fuel/Lube Oil Drain
Drain (to fuel tank)
Fuel Drain
Fuel Circulation
Fuel Inlet
510
505
500
504
503
502
550
440
445
4101
4102
ELFI Pump - Lube Oil Drain
Drain Box - Common for all Hydraulic Cylinder Units
ME Cyl. Lubricator

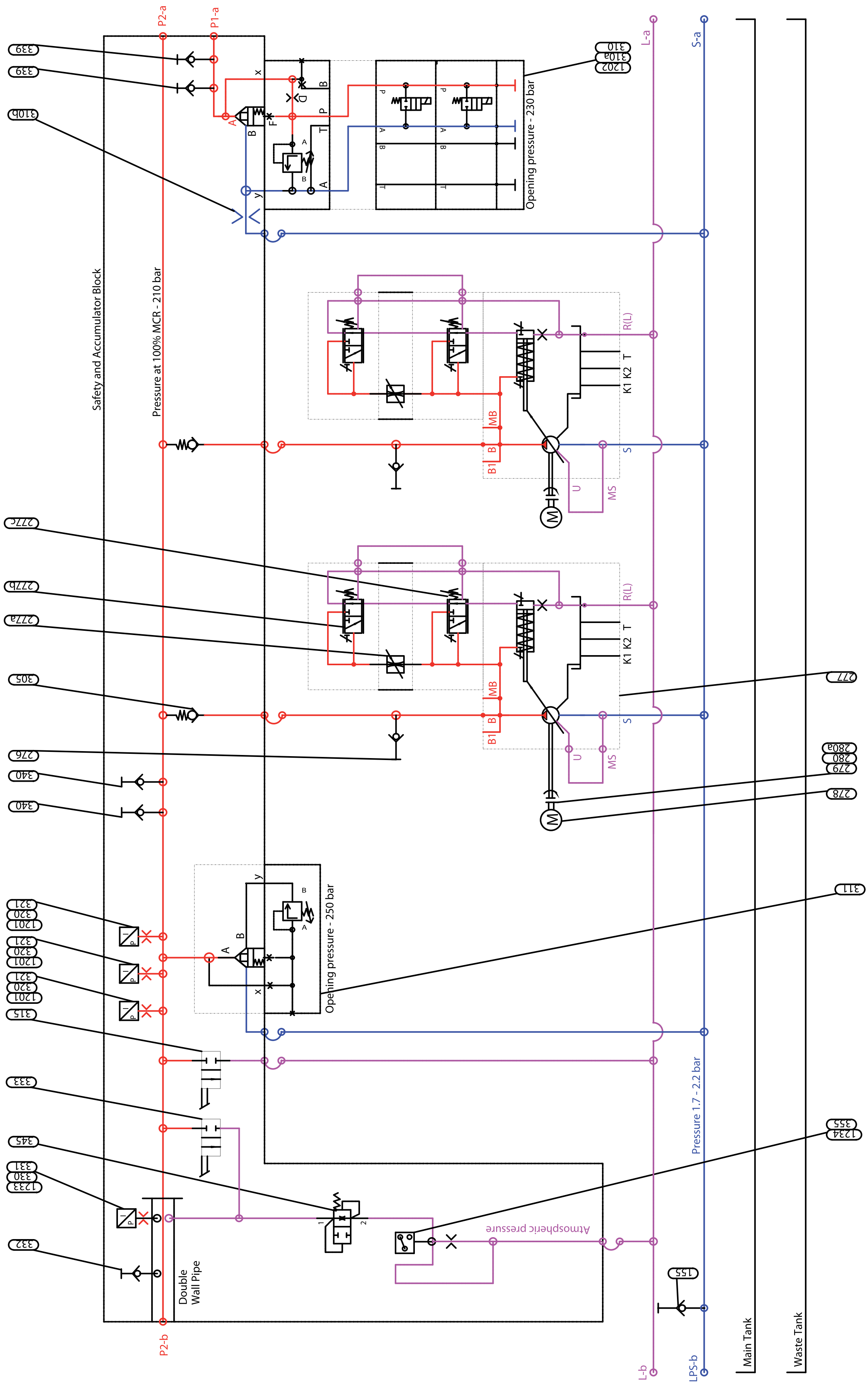


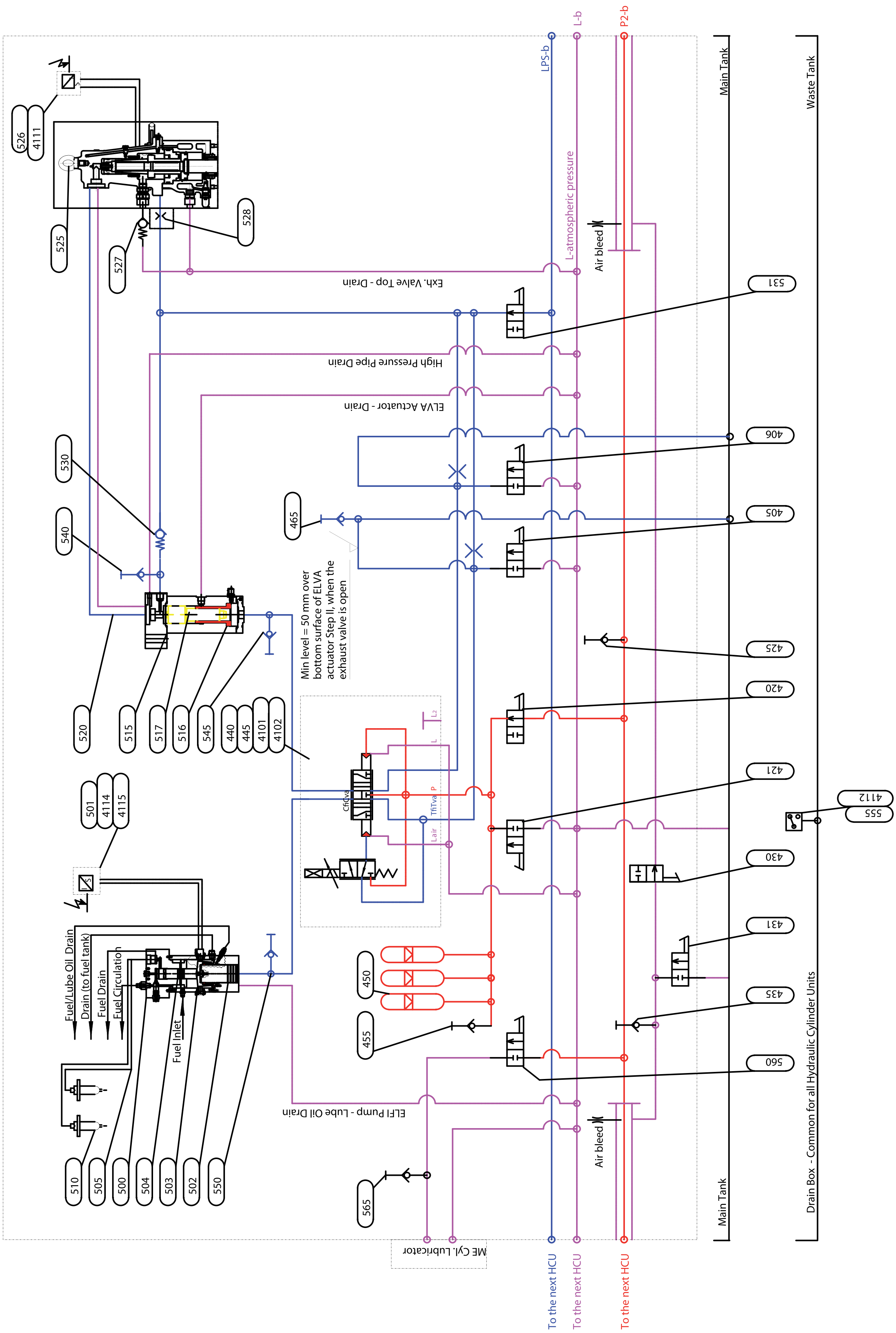
90-98 Engines ONLY
Exhaust Valve Acuator 515
Hydraulic pushrod 520
Activation piston 517
Hydraulic piston 516
Hydraulic piston
526 ZT 4111 C
Exhaust valve 525
Oil supply to hydraulic 'pushrod' for exhaust valve
Return to tank
Fuel valves 510
High pressure pipes 505
60-65-70-80 Engines
Fuel pump 500
Fuel oil inlet
Fuel oil outlet
Fuel oil drain
Fuel injection plunger 504
501 ZT 4114 C
Umbrella sealing 503
Hydraulic piston 502
Distributor block
Return to tank
ME lubricator
LS 8208 C
ZV 8204 C
ZT 8203 C
To AE
Alarm box
LS 4112 AH
555
Hydraulic Power Supply unit
Safety and accumulator block
330 PT 1233 C
345
PT 1201-1 C
PT 1201-2 C
320 PT 1201-3 C
ZV 1202 B
ZV 1202 A
Engine driven pumps
Electrically driven pumps
ZV 1243 C
TE 1270 I-AH-Y
Only 98 engine
PT 1204-1 ZL
PT 1204-2 ZL
PT 1204-3 ZL
PT 1204-n ZL
Step-up gear 50
Filter unit 130
XC 1231 AL
106
Back-flushing oil
Main filter
RW
Engine lubr. oil
Lubr and cooling oil pipes
Alarm box
To AE
LS 1235 AH
360
LS 1236 AH Z
361
Schematic mechanical-hydraulic system
RU
The letters refer to "List of flanges"
The item No. refer to "Guidance Values Automation"


Lube Oil Inlet = 1.7 - 2.2 bar
101
108
Drain Plug
103
105
110
107
110
106
104
Backflushing Oil to Purifier
Air Pressure Inlet = 7 bar
Lubricator
Air Filter
Main Tank
Waste Tank
115
Downstream Pressure - 1.7 - 2.2 bar
S

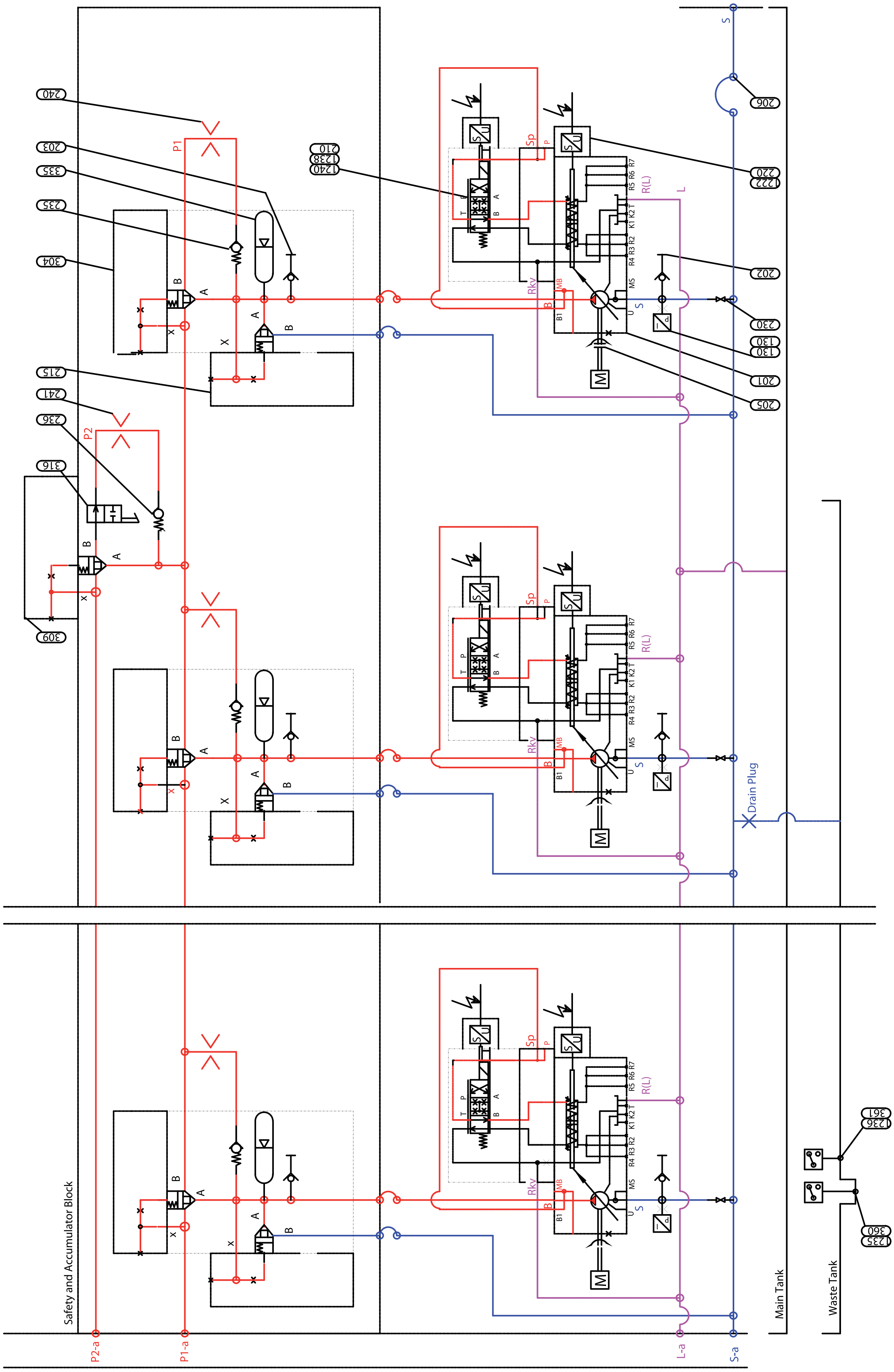

Safety and Accumulator Block
Main Tank
Waste Tank
Drain Plug
P1
P2
P1-a
P2-a
L-a
S-a

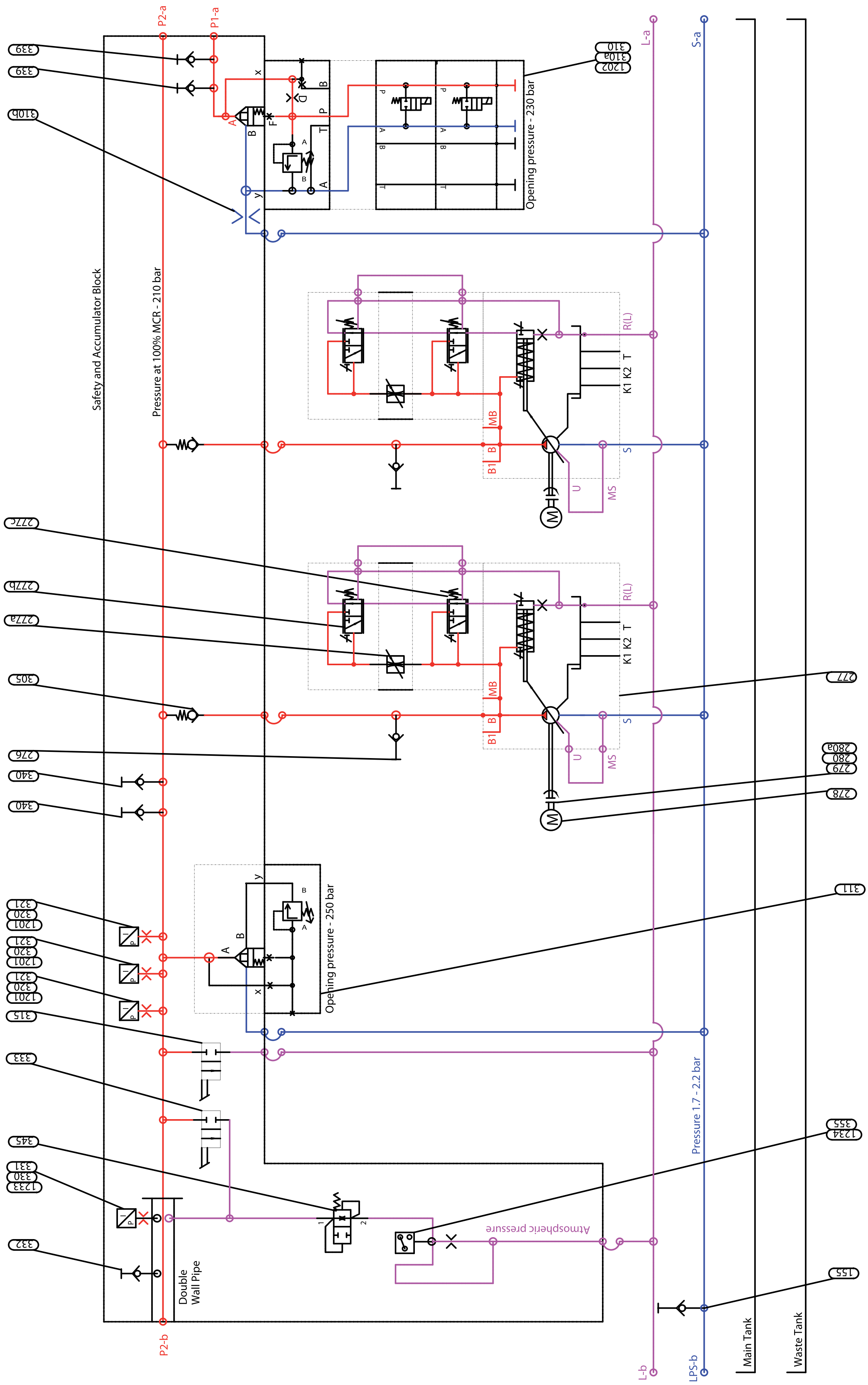
Combined HPS, Common LPS and FIVA



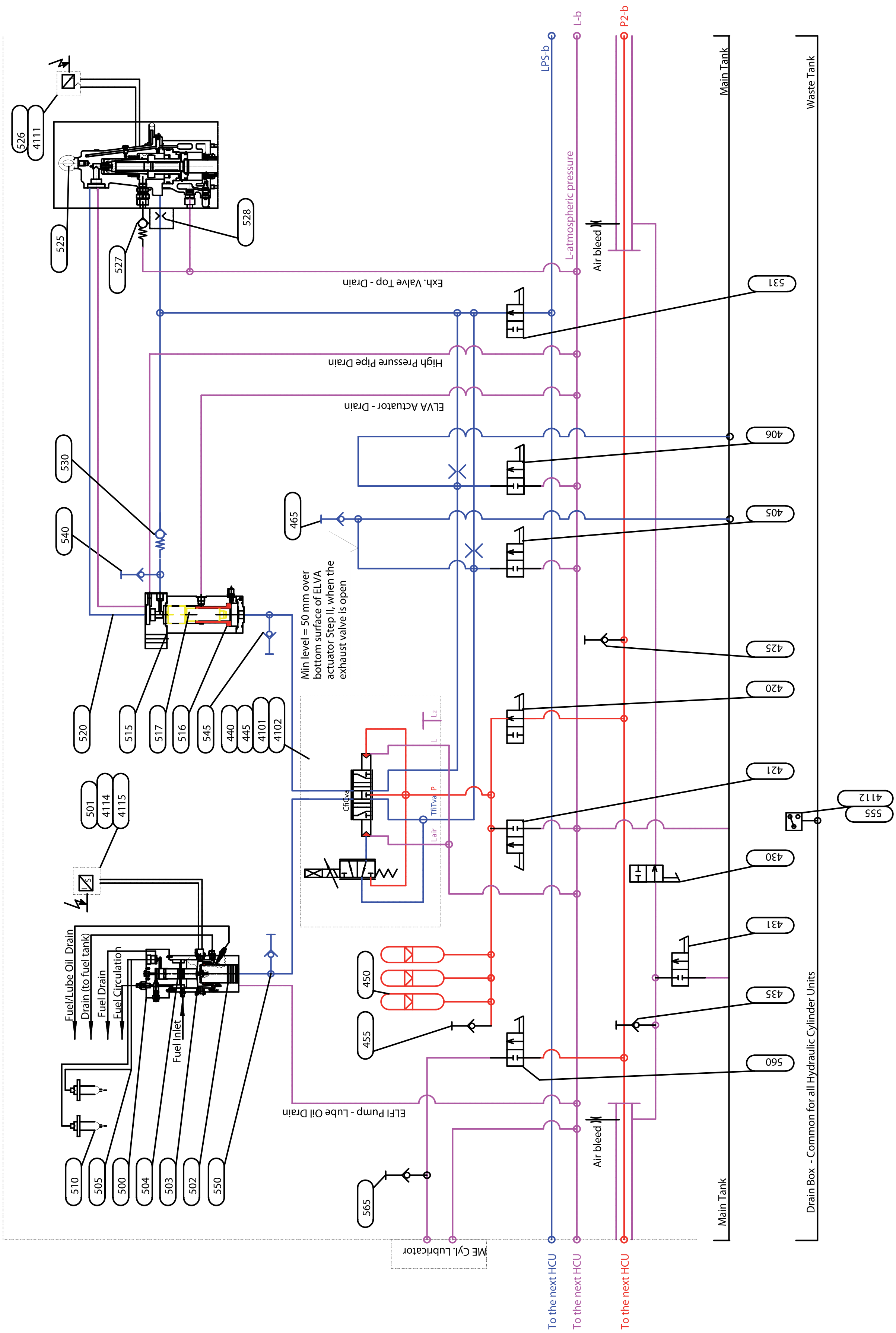

LPS-b
L-b
P2-b
Main Tank
Waste Tank
L-atmospheric pressure
Air bleed
Exh. Valve Top - Drain
High Pressure Pipe Drain
ELVA Actuator - Drain
Min level = 50 mm over bottom surface of ELVA actuator Step II, when the exhaust valve is open
ELFI Pump - Lube Oil Drain
ME Cyl. Lubricator
Fuel/Lube Oil Drain
Drain (to fuel tank)
Fuel Drain
Fuel Circulation
Fuel Inlet
Drain Box - Common for all Hydraulic Cylinder Units
To the next HCU
To the next HCU
To the next HCU
526
4111
525
527
528
530
540
465
531
406
405
425
420
421
4112
555
430
431
435
560
520
515
517
516
545
440
445
4101
4102
501
4114
4115
450
455
565
510
505
500
504
503
502
550

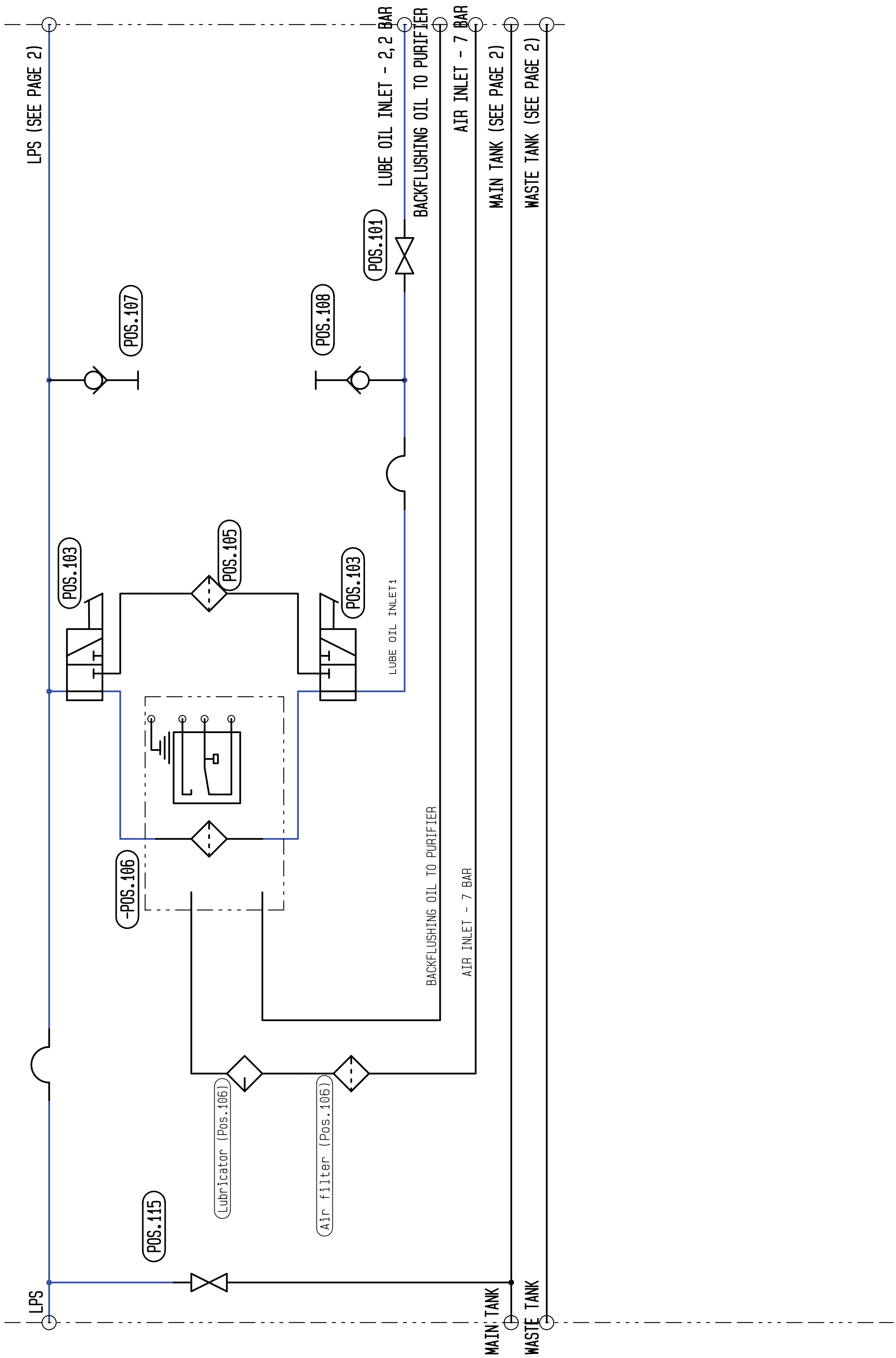
Combined HPS, Separate LPS and FIVA



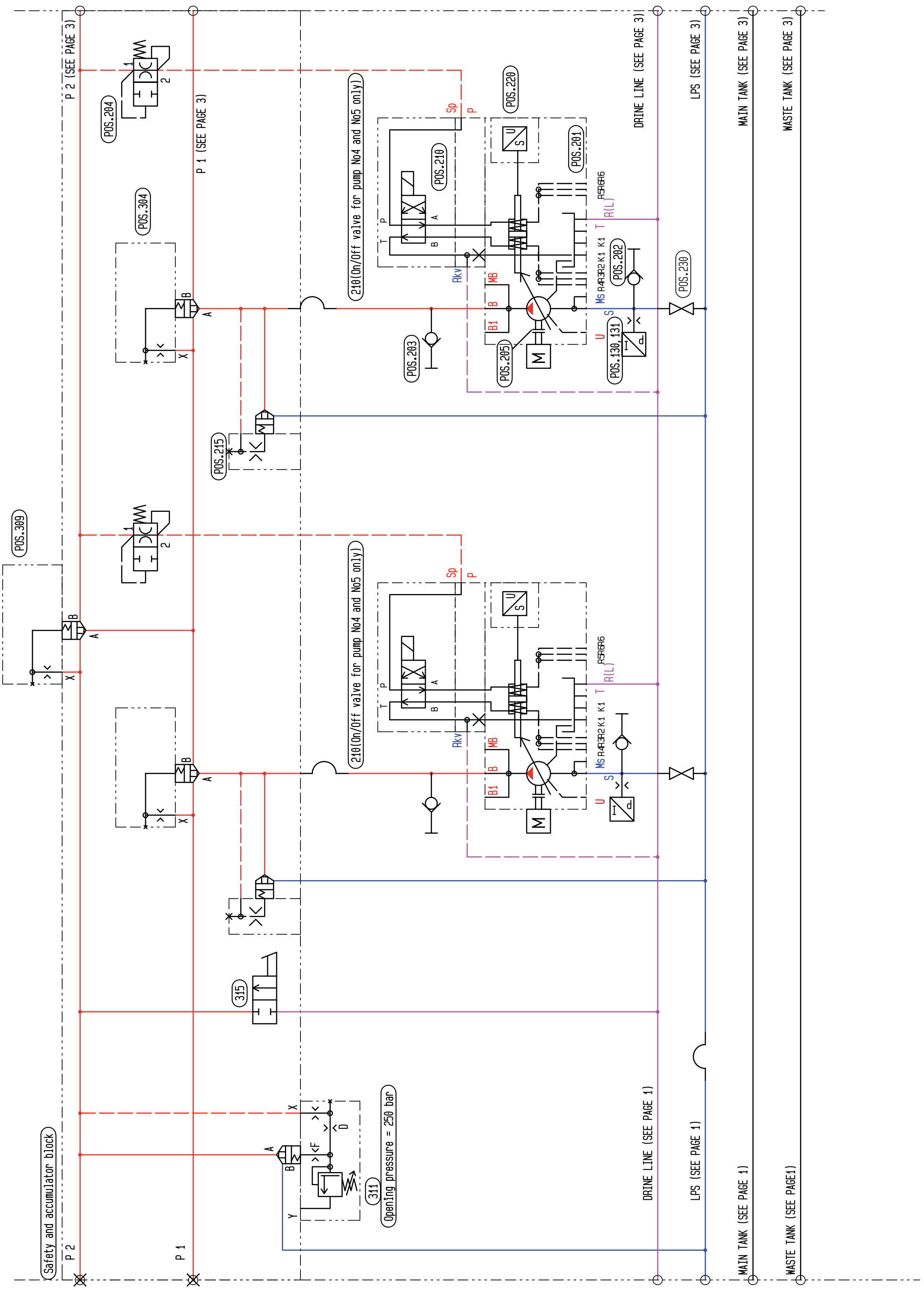

P2-a
P1-a
Safety and Accumulator Block
Pressure at 100% MCR - 210 bar
Opening pressure - 230 bar
Opening pressure - 250 bar
Double Wall Pipe
Atmospheric pressure
Pressure 1.7 - 2.2 bar
Main Tank
Waste Tank
L-a
S-a
L-b
LPS-b
P2-b
R(L)
K1 K2 T
MB
B
B1
S
U
MS
M
339
339
310b
310
310a
1202
272c
272b
272a
305
276
340
340
277
280a
280
279
278
311
321
320
1201
315
333
345
331
330
1233
332
355
1234
155

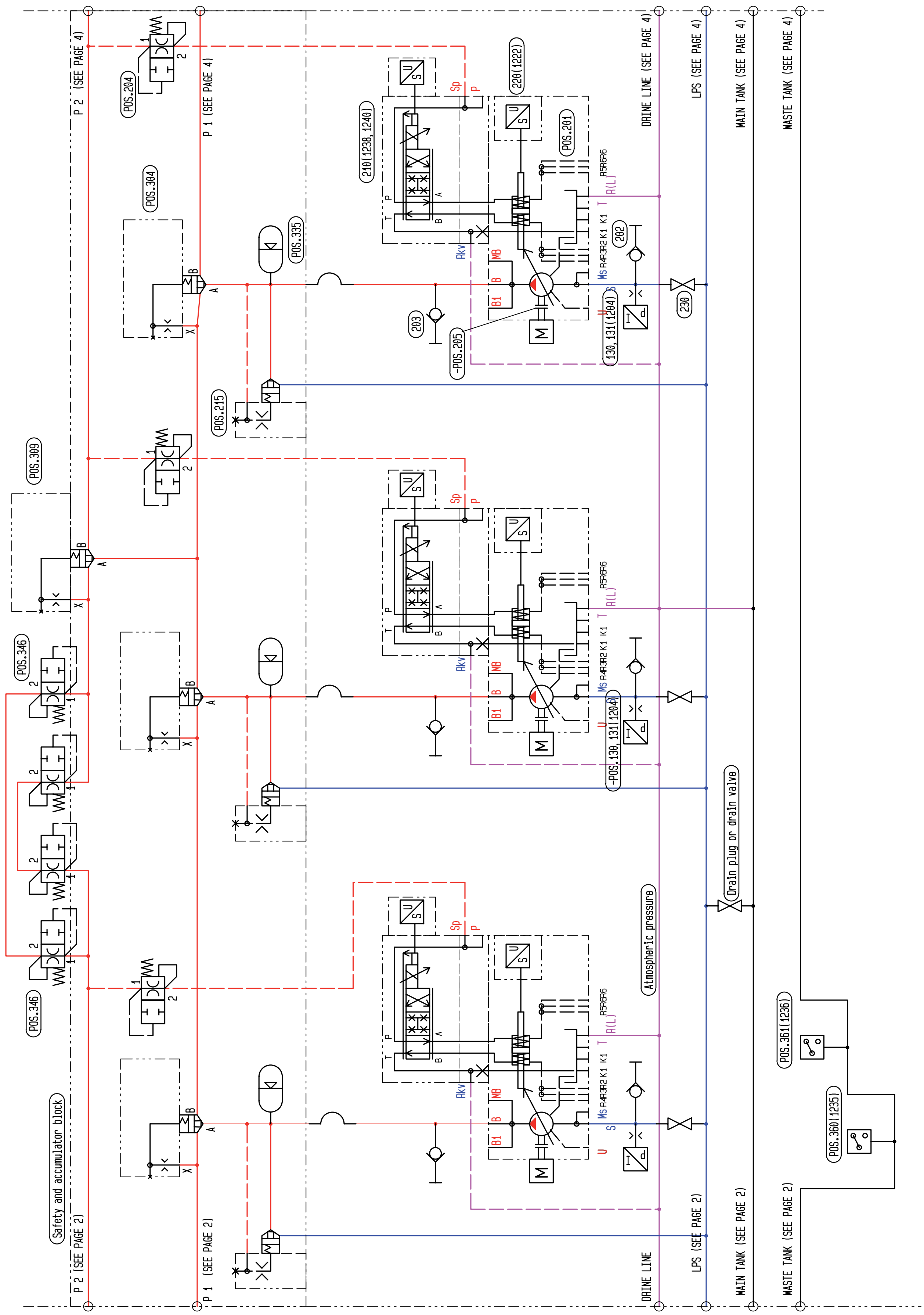
Combined HPS, Separate LPS and FIVA

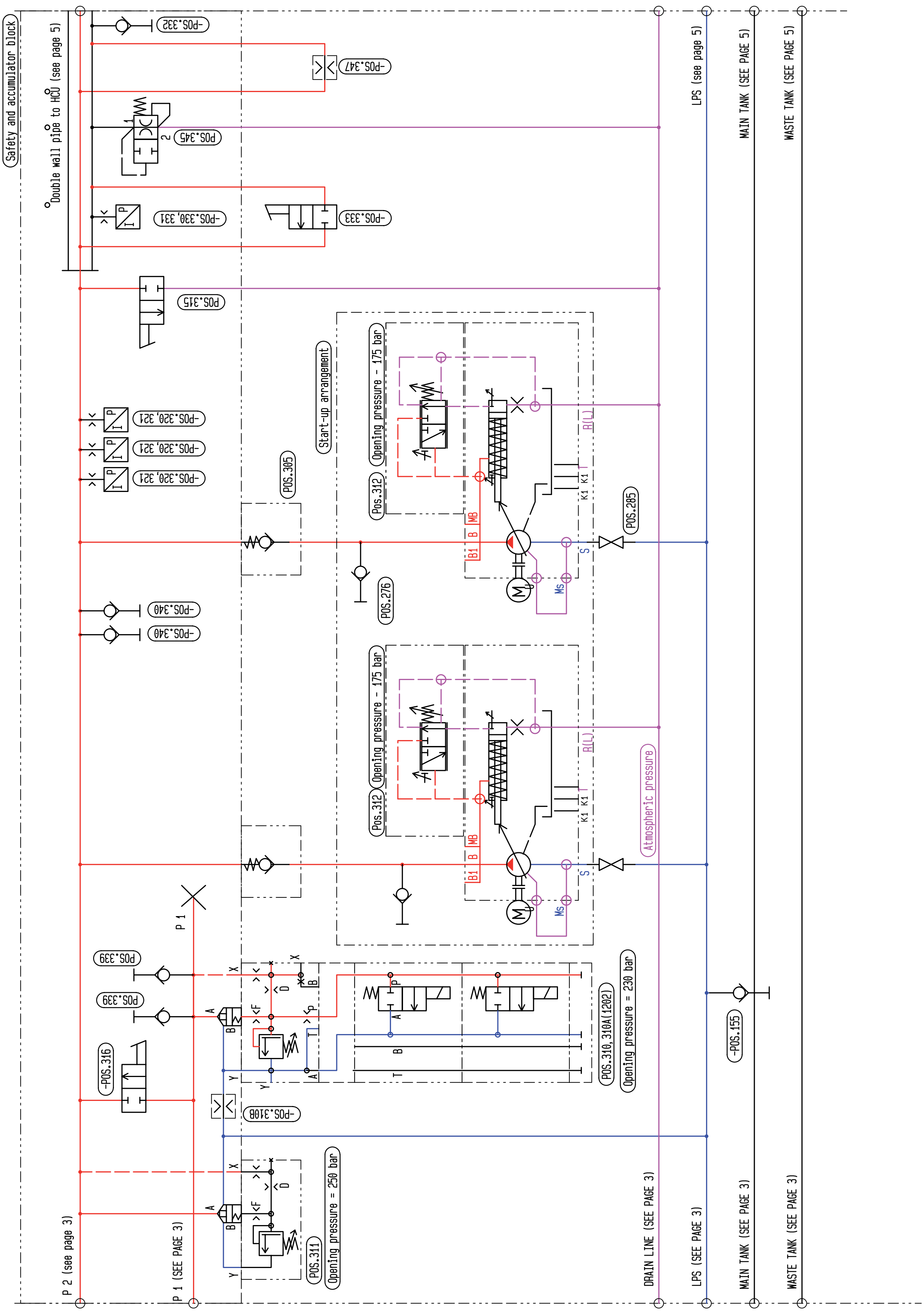




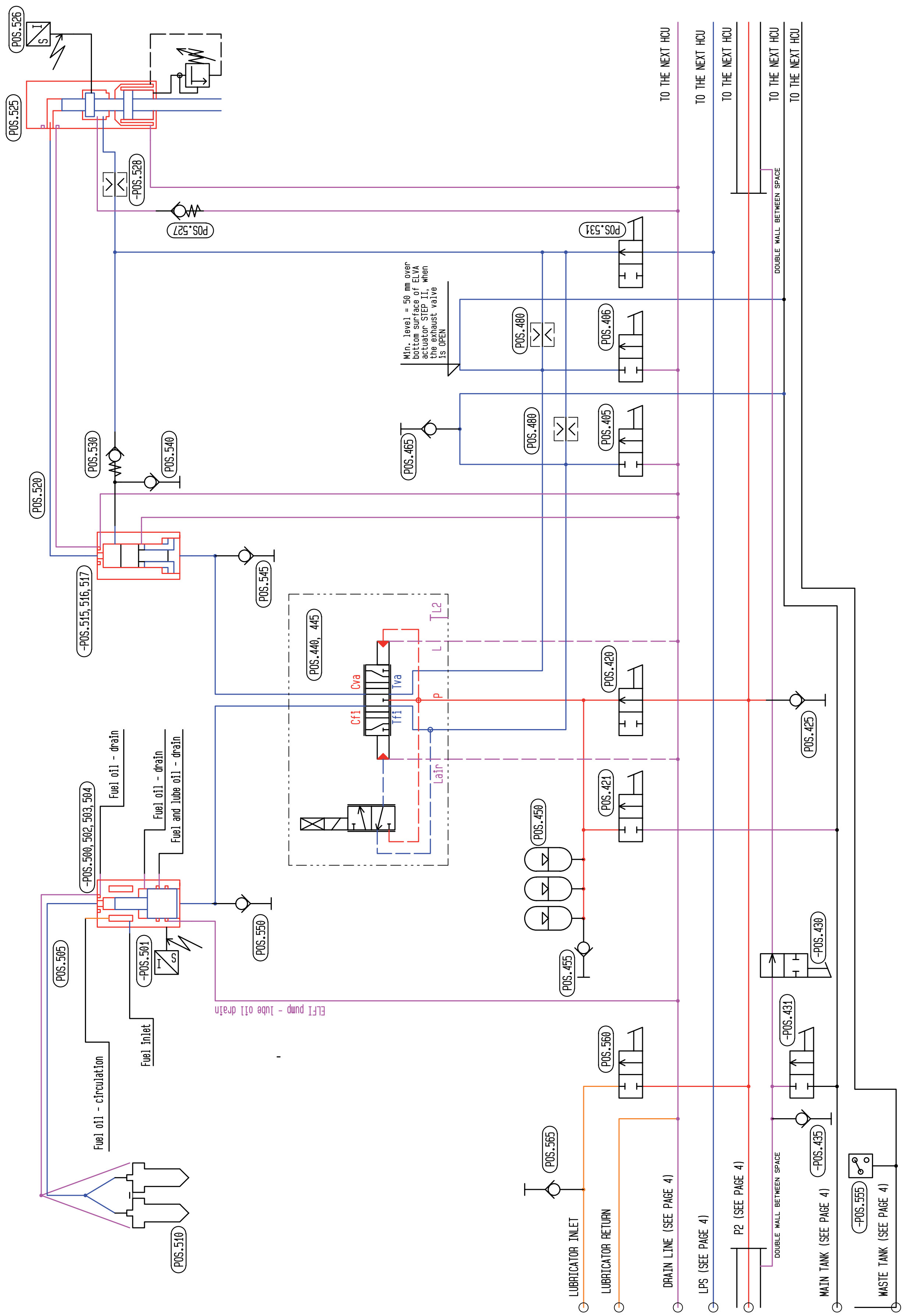
LPS (SEE PAGE 2)
LUBE OIL INLET - 2,2 BAR
BACKFLUSHING OIL TO PURIFIER
AIR INLET - 7 BAR
MAIN TANK (SEE PAGE 2)
WASTE TANK (SEE PAGE 2)
POS.101
POS.107
POS.108
POS.103
POS.105
POS.103
LUBE OIL INLET1
-POS.106
BACKFLUSHING OIL TO PURIFIER
AIR INLET - 7 BAR
Lubricator (Pos.106)
Air filter (Pos.106)
POS.115
LPS
MAIN TANK
WASTE TANK

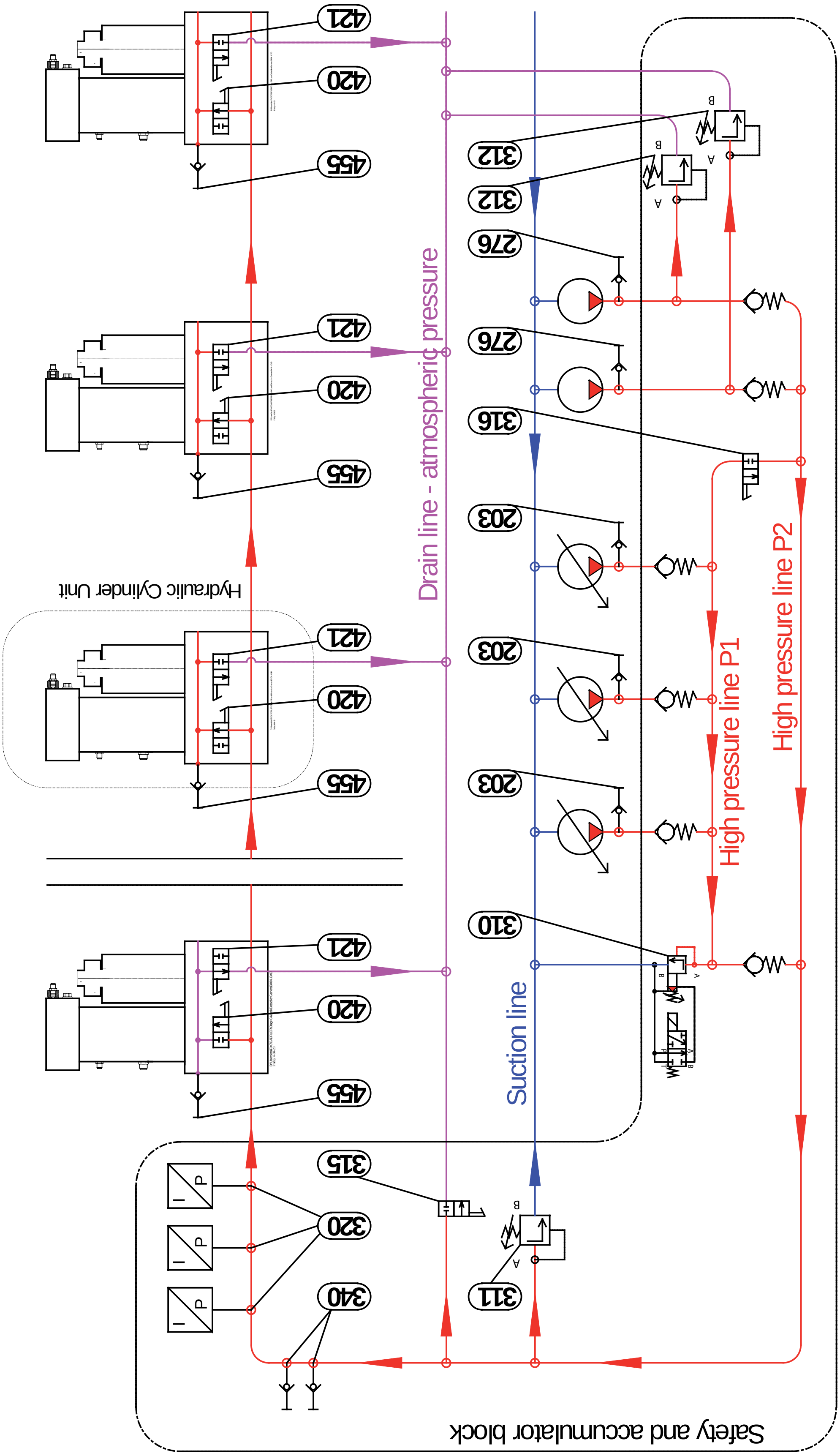

P 2 (SEE PAGE 3)
P 1 (SEE PAGE 3)
POS.204
POS.304
POS.309
POS.215
210(On/Off valve for pump No4 and No5 only)
210(On/Off valve for pump No4 and No5 only)
POS.210
POS.220
POS.201
POS.202
POS.203
POS.205
POS.130,131
POS.230
DRINE LINE (SEE PAGE 3)
LPS (SEE PAGE 3)
MAIN TANK (SEE PAGE 3)
WASTE TANK (SEE PAGE 3)
315
311
Opening pressure = 250 bar
Safety and accumulator block
P 2
P 1
DRINE LINE (SEE PAGE 1)
LPS (SEE PAGE 1)
MAIN TANK (SEE PAGE 1)
WASTE TANK (SEE PAGE1)


P 2 (SEE PAGE 4)
P 1 (SEE PAGE 4)
DRAIN LINE (SEE PAGE 4)
LPS (SEE PAGE 4)
MAIN TANK (SEE PAGE 4)
WASTE TANK (SEE PAGE 4)
POS.204
POS.304
POS.335
POS.215
POS.309
POS.346
POS.346
210(1238,1240)
220(1222)
POS.201
202
203
230
-POS.205
130,131(1204)
-POS.130,131(1204)
Atmospheric pressure
Drain plug or drain valve
POS.361(1236)
POS.360(1235)
Safety and accumulator block
P 2 (SEE PAGE 2)
P 1 (SEE PAGE 2)
DRAIN LINE
LPS (SEE PAGE 2)
MAIN TANK (SEE PAGE 2)
WASTE TANK (SEE PAGE 2)


Safety and accumulator block
Double wall pipe to HCU (see page 5)
POS.332
POS.347
POS.345
POS.330, 331
POS.333
POS.315
POS.320, 321
POS.305
Start-up arrangement
Pos.312
Opening pressure - 175 bar
POS.276
POS.285
POS.340
Atmospheric pressure
POS.339
POS.316
POS.310B
POS.310, 310A(1202)
Opening pressure = 230 bar
POS.311
Opening pressure = 250 bar
POS.155
P 1
P 2 (see page 3)
P 1 (SEE PAGE 3)
DRAIN LINE (SEE PAGE 3)
LPS (SEE PAGE 3)
MAIN TANK (SEE PAGE 3)
WASTE TANK (SEE PAGE 3)
LPS (see page 5)
MAIN TANK (SEE PAGE 5)
WASTE TANK (SEE PAGE 5)

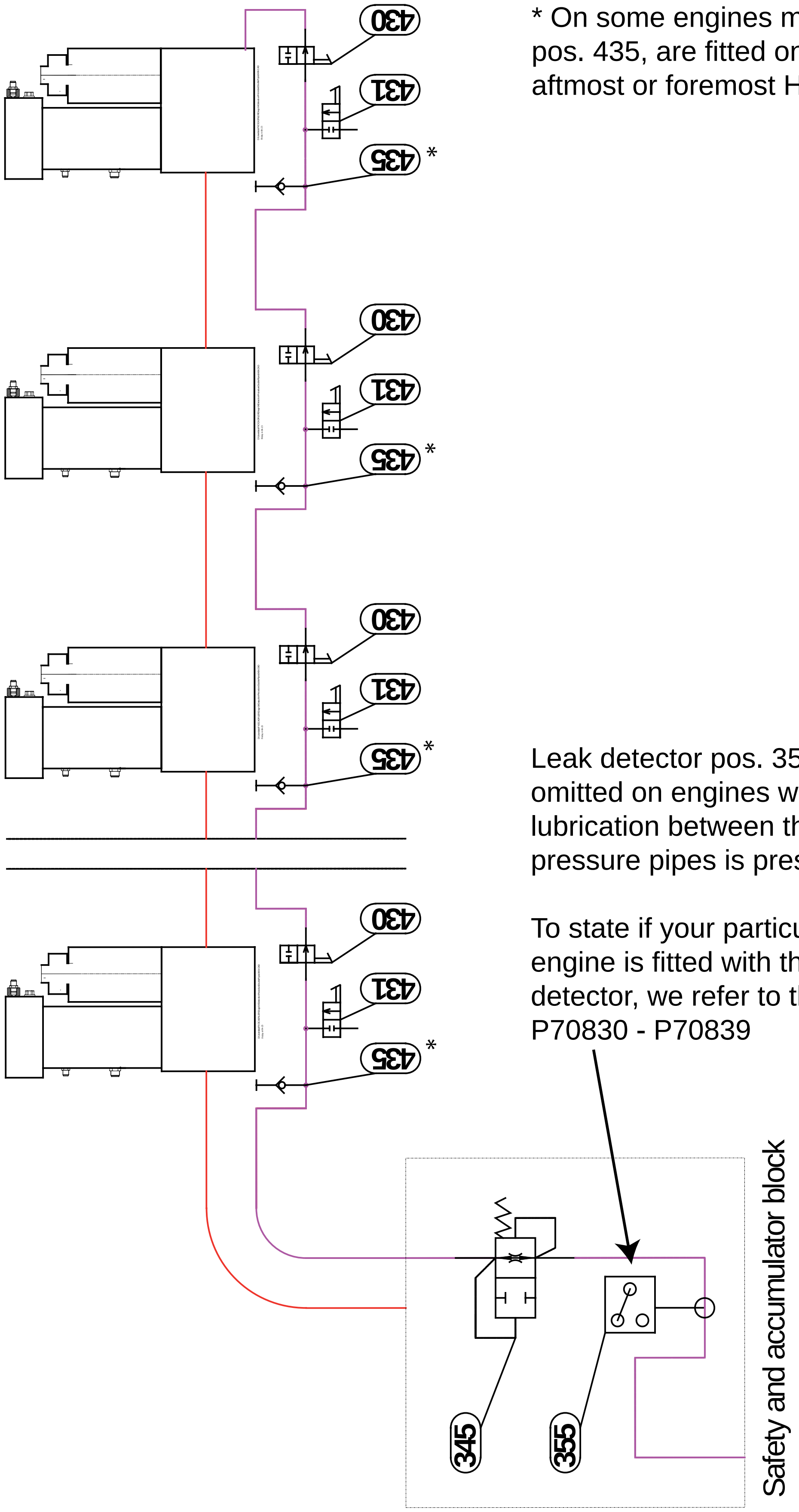
Gear Driven HPS and FIVA, Common LPS




421
420
455
312
312
276
276
316
203
203
203
310
315
320
340
311
Hydraulic Cylinder Unit
Drain line - atmospheric pressure
Suction line
High pressure line P1
High pressure line P2
Safety and accumulator block

Basic Procedures

Item	Function	Possibilities	Remarks
Measuring point 276	Pressure in START-UP system arrangement	Pressure adjustment at the valve 310, 311 and 312 Investigation of pressure building time. Investigation of pumps pressure and displacement ability	You can see this pressure at the MOP panel (Engine STAND-BY) Normal pressure adjusted to 175 bar. To adjust the pressure at the valve 310 – OPEN the valve 316.
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 panel. Normal pressure = System pressure
Measuring point 340	System pressure	Investigation of system pressure.	You can always see this pressure at the MOP panel. Normal pressure ? set point system pressure.
Leak detection. Measuring point 276 and 340	Procedure for leak detection on entire system.	Investigation of pressure and possible leakages.	Stop the engine. Start the pressure building procedure with the START-UP pump arr. Normal, pressure will increase to a pressure adjusted at the START-UP pump arrangement. (175 bar) If not, cut-out the Hydraulic Cylinder Unit, one by one, by closing the 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 and possible leakages. Investigation of pressure building time. Investigation of pressure drop time.	Can be detected with engine in service. Cylinder cut-out (Electronically). CLOSE the valve 420 at the HCU and investigate the pressure drop time. Compare the pressure drop time to the same value at the next HCU. Can be investigated when the engine is stopped. Use the START-UP arrangement to build the pressure up at one HCU. Then compare the pressure building time to the same value at the next HCU

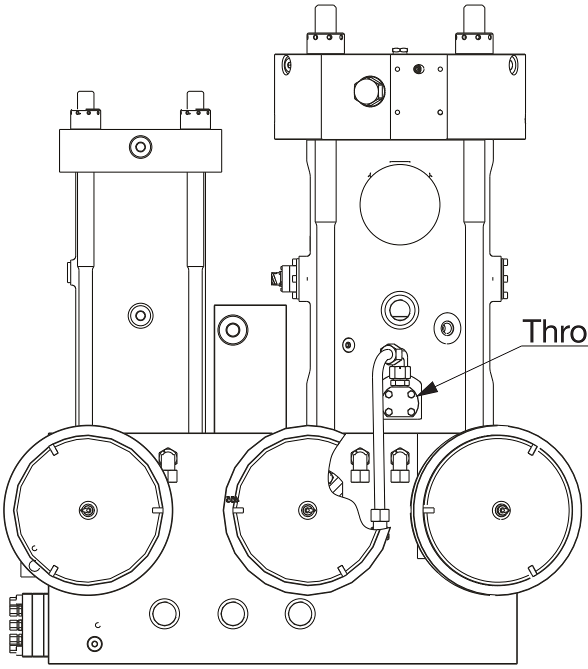


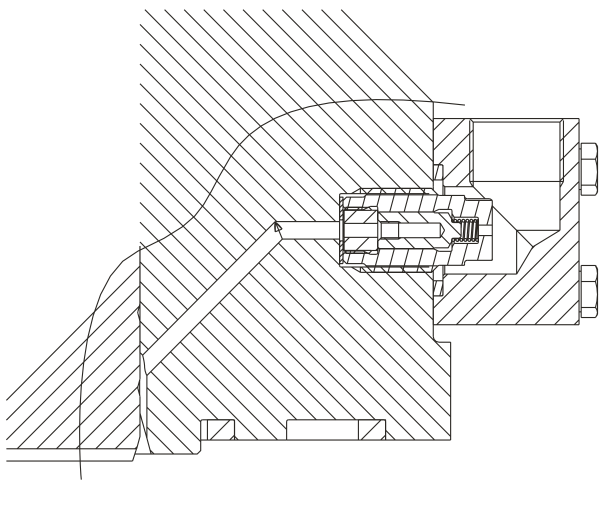
* On some engines minimess pos. 435, are fitted only at the aftmost or foremost HCU.

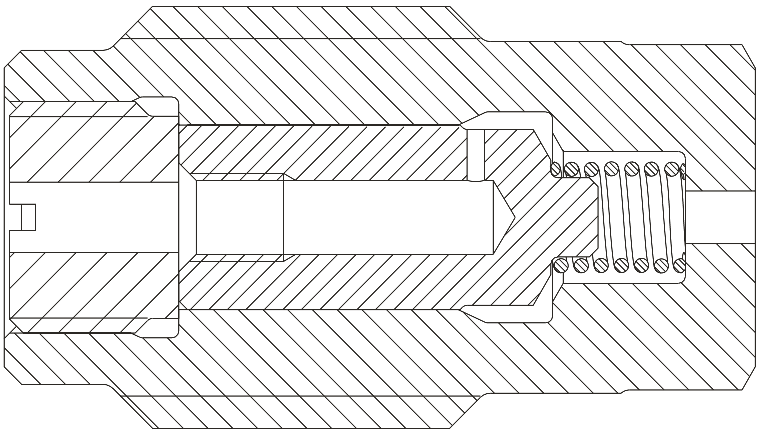
Leak detector pos. 355 is omitted on engines where lubrication between the high pressure pipes is present.

To state if your particular engine is fitted with this leak detector, we refer to the plates P70830 - P70839

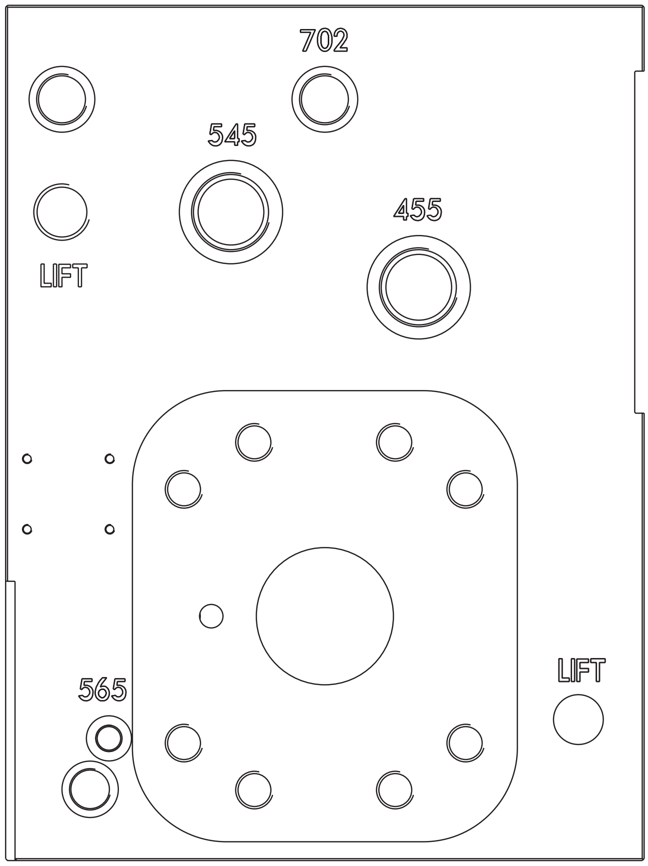
Item	Function	Possibilities	Remarks
Leak detection in double wall pipes. **Measuring points 435**	Procedure for leak detection on entire system	Investigation of pressure and possible leakages. Leak position detection	You can always see this pressure at the MOP. CLOSE the valve 430 at the last but one Hydraulic Cylinder unit. OPEN the valve 431 at last HCU to decrease the pressure in the space between the inner and outer pipe. CLOSE the valve 431 at the last HCU again. Check the pressure in the space between at pos. 435, at the last HCU. If the pressure increase to the system pressure level, the leakage has been found. When the leakage has been eliminated, bring all the valves to their normal running position.

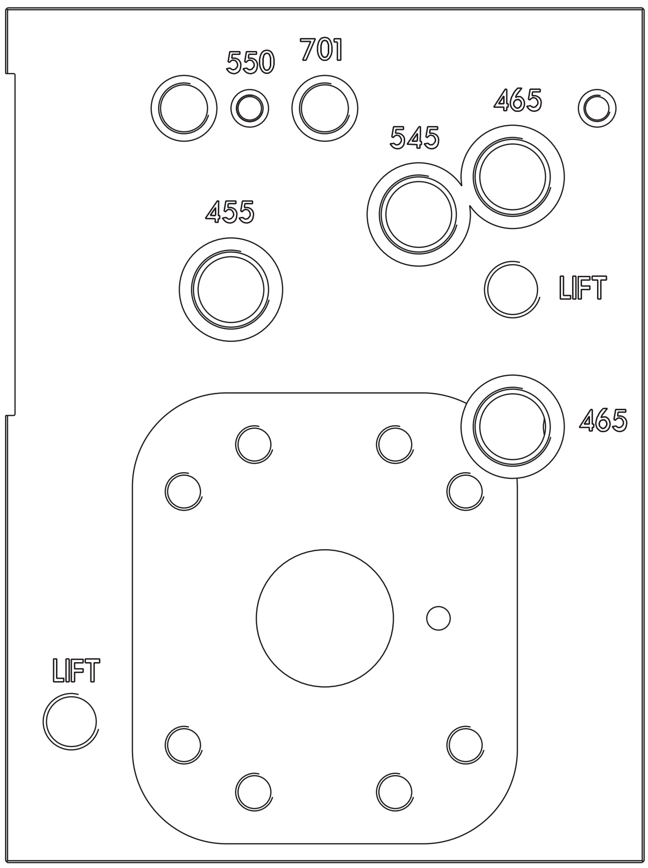

Throttle Valve

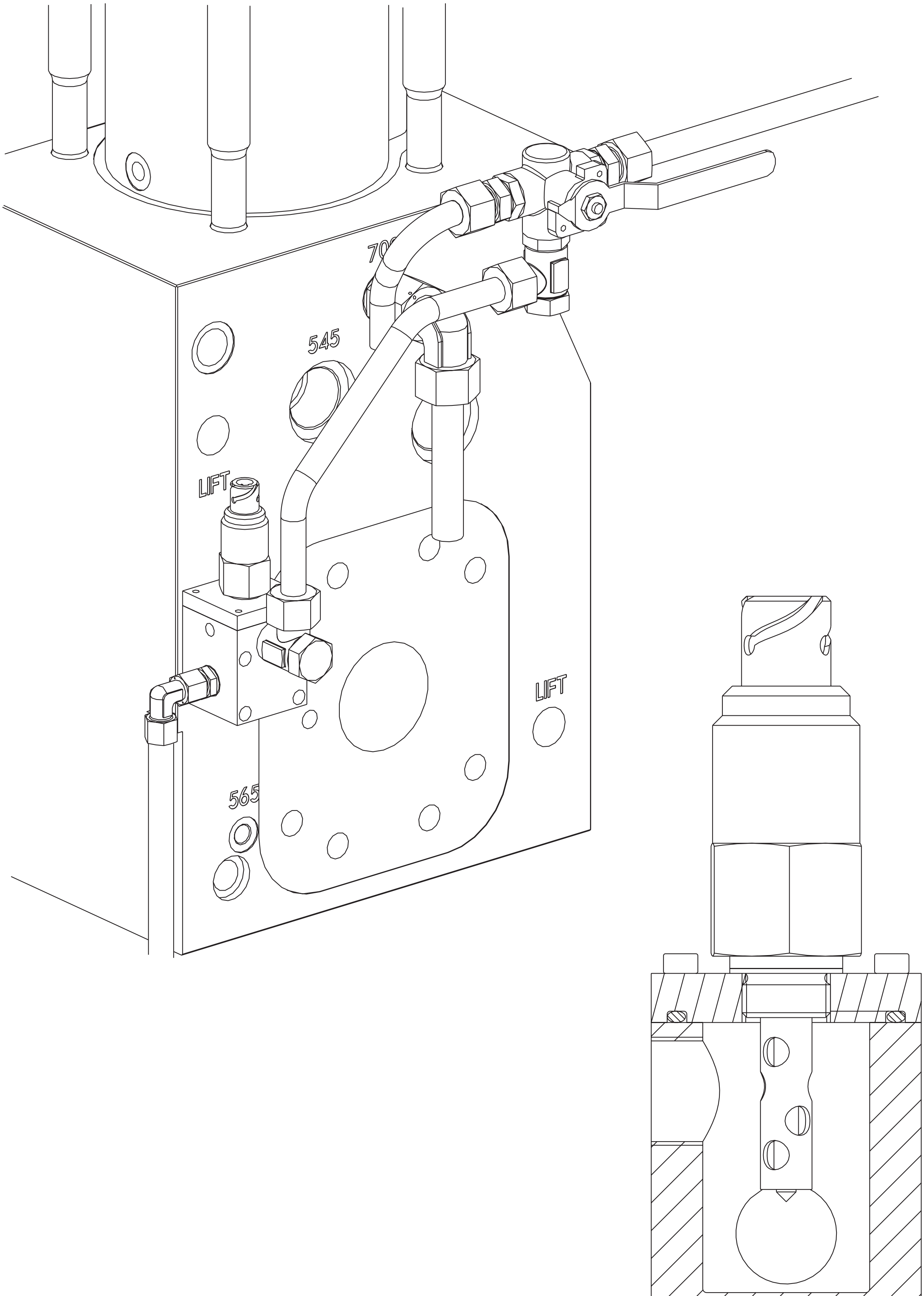




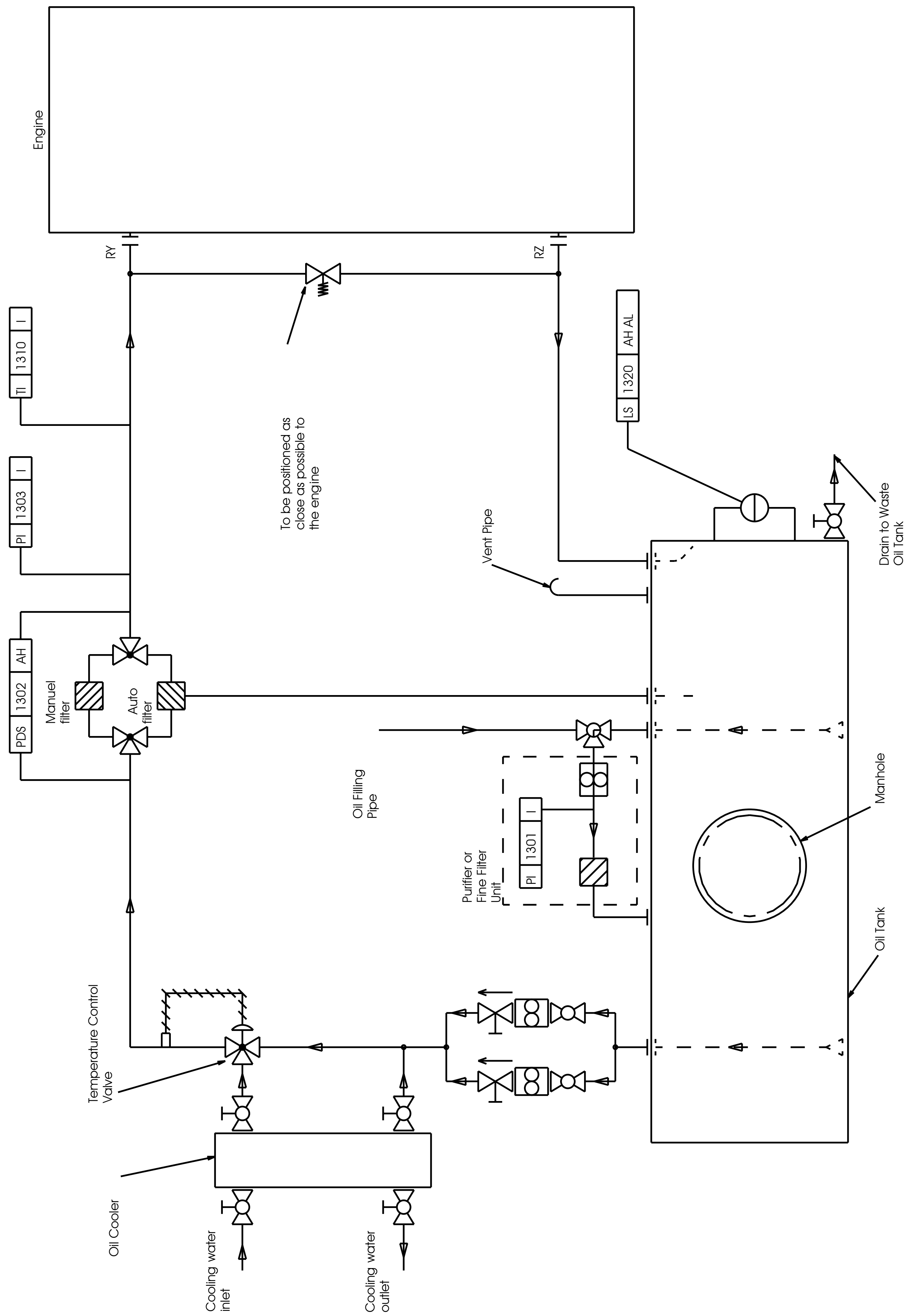
Drainholes in HCU Block







545
LIFT
LIFT
565



Engine
RY
RZ
TI 1310 I
PI 1303 I
PDS 1302 AH
Manuel filter
Auto filter
To be positioned as close as possible to the engine
LS 1320 AH AL
Vent Pipe
Drain to Waste Oil Tank
Oil Filling Pipe
Purifier or Fine Filter Unit
PI 1301 I
Manhole
Oil Tank
Temperature Control Valve
Oil Cooler
Cooling water inlet
Cooling water outlet

Fig. 1
Double Wall pipe:

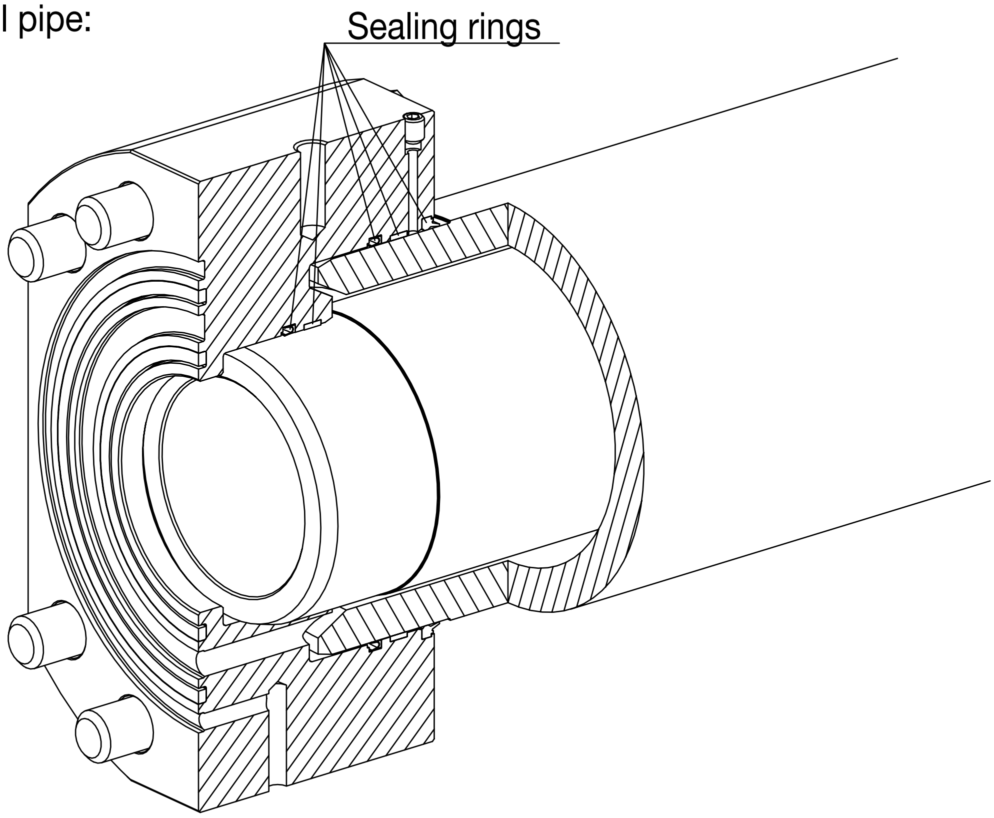


Fig. 2
End Flange:

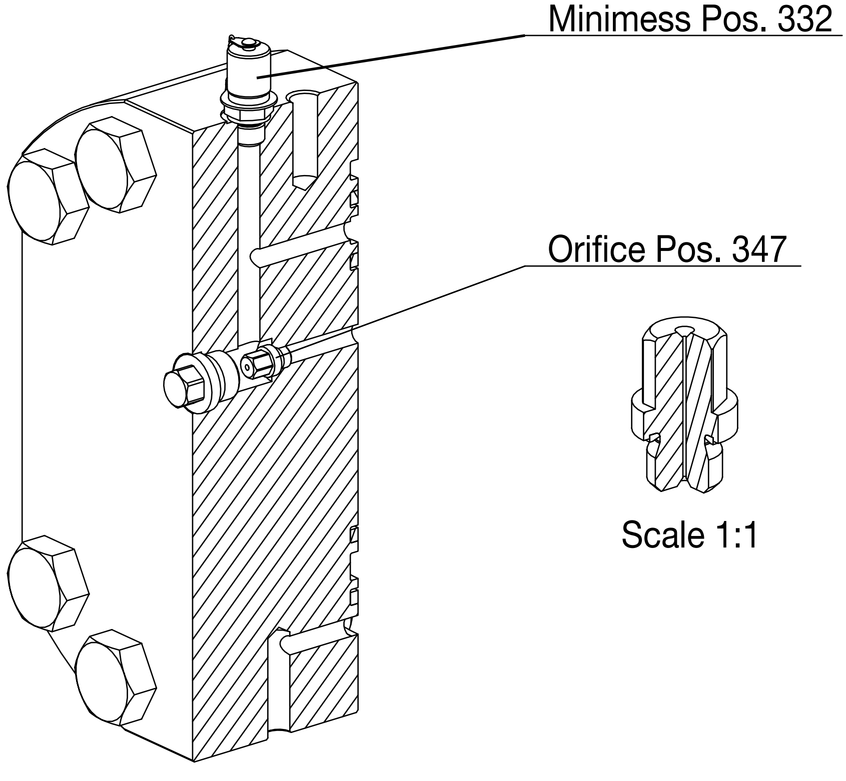
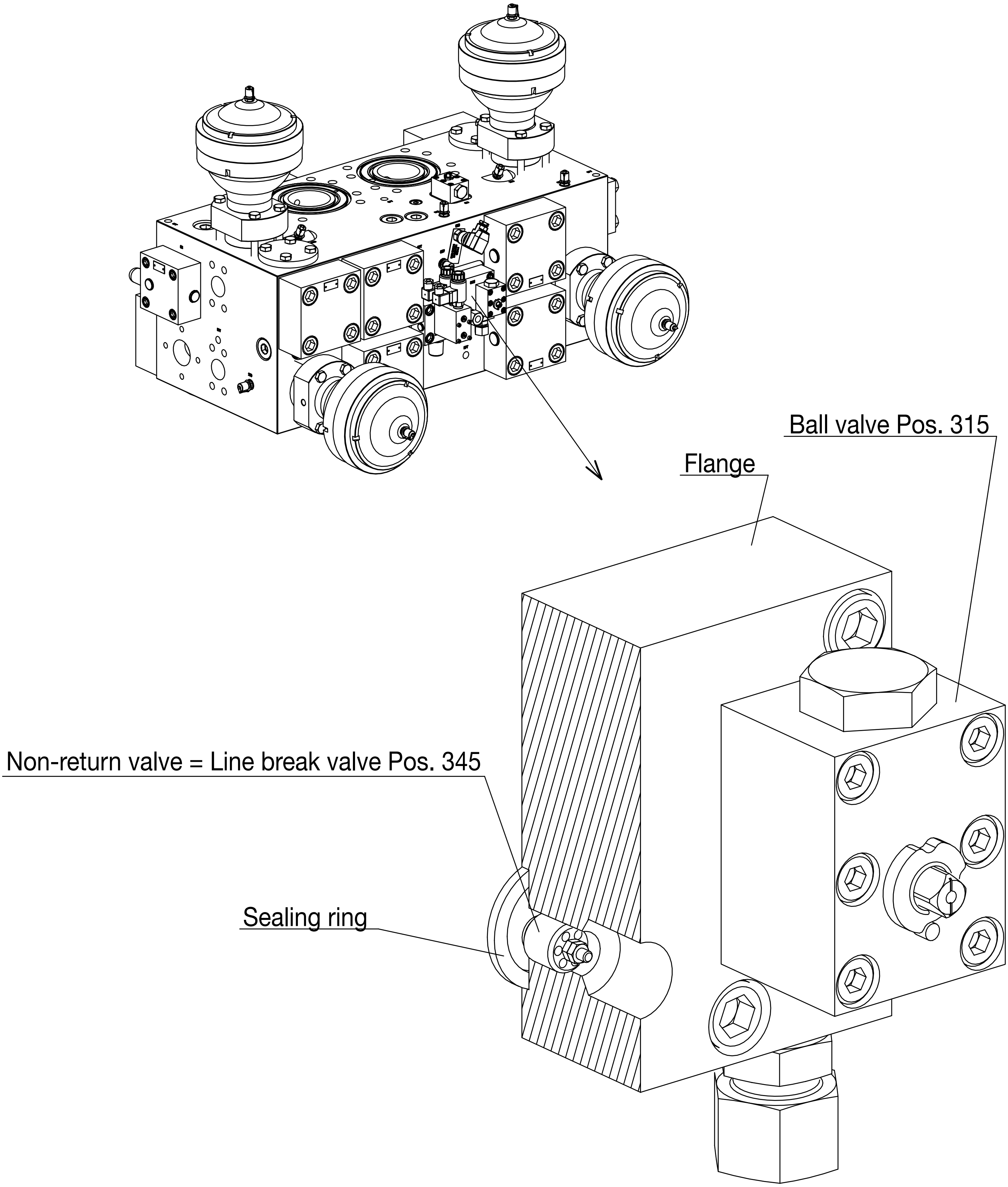
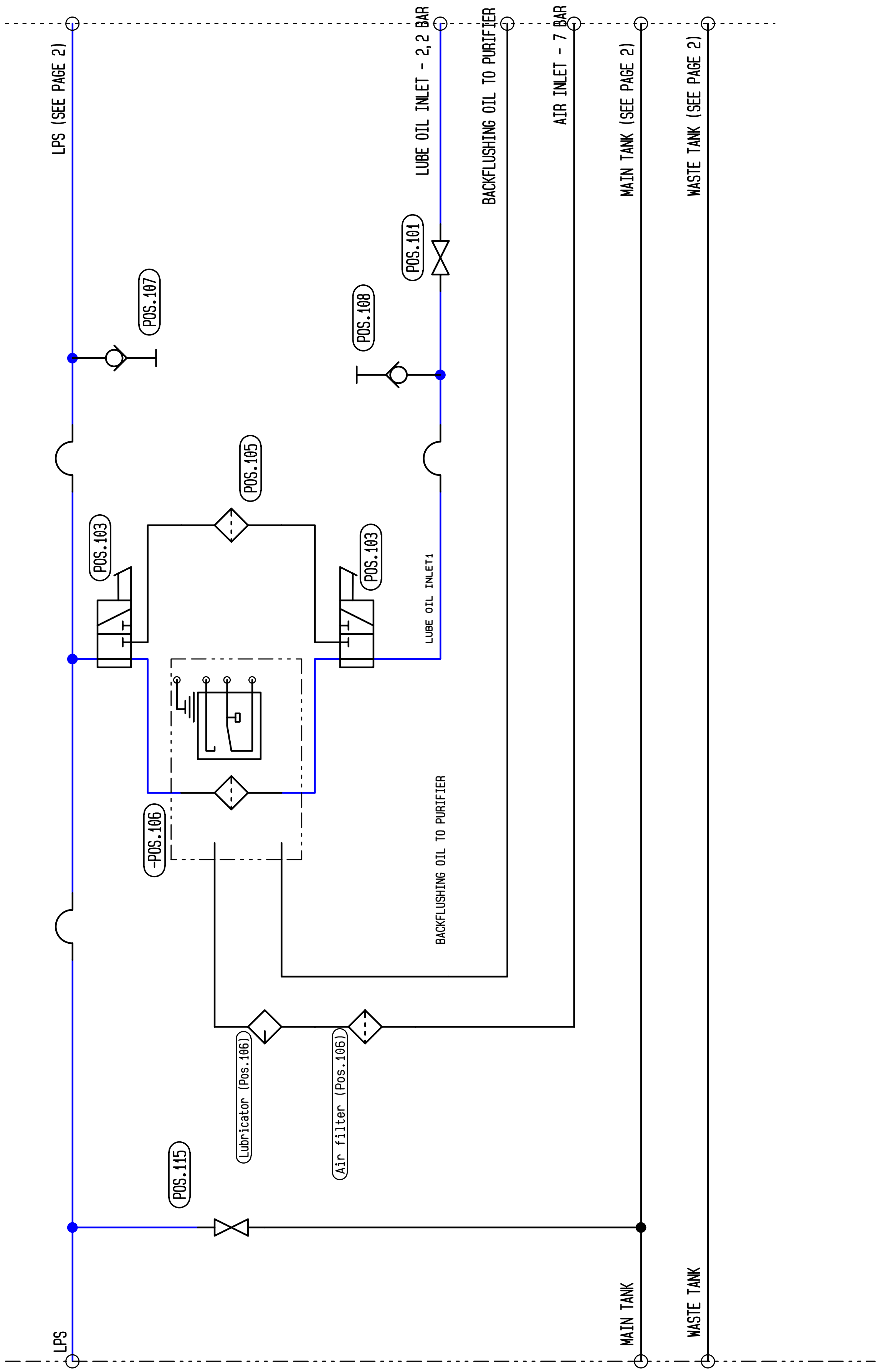
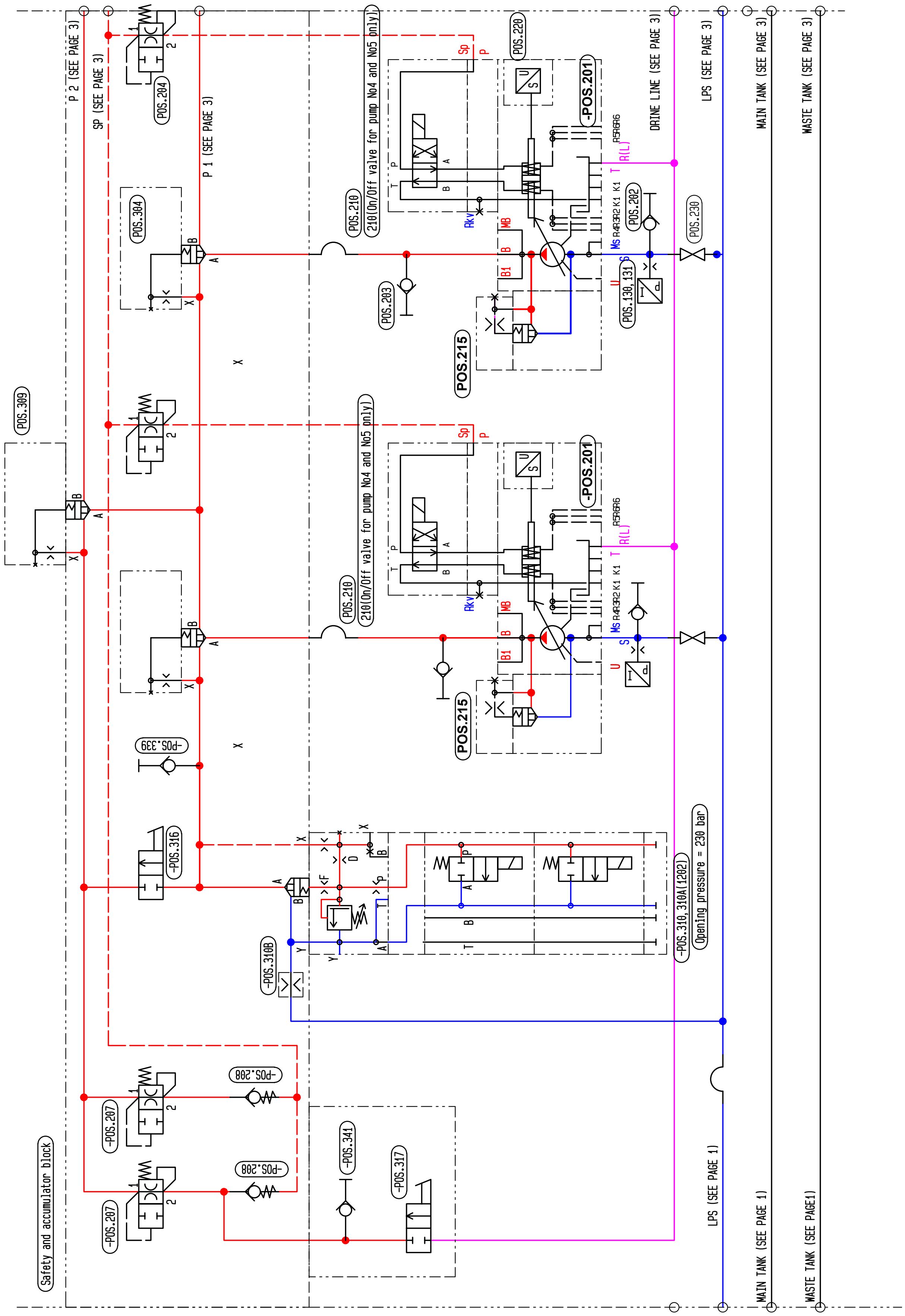
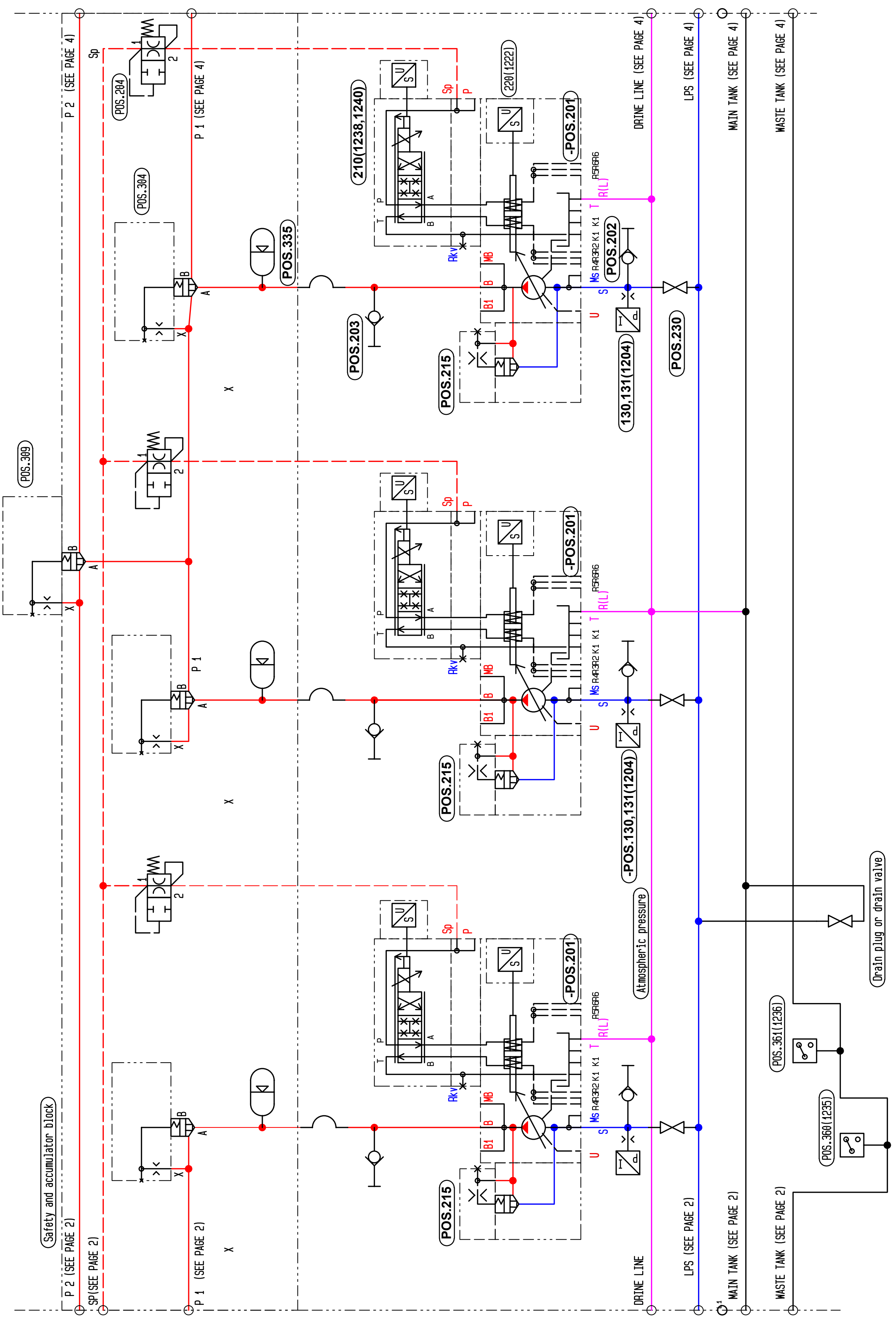


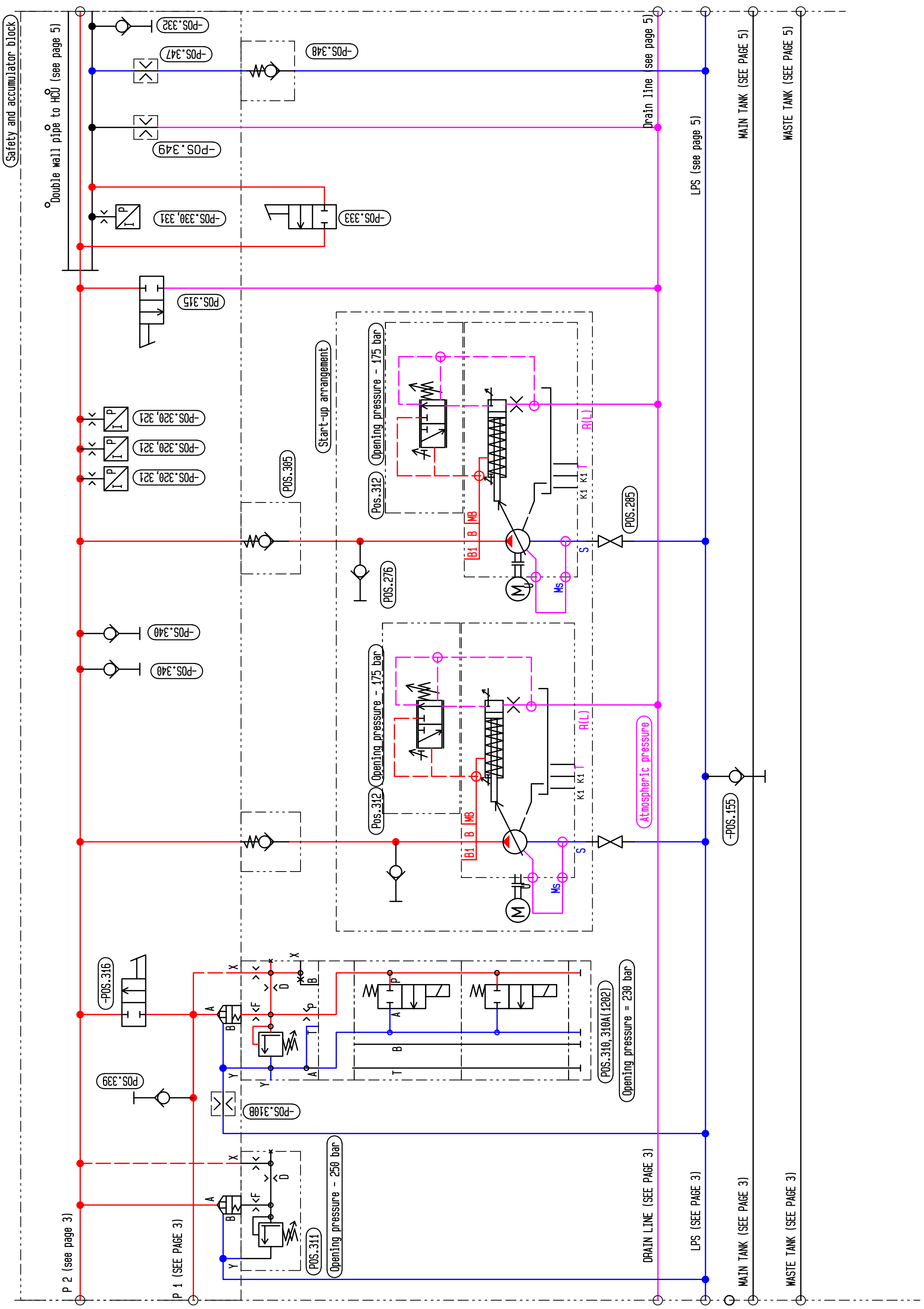
Fig. 3 Design may vary

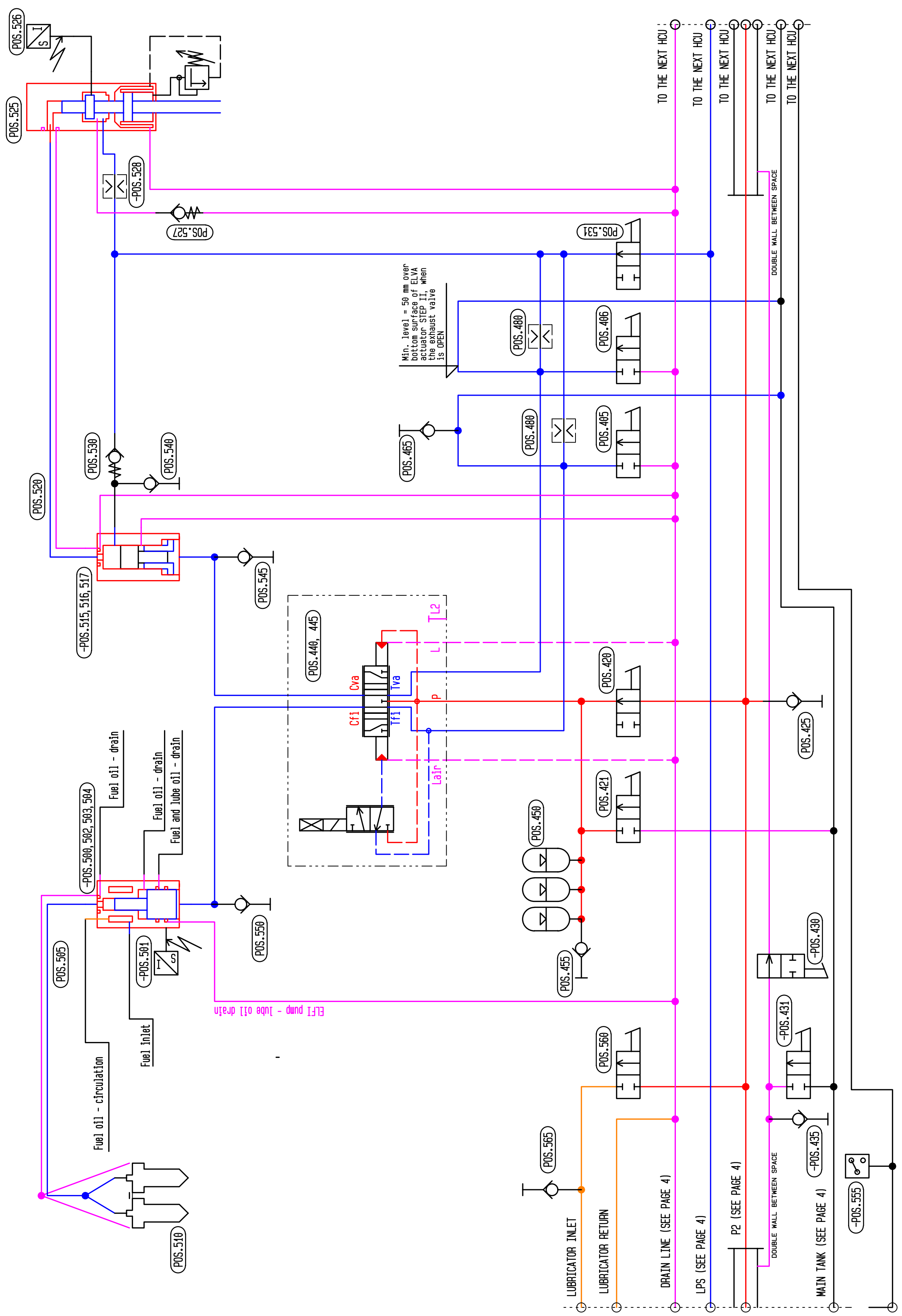


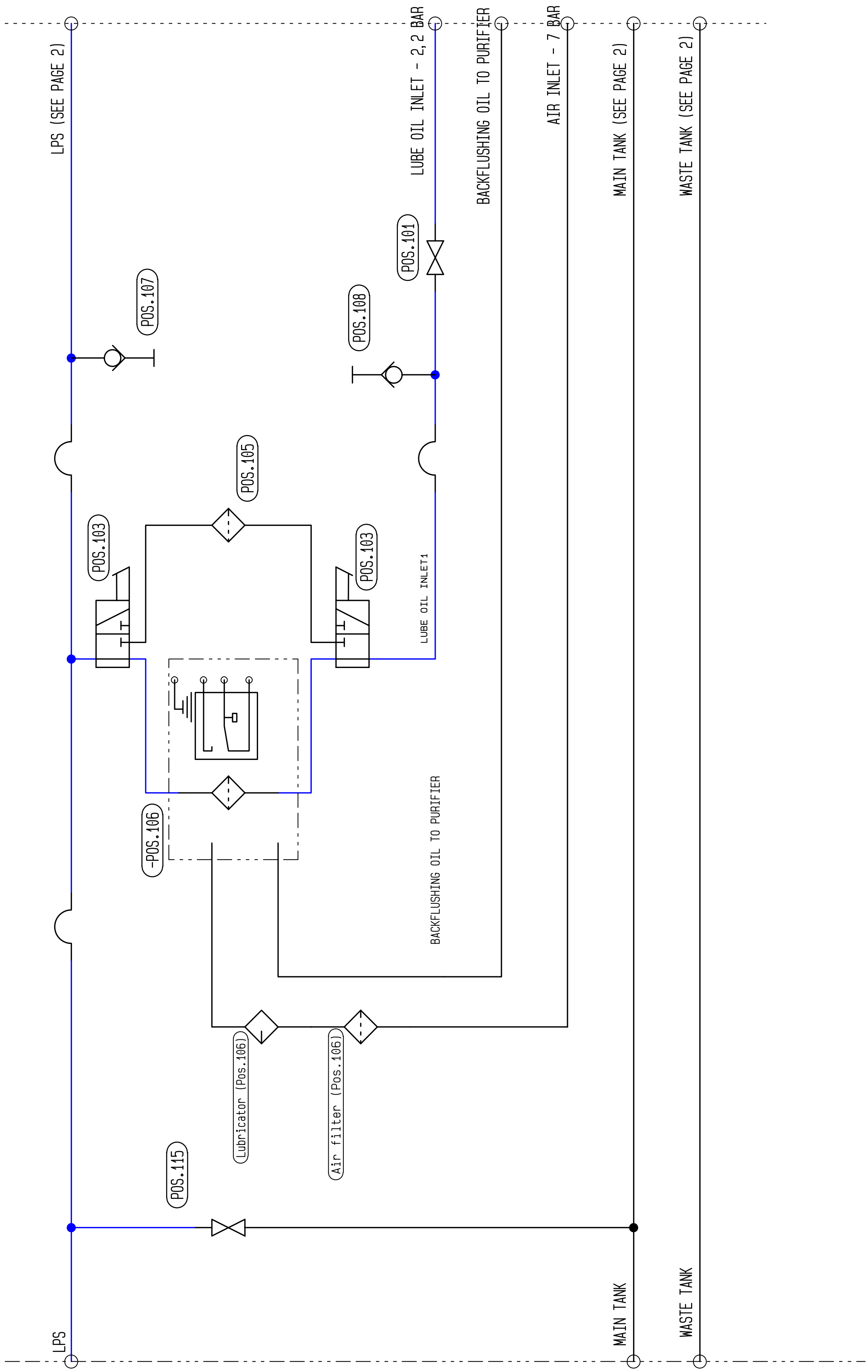

LPS (SEE PAGE 2)
LUBE OIL INLET - 2,2 BAR
BACKFLUSHING OIL TO PURIFIER
AIR INLET - 7 BAR
MAIN TANK (SEE PAGE 2)
WASTE TANK (SEE PAGE 2)
POS.101
POS.107
POS.108
POS.105
POS.103
POS.103
LUBE OIL INLET1
-POS.106
BACKFLUSHING OIL TO PURIFIER
Lubricator (Pos.106)
Air filter (Pos.106)
POS.115
LPS
MAIN TANK
WASTE TANK

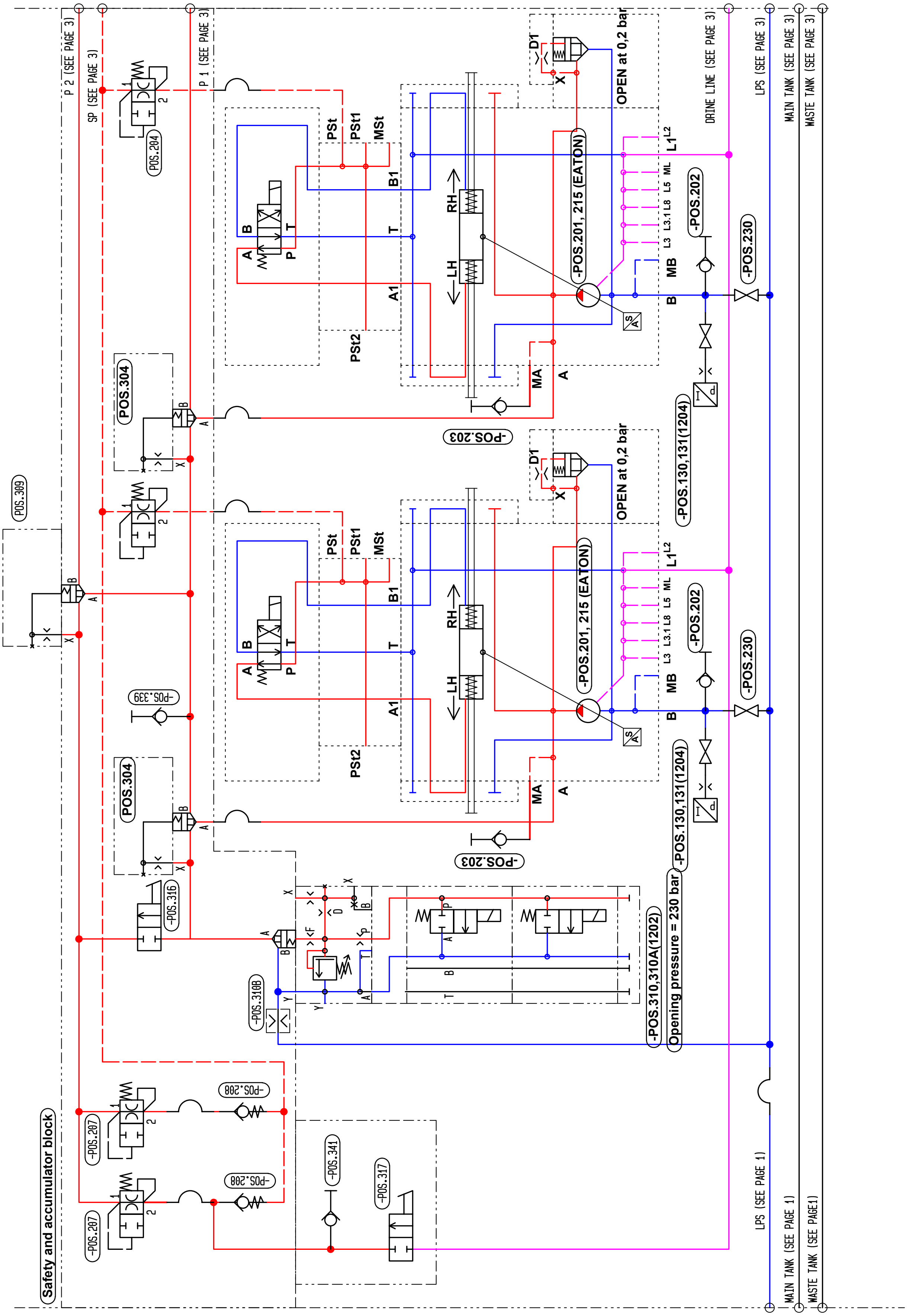

P 2 (SEE PAGE 3)
SP (SEE PAGE 3)
P 1 (SEE PAGE 3)
POS.204
POS.304
POS.309
POS.210
210(On/Off valve for pump No4 and No5 only)
POS.220
-POS.201
POS.202
POS.230
POS.203
POS.215
POS.130,131
DRINE LINE (SEE PAGE 3)
LPS (SEE PAGE 3)
MAIN TANK (SEE PAGE 3)
WASTE TANK (SEE PAGE 3)
-POS.339
-POS.316
-POS.310B
-POS.310,310A(1202)
Opening pressure = 230 bar
-POS.208
-POS.207
-POS.341
-POS.317
Safety and accumulator block
LPS (SEE PAGE 1)
MAIN TANK (SEE PAGE 1)
WASTE TANK (SEE PAGE1)

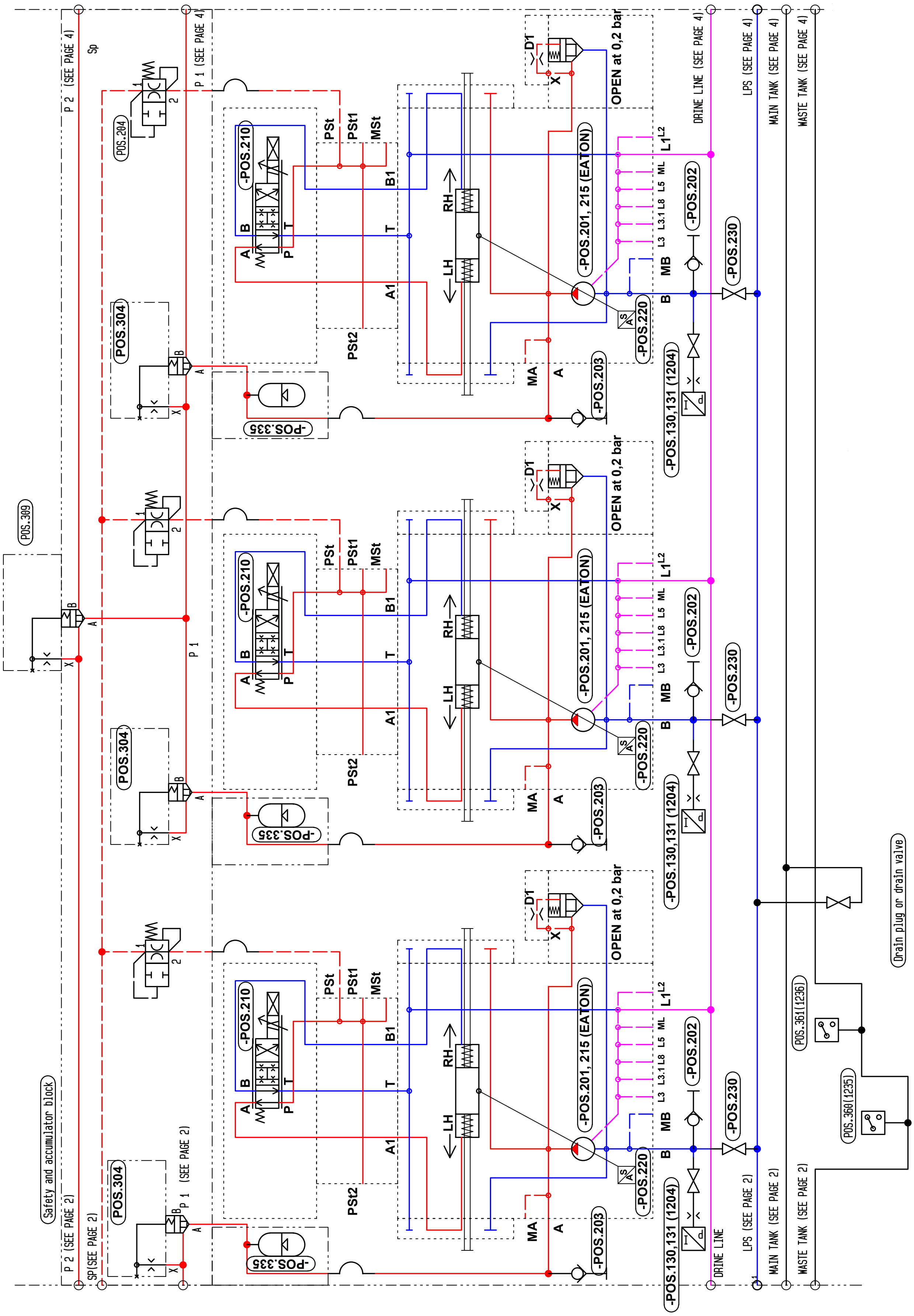

P 2 (SEE PAGE 4)
Sp
P 1 (SEE PAGE 4)
POS.204
POS.304
POS.309
POS.335
210(1238,1240)
220(1222)
-POS.201
POS.202
POS.203
POS.215
POS.230
130,131(1204)
-POS.130,131(1204)
DRINE LINE (SEE PAGE 4)
LPS (SEE PAGE 4)
MAIN TANK (SEE PAGE 4)
WASTE TANK (SEE PAGE 4)
Atmospheric pressure
Drain plug or drain valve
POS.361(1236)
POS.360(1235)
Safety and accumulator block
P 2 (SEE PAGE 2)
SP(SEE PAGE 2)
P 1 (SEE PAGE 2)
DRINE LINE
LPS (SEE PAGE 2)
MAIN TANK (SEE PAGE 2)
WASTE TANK (SEE PAGE 2)


Safety and accumulator block
Double wall pipe to HCU (see page 5)
-POS.332
-POS.347
-POS.348
-POS.349
-POS.330,331
-POS.333
POS.315
Drain line (see page 5)
LPS (see page 5)
MAIN TANK (SEE PAGE 5)
WASTE TANK (SEE PAGE 5)
Start-up arrangement
Opening pressure - 175 bar
Pos.312
POS.305
-POS.320,321
R(L)
T
K1 K1
MB
B
B1
S
Ms
POS.285
POS.276
-POS.340
Atmospheric pressure
-POS.155
-POS.316
POS.339
-POS.310B
POS.310,310A(1202)
Opening pressure = 230 bar
POS.311
Opening pressure - 250 bar
P 2 (see page 3)
P 1 (SEE PAGE 3)
DRAIN LINE (SEE PAGE 3)
LPS (SEE PAGE 3)
MAIN TANK (SEE PAGE 3)
WASTE TANK (SEE PAGE 3)

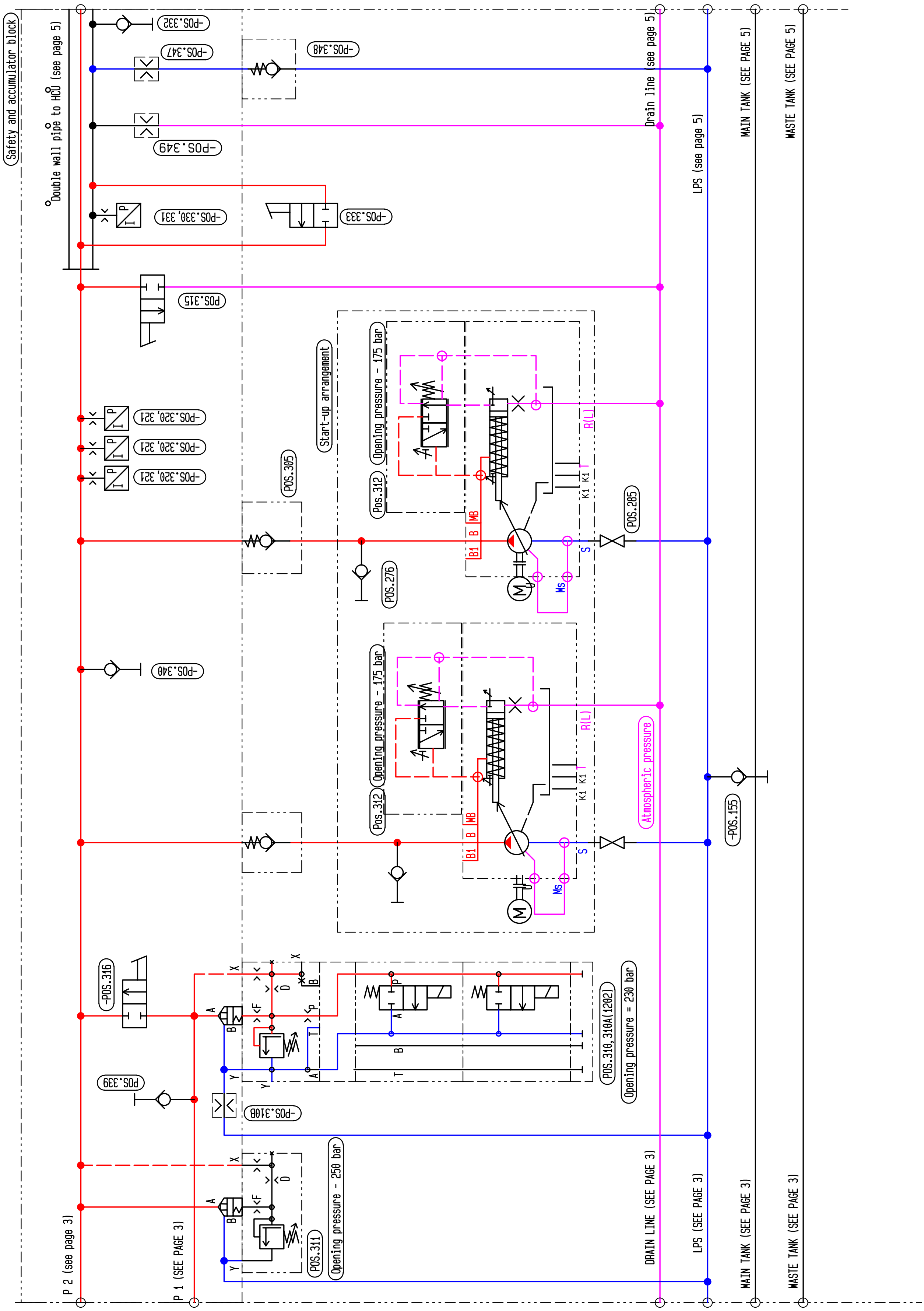

POS.526
POS.525
POS.528
POS.527
POS.531
TO THE NEXT HCU
TO THE NEXT HCU
TO THE NEXT HCU
TO THE NEXT HCU
TO THE NEXT HCU
DOUBLE WALL BETWEEN SPACE
Min. level = 50 mm over bottom surface of ELVA actuator STEP II, when the exhaust valve is OPEN
POS.480
POS.406
POS.480
POS.405
POS.465
POS.530
POS.540
POS.520
POS.515,516,517
POS.545
POS.440, 445
Cva
Tva
Cfi
Tfi
P
L
TL2
Lair
POS.420
POS.425
POS.421
POS.450
POS.455
Fuel oil - drain
Fuel oil - drain
Fuel and lube oil - drain
POS.500,502,503,504
POS.505
POS.501
POS.550
ELFI pump - lube oil drain
Fuel inlet
Fuel oil - circulation
POS.510
POS.560
POS.565
POS.430
POS.431
POS.435
POS.555
LUBRICATOR INLET
LUBRICATOR RETURN
DRAIN LINE (SEE PAGE 4)
LPS (SEE PAGE 4)
P2 (SEE PAGE 4)
DOUBLE WALL BETWEEN SPACE
MAIN TANK (SEE PAGE 4)

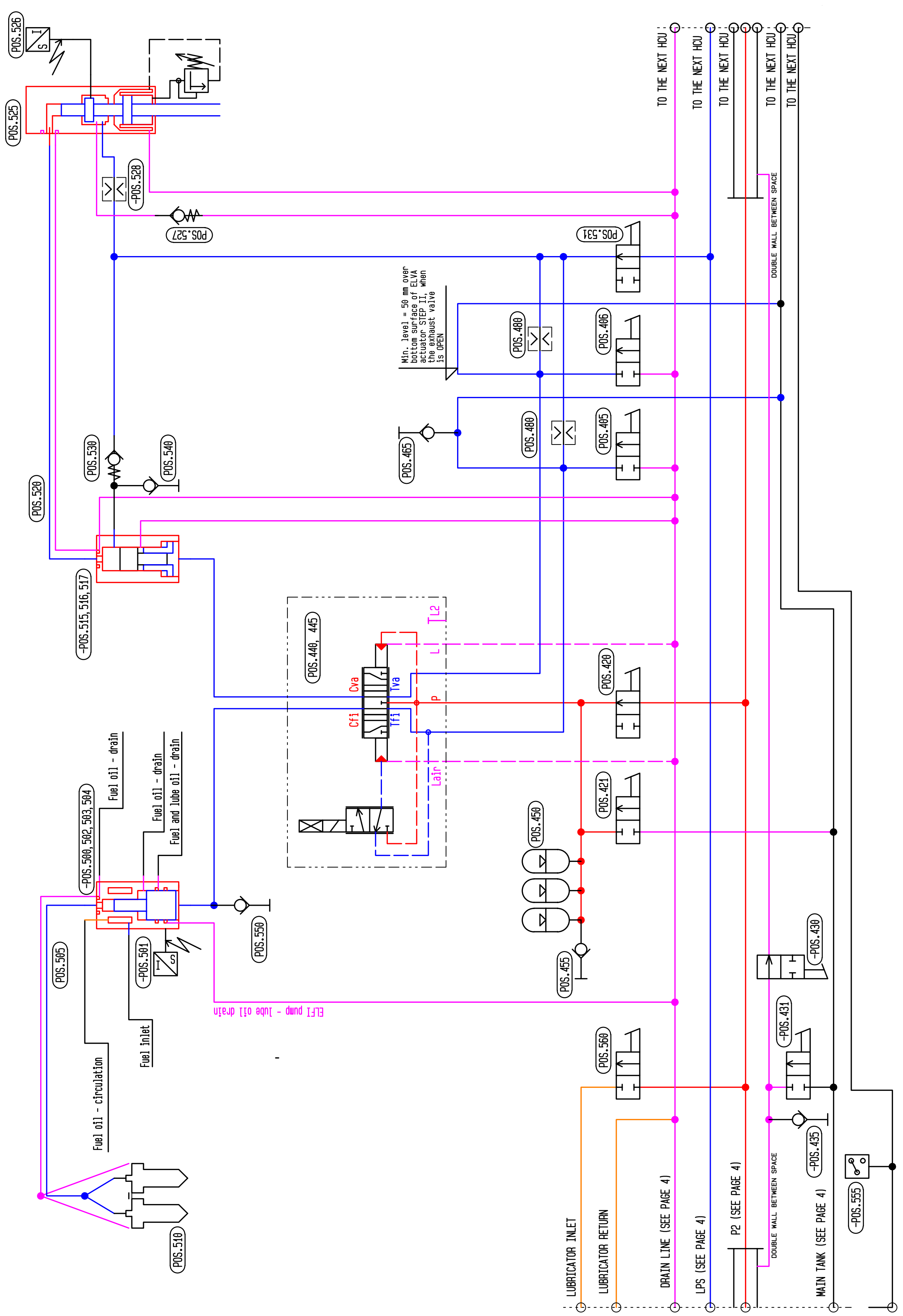

LPS (SEE PAGE 2)
LUBE OIL INLET - 2,2 BAR
BACKFLUSHING OIL TO PURIFIER
AIR INLET - 7 BAR
MAIN TANK (SEE PAGE 2)
WASTE TANK (SEE PAGE 2)
POS.101
POS.107
POS.108
POS.105
POS.103
POS.103
LUBE OIL INLET1
-POS.106
BACKFLUSHING OIL TO PURIFIER
Lubricator (Pos.106)
Air filter (Pos.106)
POS.115
LPS
MAIN TANK
WASTE TANK


Safety and accumulator block
OPEN at 0,2 bar
-POS.201, 215 (EATON)
-POS.202
-POS.203
-POS.230
-POS.130,131(1204)
-POS.310,310A(1202)
Opening pressure = 230 bar
POS.304
POS.309
-POS.339
DRAIN LINE (SEE PAGE 3)
LPS (SEE PAGE 3)
MAIN TANK (SEE PAGE 3)
WASTE TANK (SEE PAGE 3)
LPS (SEE PAGE 1)
MAIN TANK (SEE PAGE 1)
WASTE TANK (SEE PAGE1)
P 2 (SEE PAGE 3)
SP (SEE PAGE 3)
P 1 (SEE PAGE 3)

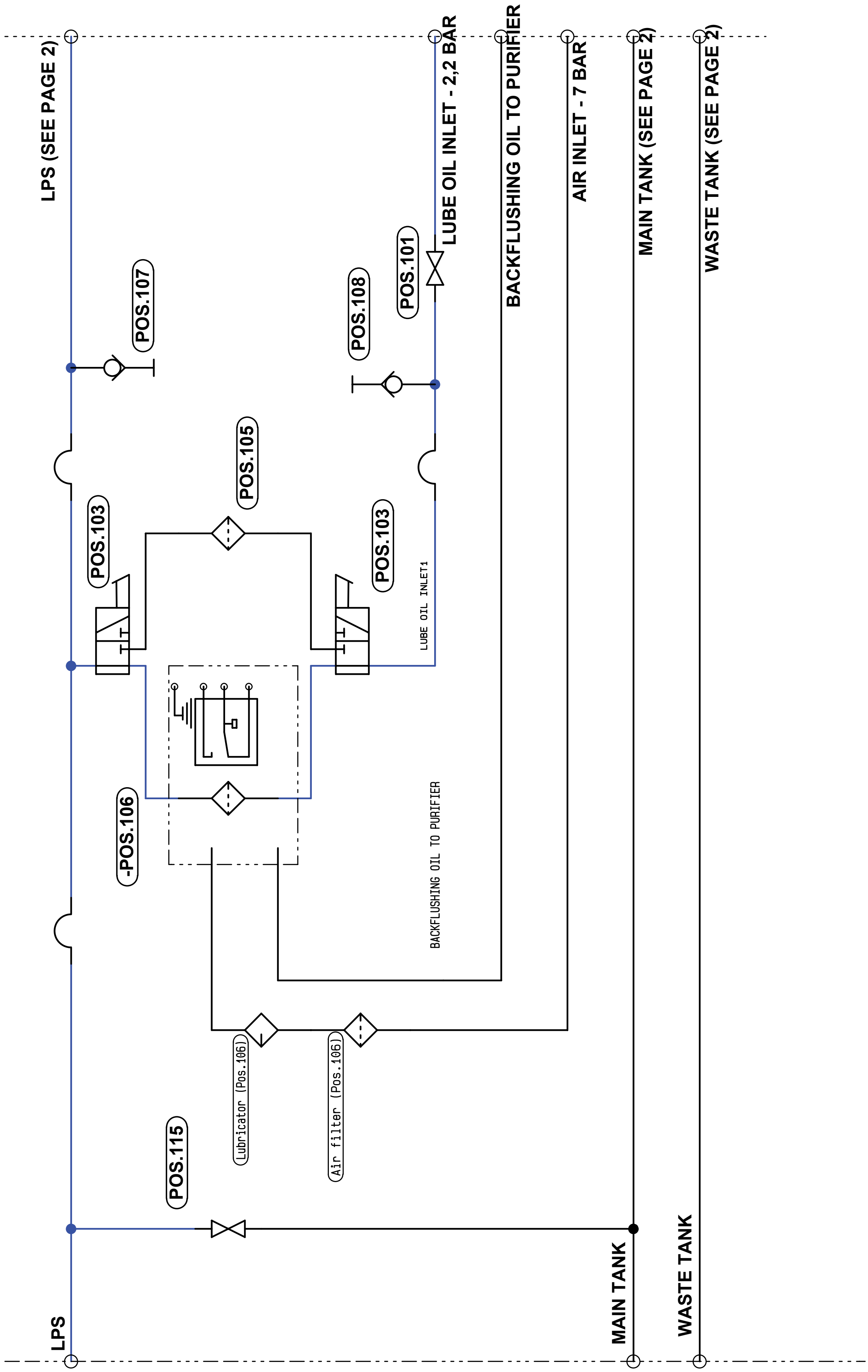

P 2 (SEE PAGE 4)
P 1 (SEE PAGE 4)
Sp
POS.204
POS.304
POS.309
-POS.210
-POS.335
-POS.201, 215 (EATON)
-POS.202
-POS.203
-POS.220
-POS.230
-POS.130,131 (1204)
OPEN at 0,2 bar
PSt
PSt1
MSt
PSt2
B1
A1
T
RH
LH
MA
MB
D1
L1
L2
L3
L3.1
L8
L5
ML
DRINE LINE (SEE PAGE 4)
LPS (SEE PAGE 4)
MAIN TANK (SEE PAGE 4)
WASTE TANK (SEE PAGE 4)
Safety and accumulator block
P 2 (SEE PAGE 2)
SP(SEE PAGE 2)
P 1 (SEE PAGE 2)
DRINE LINE
LPS (SEE PAGE 2)
MAIN TANK (SEE PAGE 2)
WASTE TANK (SEE PAGE 2)
Drain plug or drain valve
POS.361(1236)
POS.360(1235)

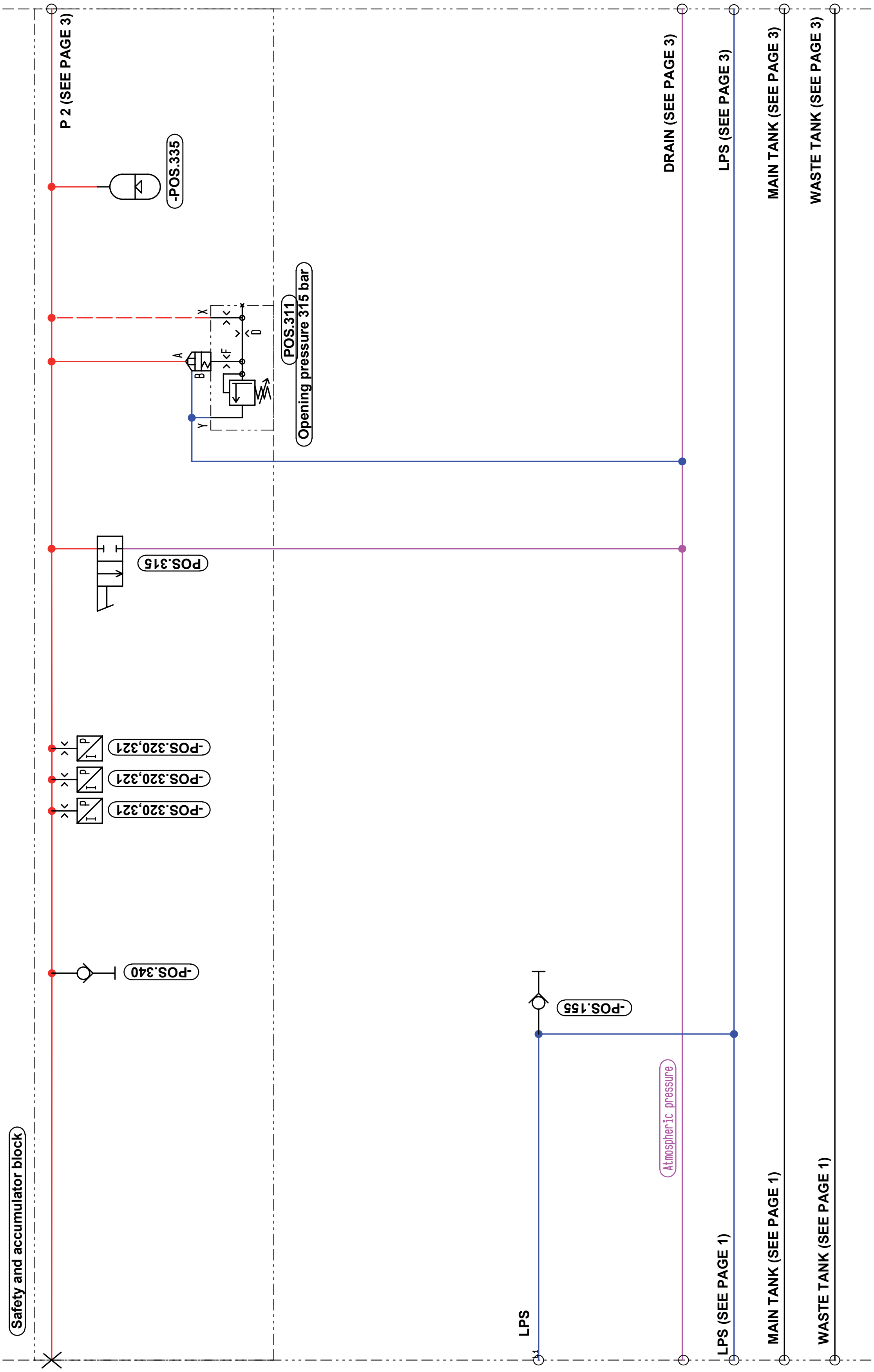
Gear Driven HPS, Common LPS, K98ME/ME-C, Version 4, Eaton Pumps

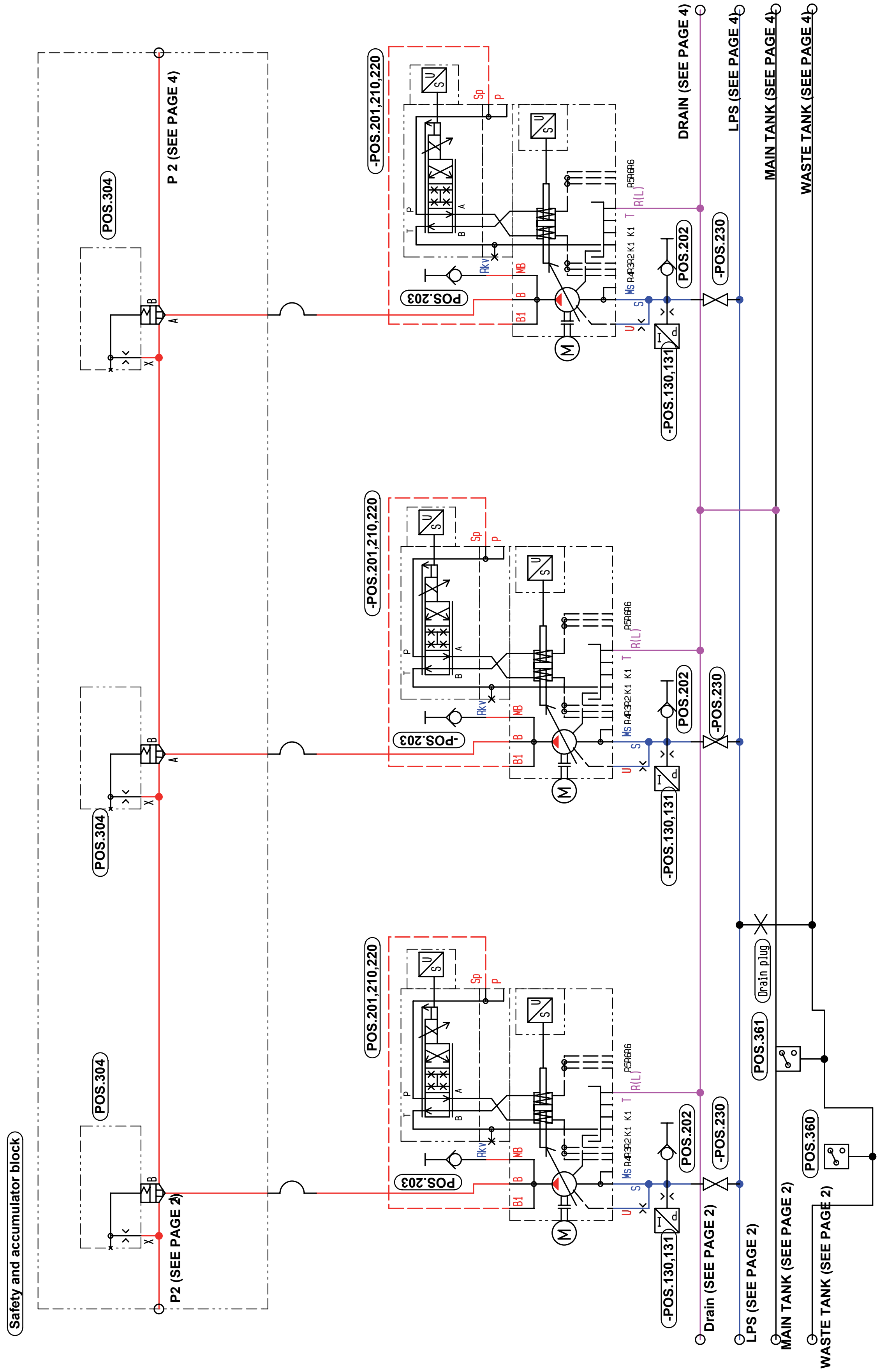


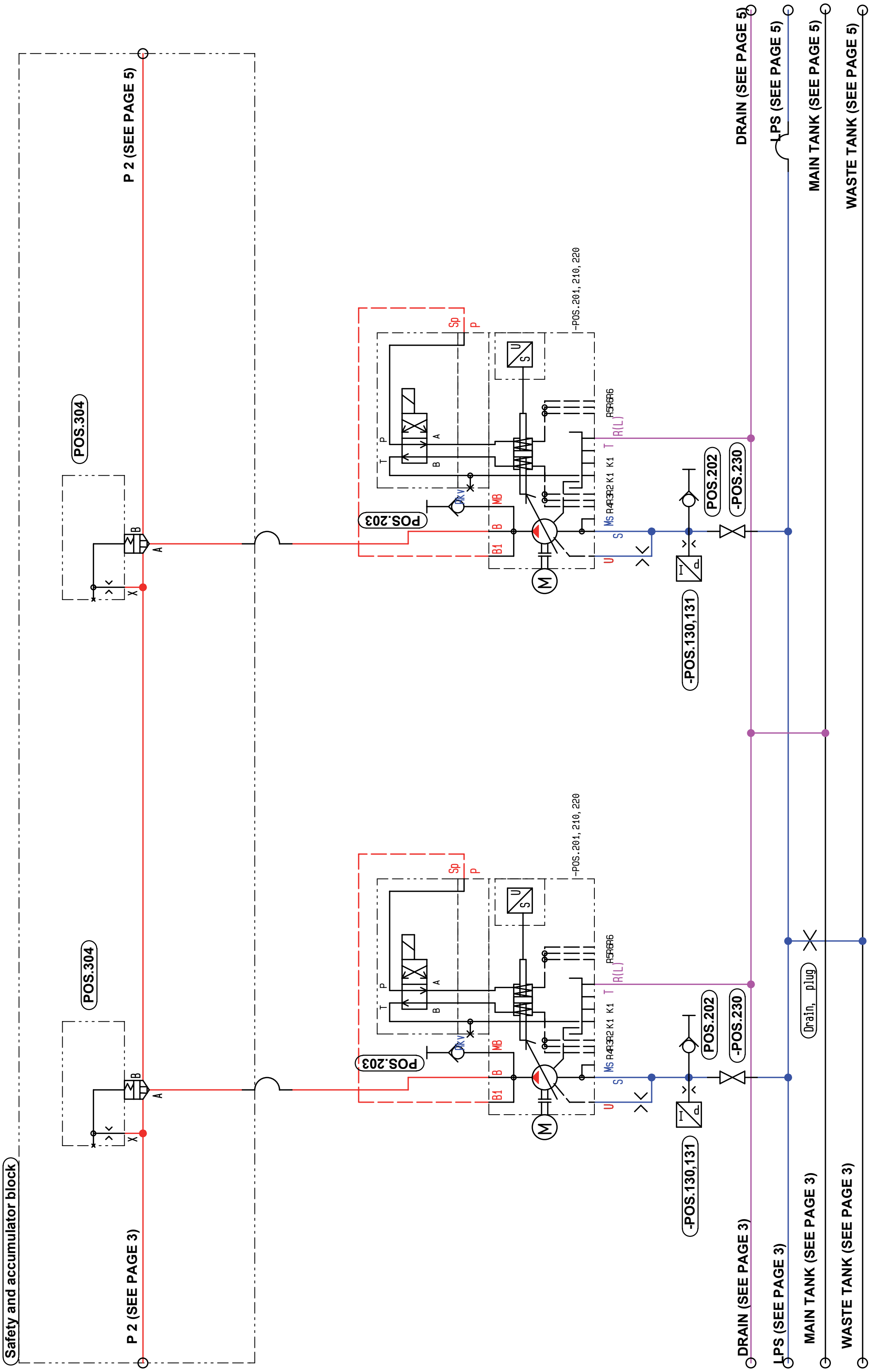

POS.526
POS.525
POS.528
POS.527
POS.531
POS.480
POS.406
POS.405
POS.465
Min. level = 50 mm over bottom surface of ELVA actuator STEP II, when the exhaust valve is OPEN
POS.530
POS.540
POS.520
POS.515, 516, 517
POS.440, 445
Cva
Cf1
Tva
Tf1
TL2
L
P
Lair
POS.420
POS.421
POS.450
POS.455
POS.500, 502, 503, 504
Fuel oil - drain
Fuel oil - drain
Fuel and lube oil - drain
POS.505
POS.501
POS.550
ELFI pump - lube oil drain
Fuel inlet
Fuel oil - circulation
POS.510
POS.560
POS.430
POS.431
POS.435
POS.555
DOUBLE WALL BETWEEN SPACE
TO THE NEXT HCU
LUBRICATOR INLET
LUBRICATOR RETURN
DRAIN LINE (SEE PAGE 4)
LPS (SEE PAGE 4)
P2 (SEE PAGE 4)
MAIN TANK (SEE PAGE 4)

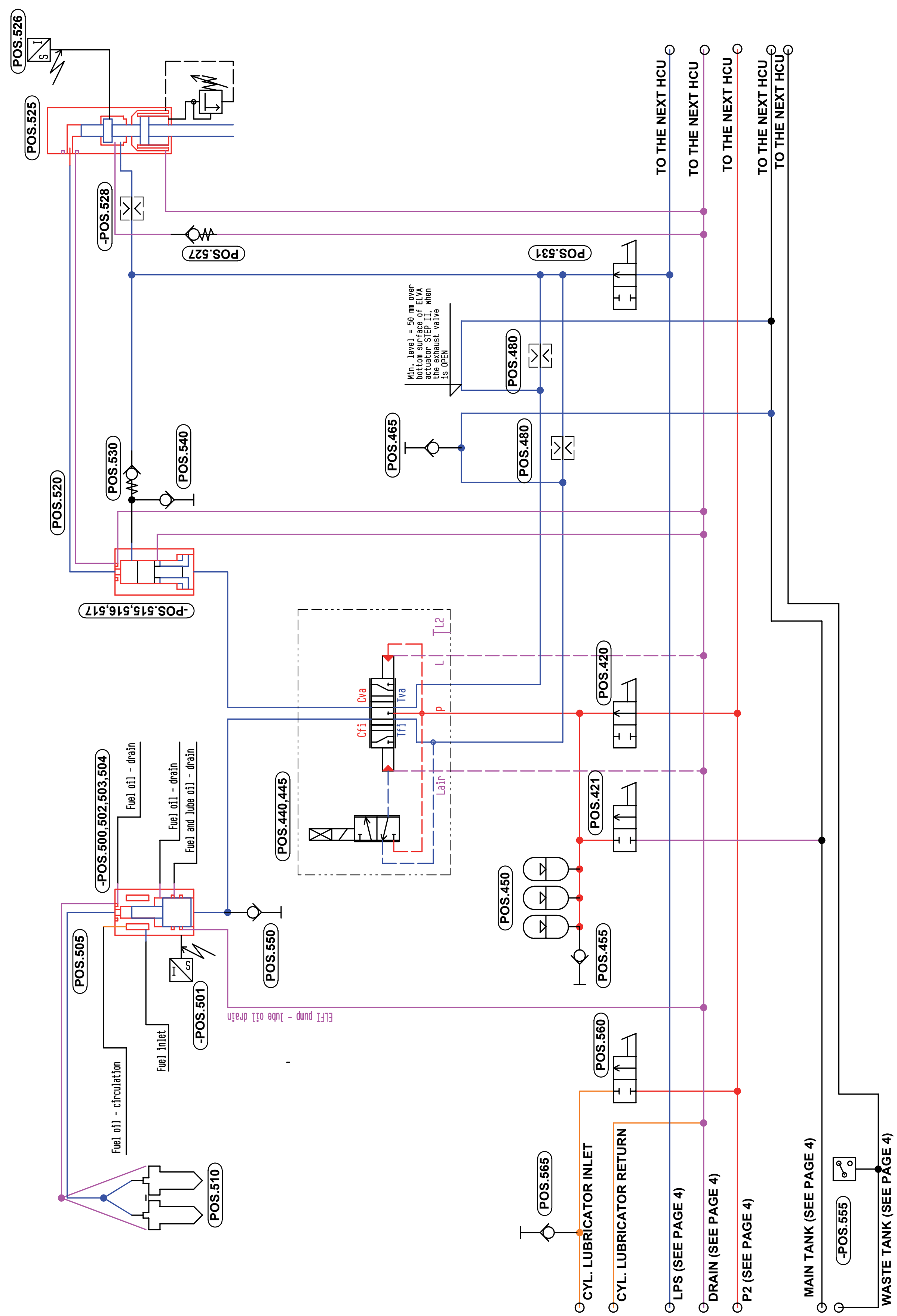
El driven HPS, Common LPS, FIVA, ME Version 5, Rexroth Pumps

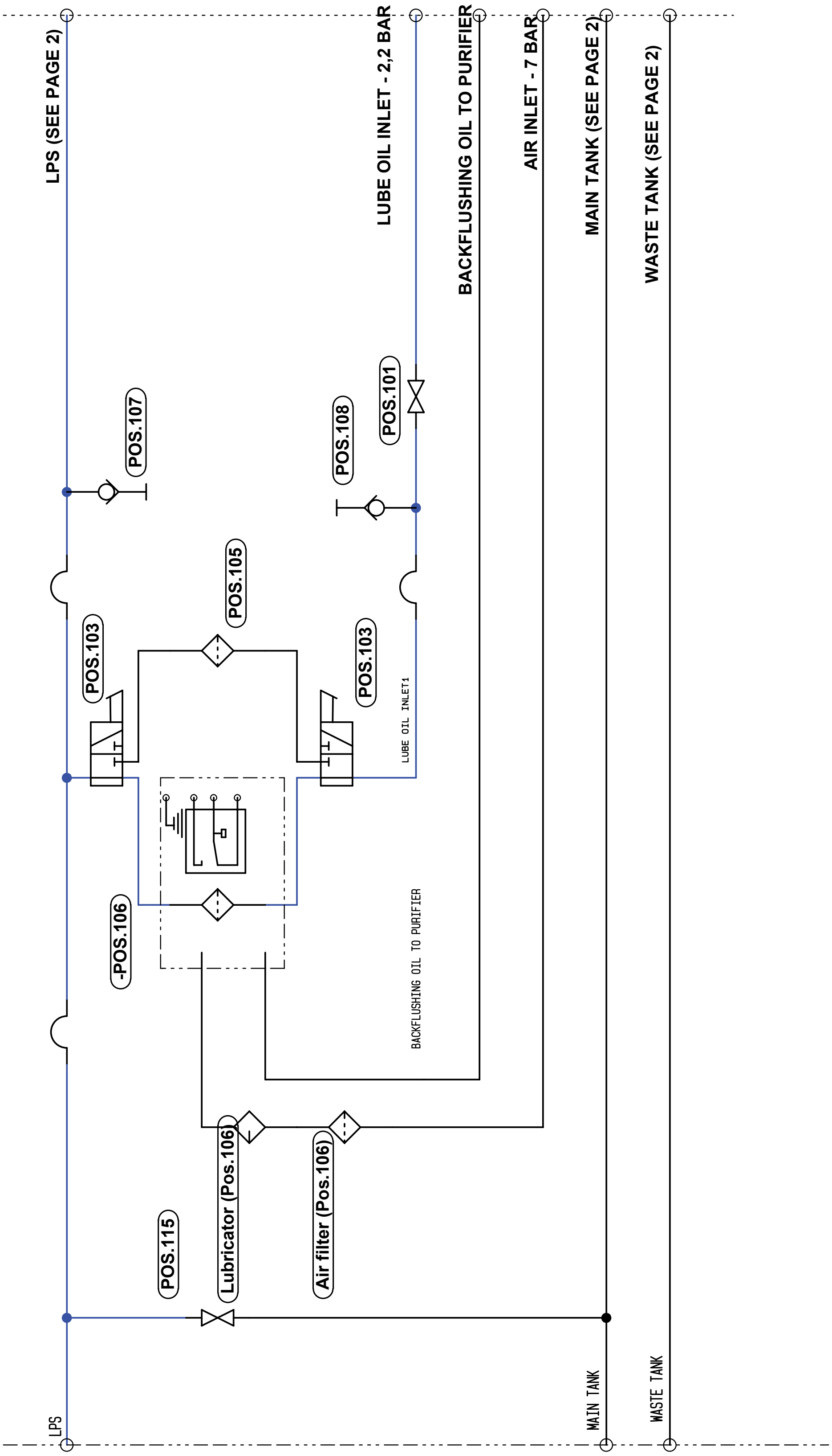


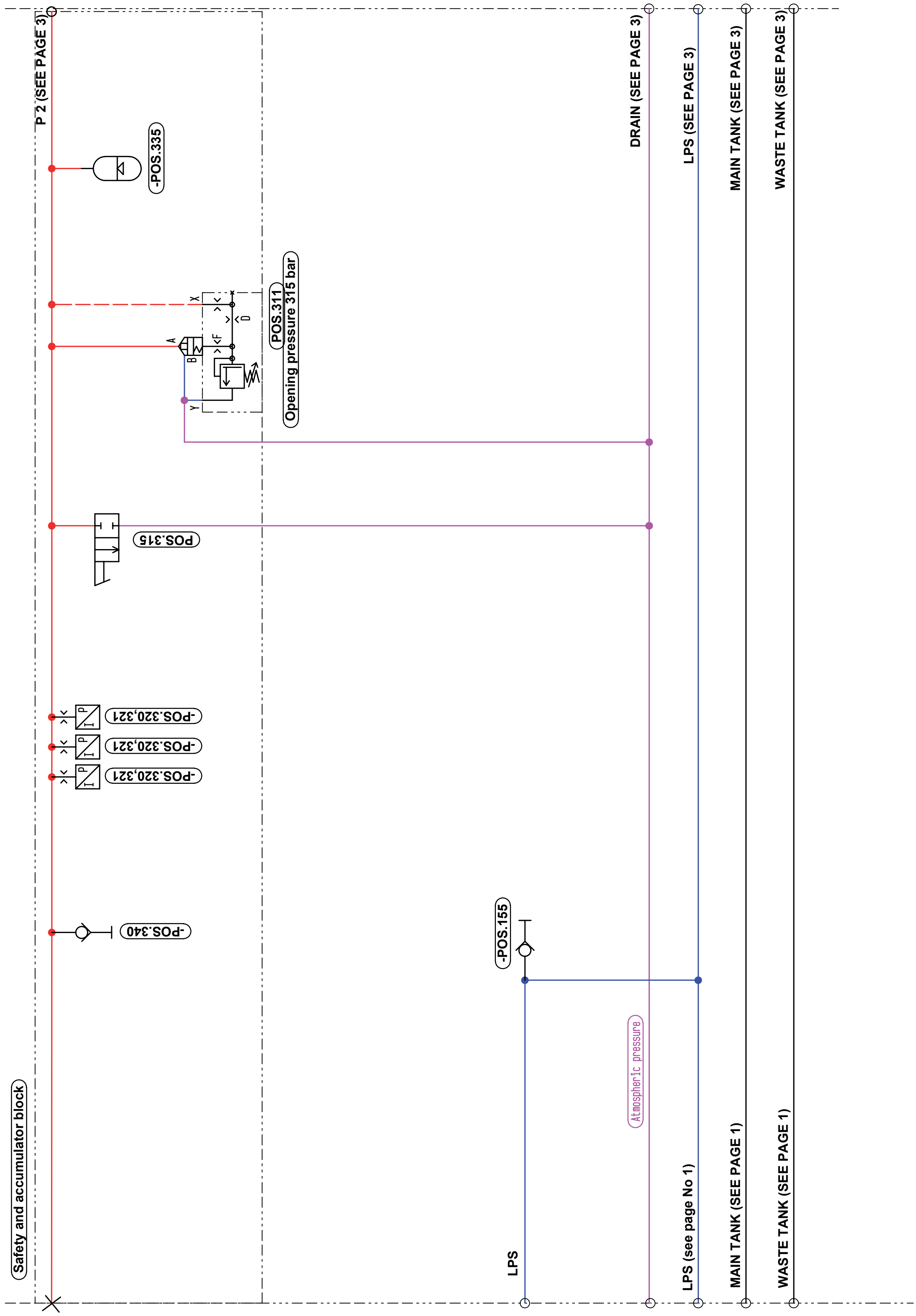

P 2 (SEE PAGE 3)
-POS.335
POS.311
Opening pressure 315 bar
POS.315
-POS.320,321
-POS.320,321
-POS.320,321
-POS.340
-POS.155
Safety and accumulator block
LPS
DRAIN (SEE PAGE 3)
LPS (SEE PAGE 3)
MAIN TANK (SEE PAGE 3)
WASTE TANK (SEE PAGE 3)
Atmospheric pressure
LPS (SEE PAGE 1)
MAIN TANK (SEE PAGE 1)
WASTE TANK (SEE PAGE 1)

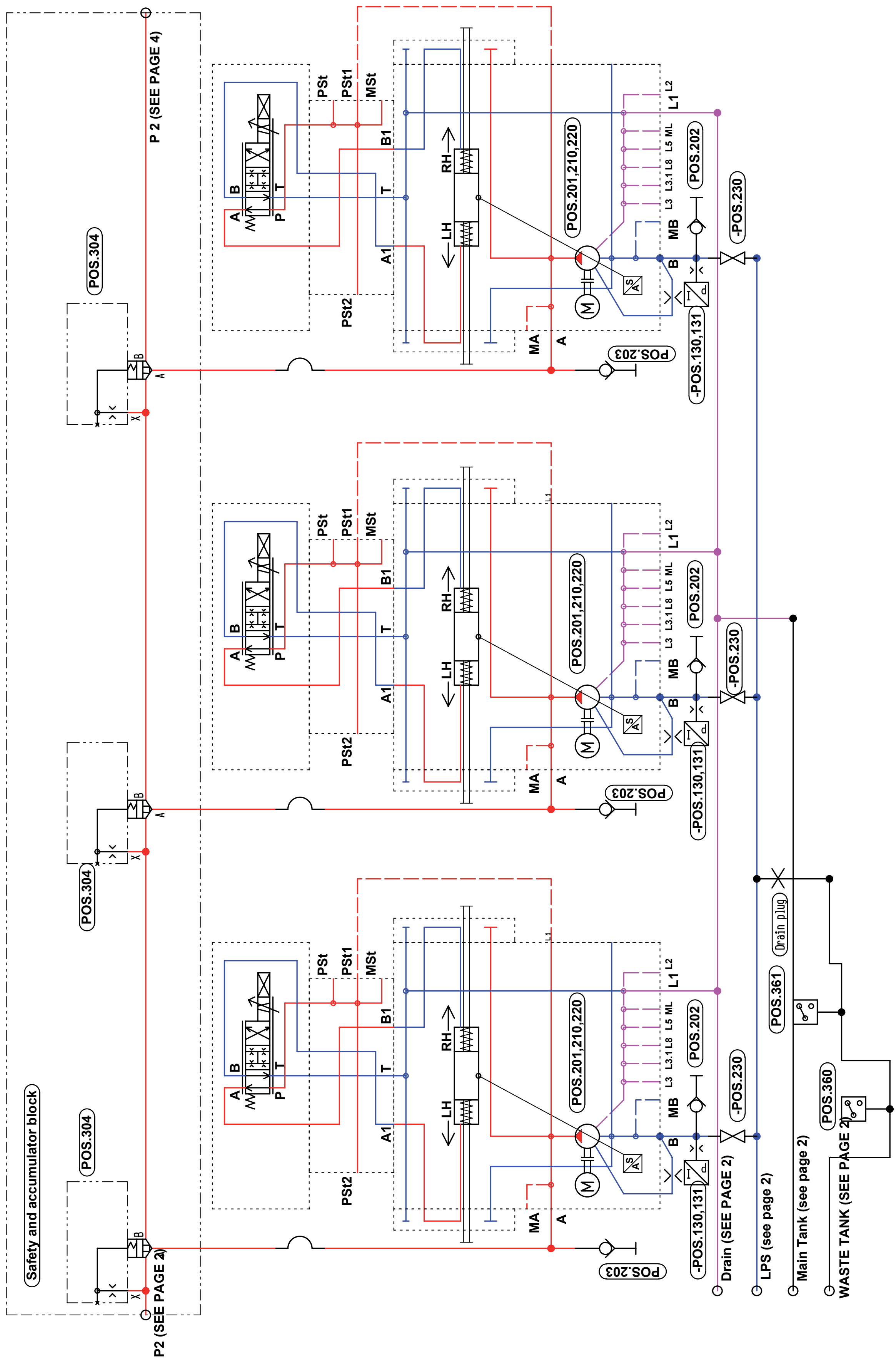

Safety and accumulator block
P 2 (SEE PAGE 4)
P2 (SEE PAGE 2)
POS.304
POS.201,210,220
POS.203
POS.202
POS.230
POS.130,131
DRAIN (SEE PAGE 4)
LPS (SEE PAGE 4)
MAIN TANK (SEE PAGE 4)
WASTE TANK (SEE PAGE 4)
Drain plug
POS.361
POS.360
Drain (SEE PAGE 2)
LPS (SEE PAGE 2)
MAIN TANK (SEE PAGE 2)
WASTE TANK (SEE PAGE 2)

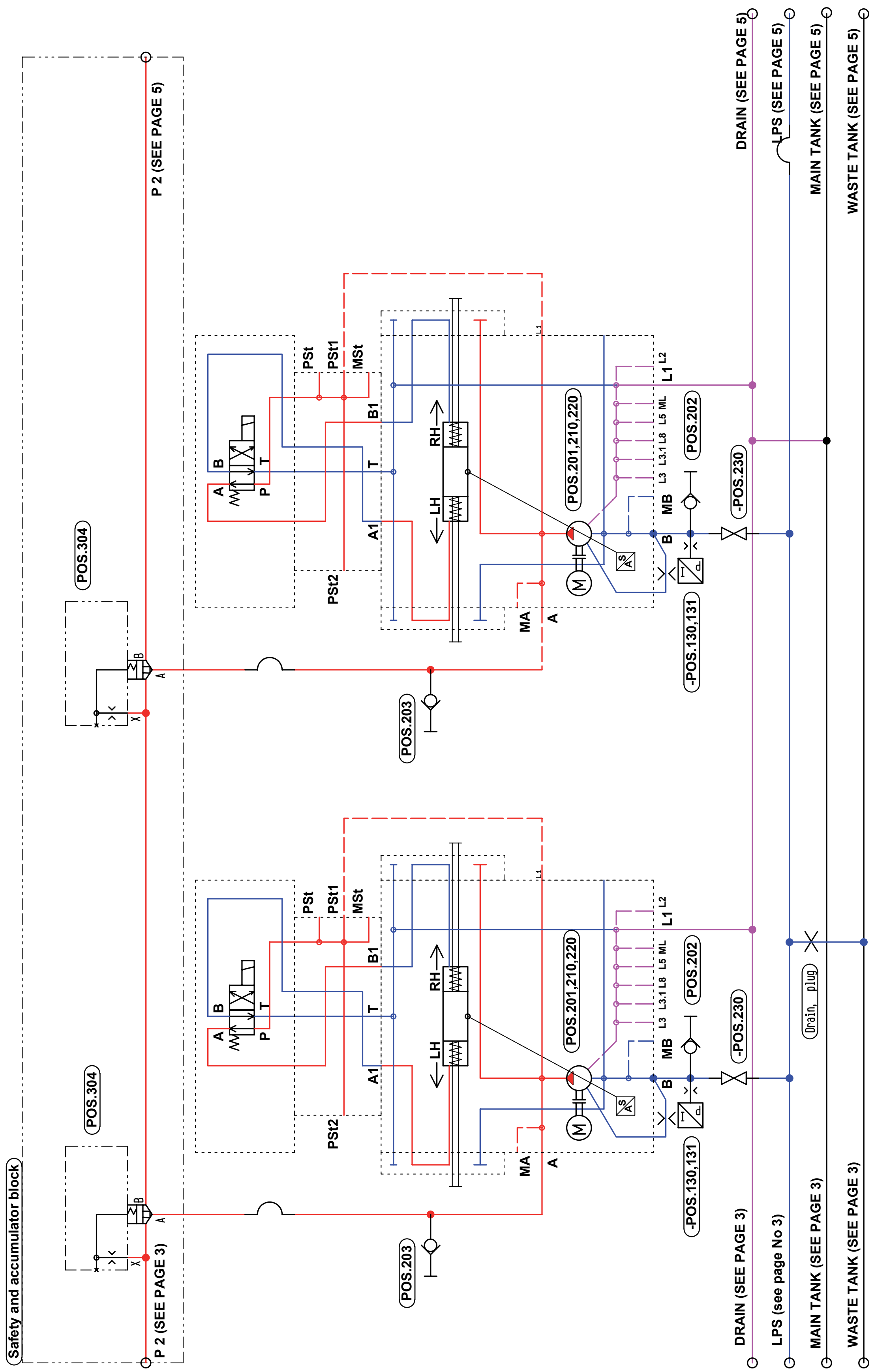

Safety and accumulator block
P 2 (SEE PAGE 5)
P 2 (SEE PAGE 3)
POS.304
POS.304
POS.203
POS.203
-POS.201, 210, 220
-POS.201, 210, 220
POS.202
POS.202
-POS.230
-POS.230
-POS.130,131
-POS.130,131
Drain, plug
DRAIN (SEE PAGE 5)
LPS (SEE PAGE 5)
MAIN TANK (SEE PAGE 5)
WASTE TANK (SEE PAGE 5)
DRAIN (SEE PAGE 3)
LPS (SEE PAGE 3)
MAIN TANK (SEE PAGE 3)
WASTE TANK (SEE PAGE 3)


POS.526
POS.525
POS.528
POS.527
POS.531
POS.480
POS.465
POS.480
POS.530
POS.540
POS.520
POS.515,516,517
POS.420
POS.421
POS.440,445
POS.450
POS.455
POS.500,502,503,504
POS.505
POS.501
POS.550
POS.510
POS.560
POS.565
POS.555
TO THE NEXT HCU
TO THE NEXT HCU
TO THE NEXT HCU
TO THE NEXT HCU
TO THE NEXT HCU
Min. level = 50 mm over bottom surface of ELVA actuator STEP II, when the exhaust valve is OPEN
Fuel oil - drain
Fuel oil - drain
Fuel and lube oil - drain
Fuel oil - circulation
Fuel inlet
ELFI pump - lube oil drain
Cva
Tva
Cfi
Tfi
P
L
TL2
Lair
CYL. LUBRICATOR INLET
CYL. LUBRICATOR RETURN
LPS (SEE PAGE 4)
DRAIN (SEE PAGE 4)
P2 (SEE PAGE 4)
MAIN TANK (SEE PAGE 4)
WASTE TANK (SEE PAGE 4)


LPS (SEE PAGE 2)
LUBE OIL INLET - 2,2 BAR
BACKFLUSHING OIL TO PURIFIER
AIR INLET - 7 BAR
MAIN TANK (SEE PAGE 2)
WASTE TANK (SEE PAGE 2)
POS.107
POS.108
POS.101
POS.105
POS.103
POS.103
LUBE OIL INLET1
-POS.106
BACKFLUSHING OIL TO PURIFIER
POS.115
Lubricator (Pos.106)
Air filter (Pos.106)
LPS
MAIN TANK
WASTE TANK


P 2 (SEE PAGE 3)
-POS.335
POS.311
Opening pressure 315 bar
POS.315
-POS.320,321
-POS.320,321
-POS.320,321
-POS.340
-POS.155
DRAIN (SEE PAGE 3)
LPS (SEE PAGE 3)
MAIN TANK (SEE PAGE 3)
WASTE TANK (SEE PAGE 3)
Atmospheric pressure
Safety and accumulator block
LPS
LPS (see page No 1)
MAIN TANK (SEE PAGE 1)
WASTE TANK (SEE PAGE 1)


P 2 (SEE PAGE 4)
Safety and accumulator block
POS.304
P2 (SEE PAGE 2)
PSt
PSt1
MSt
PSt2
B1
A1
T
RH
LH
MA
A
B
MB
L1
L2
POS.201,210,220
POS.202
POS.203
POS.230
POS.130,131
POS.361
POS.360
Drain plug
Drain (SEE PAGE 2)
LPS (see page 2)
Main Tank (see page 2)
WASTE TANK (SEE PAGE 2)


P 2 (SEE PAGE 5)
P 2 (SEE PAGE 3)
Safety and accumulator block
POS.304
POS.304
POS.203
POS.203
PSt
PSt1
MSt
PSt2
B1
A1
T
RH
LH
MA
A
B
MB
L1
L2
L3
L3.1
L8
L5
ML
POS.201,210,220
POS.202
POS.230
POS.130,131
Drain, plug
DRAIN (SEE PAGE 5)
LPS (SEE PAGE 5)
MAIN TANK (SEE PAGE 5)
WASTE TANK (SEE PAGE 5)
DRAIN (SEE PAGE 3)
LPS (see page No 3)
MAIN TANK (SEE PAGE 3)
WASTE TANK (SEE PAGE 3)

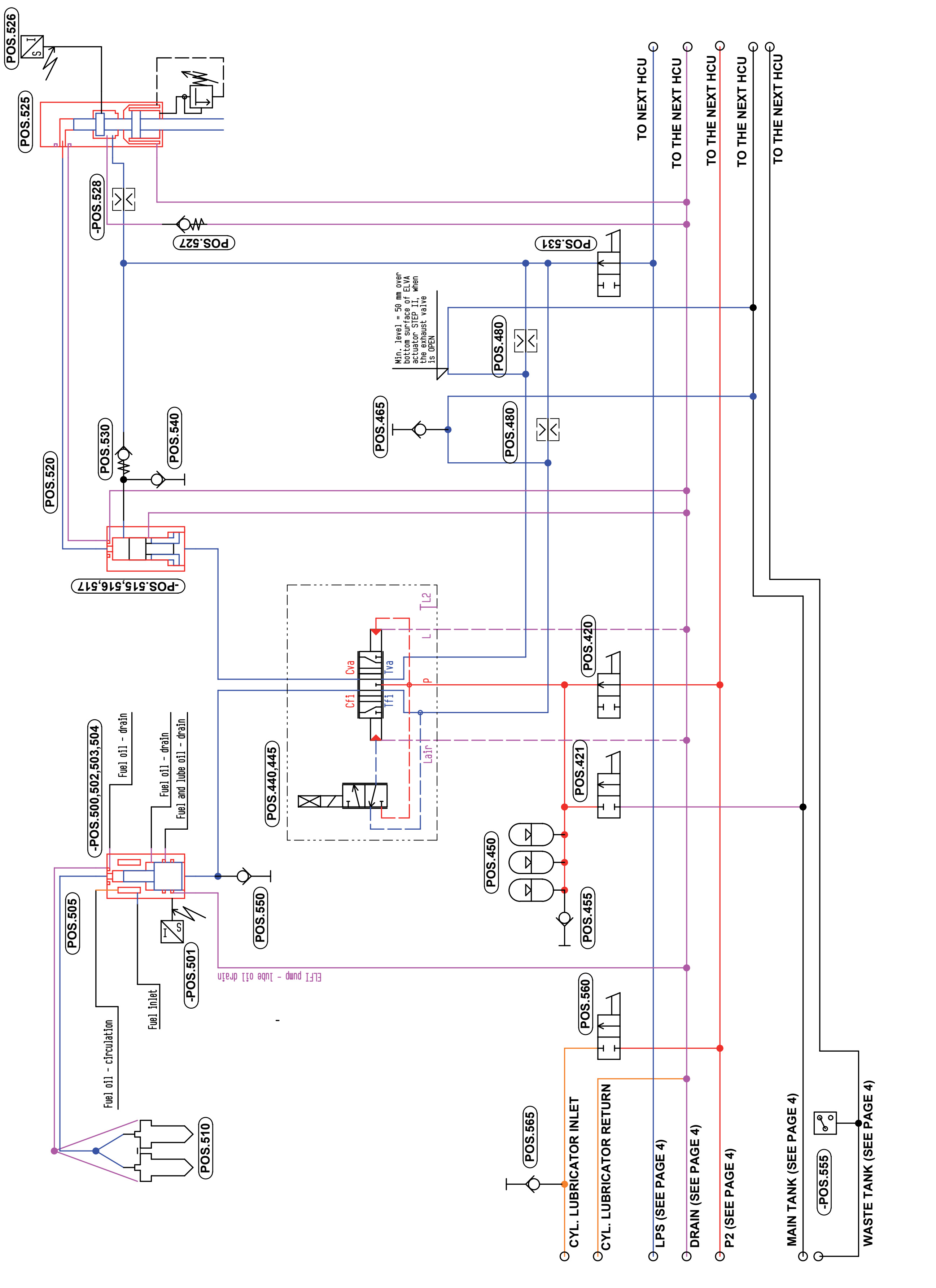

POS.526
POS.525
POS.528
POS.527
POS.531
TO NEXT HCU
TO THE NEXT HCU
TO THE NEXT HCU
TO THE NEXT HCU
TO THE NEXT HCU
Min. level = 50 mm over bottom surface of ELVA actuator STEP II, when the exhaust valve is OPEN
POS.480
POS.465
POS.480
POS.520
POS.530
POS.540
-POS.515,516,517
L2
L
Cva
Tva
P
Cf1
Tf1
Lair
POS.420
POS.421
POS.440,445
-POS.500,502,503,504
Fuel oil - drain
Fuel oil - drain
Fuel and lube oil - drain
POS.450
POS.455
POS.505
POS.550
-POS.501
ELFI pump - lube oil drain
Fuel inlet
Fuel oil - circulation
POS.560
POS.510
POS.565
CYL. LUBRICATOR INLET
CYL. LUBRICATOR RETURN
LPS (SEE PAGE 4)
DRAIN (SEE PAGE 4)
P2 (SEE PAGE 4)
MAIN TANK (SEE PAGE 4)
-POS.555
WASTE TANK (SEE PAGE 4)

Table of Contents

709-01 Water Cooling Systems

709-02 Cooling Water Treatment

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PLATES

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.
For a specific plant, the correct details must be found in the piping diagrams supplied by the shipyard.

2. Seawater Cooling System *(Plate 70901)*

Seawater is drawn up through the sea connection (1) by the seawater pump (2). From the pump, the water-flow is divided into three separate branches:

1. through the adjustable valve (3) direct to the main engine scavenge air cooler(s).
2. through the non-return valve (5) to the auxiliary engines
3. through the adjustable valve (3) to the lub. oil cooler and jacket water cooler, which are connected in series.

   Other branches may be installed in parallel with branch 3:
   – Water supply to PTO/RCF lube oil cooler (if installed).

The sea water from the above-mentioned branches is later mixed again, and then continues to the thermostatically controlled 3-way regulating valve (6) at the seawater overboard valve (7).

Regulating valve (6) is controlled by the sensor (8) which is located in the seawater inlet pipe. The thermostat is adjusted so that the water temperature at the pump inlet is kept above 10°C, in order to prevent the lub. oil from becoming too viscous on the cold cooling surfaces *(see also 'Alarm Limits', Section 701-01).*

If the seawater inlet temperature drops below the set level, then regulating valve (6) opens for the return flow to the seawater pump suction piping.

3. Jacket Water Cooling System *Plates 70902, 70904*

The jacket water is circulated through the cooler and the main engine cylinders by the jacket water pump (1). The thermostatically controlled regulating valve (2), at the outlet from the cooler, mixes cooled and uncooled jacket water in such proportions that the temperature of the *outlet water from the main engine is maintained at about 80-85°C. See Section 701-02.*

Regulating valve (2) is controlled by the sensor (3), which is located in the cooling water outlet of the main engine.

In order to avoid increased cylinder wear it is important to maintain the cooling water outlet temperature at 80-85°C.

A lower temperature may cause condensation of sulphuric acid on the cylinder walls.

An integrated loop in the auxiliary engines ensures a constant temperature of 80°C at the outlets from the auxiliary engines.

To prevent air accumulation in the cooling water system, a deaerating tank (4) (cyclone tank) has been inserted in the piping. The expansion tank (5) takes up the difference in the water volume at changes of temperature.

Also an alarm device is installed to give off alarm, in case of excessive air/steam formation in the system. *See Section 701-02.*

Pressure gauges are installed to enable checking of the pressure difference across the engine. *See Section 701-02.*

3.1 Operation in Port *(Plate 70902)*

The main engine is preheated by utilising hot water from the auxiliary engine(s). This preheating is activated by closing valves (6) and opening valves (7).

Activating valves (6) and (7) 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 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 (2).

In this operating mode, the temperature sensor (3) for valve (2) measures in a non-flow, low temperature piping. Valve (2) will consequently be set to lead the cooling water to the jacket water cooler (8), and further on to the auxiliary engine-driven pumps.

The integrated loop in the auxiliary engines will ensure a constant temperature of 80°C at the auxiliary engine outlet, thus preheating the main engine.

Auxiliary engines in stand-by are automatically preheated by hot water entering through valves F3 and leaving through valves F1.

4. Central Cooling System *(Plate 70903)*

In the *central cooling water system*, the central cooling water pump (3) circulates the low-temperature freshwater (central cooling water) in a cooling circuit: in parallel through the scavenge air cooler(s), through the lub. oil cooler and jacket water cooler, the two last mentioned connected in series, and through the auxiliary engines.

The temperature in the low temperature part of the system is monitored by the thermostatically controlled regulating valve (4). Adjust the regulating valve so that the min. temperature at inlet to the air cooler, the oil cooler, and the auxiliary engines is above 10°C.

Regarding main and auxiliary jacket cooling water systems, *see previous section 3., 'Jacket Water Cooling System'.*

4.1 Operation in Port *(Plate 70903)*

The main engine is preheated by utilising hot water from the auxiliary engine(s). This preheating is activated by closing valves (6) and opening valves (7).

Activating valves (6) and (7) will change the direction of flow, and the water will now be circulated by the smaller port service central water pump.

From the auxiliary engines, the water flows 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 of the jacket water cooler.

In this operating mode, the temperature sensor for the thermostatically controlled 3-way valve measures in a non-flow, low temperature piping. The valve will consequently be set to make the cooling water by-pass the jacket water cooler and return to the port service pump.

The integrated loop in the auxiliary engines will ensure a constant temperature of 80°C at the auxiliary engine outlet, thus preheating the main engine.

Auxiliary engines in stand-by are automatically preheated by hot water entering through valves F3 and leaving through valves G1.

5. Preheating during Standstill

Preheat the engine in accordance with *Section 703-07.*

Preheat by means of:

- A built-in preheater, *see also Plate 70904.*

  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 3.1, '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 **90-100°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 *The cooling space is not completely filled with water. This results in local overheating, and hence the formation of steam.* • 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. *See also Section 707-01.* **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 9. 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.

! *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

! *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 Section 709-01.

2. Checking the System and Water during Service

Check the cooling water system and the water at the intervals given below:

We recommend to keep a record of all tests, to follow the condition and trend of the cooling water.

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 system during running.

Take the sample from the circulating system, 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.

! *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.

! *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.

! *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

! *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

! *Be careful. Use protective spectacles and gloves.*

4.2.A 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.B 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.C Circulate the solution

Circulate the agent for the period specified by the supplier. Check and repair any leaks.

4.2.D 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.

! *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.A Prepare for descaling

Fill up with clean tap water.

Heat the water to a maximum of 70°C, and circulate it continuously.

! *Some ready-mixed cleaning agents are specified to be used at a lower temperature. This maximum temperature must be adhered to.*

4.3. B 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.C 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.D 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).

> ! *Check the acid content of the system oil directly after the descaling, and again 24 hours later. See Section 708-04.*

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 / 1000 l 20 l / 1000 l
Drew Ameriod Marine Boonton, N.J./USA	DEWT NC Liquidewt Maxiguard	Powder Liquid Liquid	3.2 kg / 1000 l 8 l / 1000 l 16 l / 1000 l
Nalfloc Ltd. Northwich, Cheshire, England	NALFLEET 9-121 NALFLEET 9-108	Powder Powder Liquid	2.5 kg / 1000 l 2.2 kg / 1000 l 5 l / 1000 l
Rohm & Haas (ex Duolite) Paris, France	RD11 DIAPROSIM RD25 DIA PROSIM	Powder Liquid	3 kg / 1000 l 50 l / 1000 l
Vecom Maassluis, Holland	CWT Diesel QC2	Liquid	12 l / 1000 l
Wilhelsen Ships Service AS Lysaker, Norway	Unitor Dieselguard NB Unitor Rocor NB Liquid	Powder Liquid	2 kg / 1000 l 9 l / 1000 l

Generally we recommend 2000-2500 ppm Nitrite.
(*) Initial dosage may be larger.

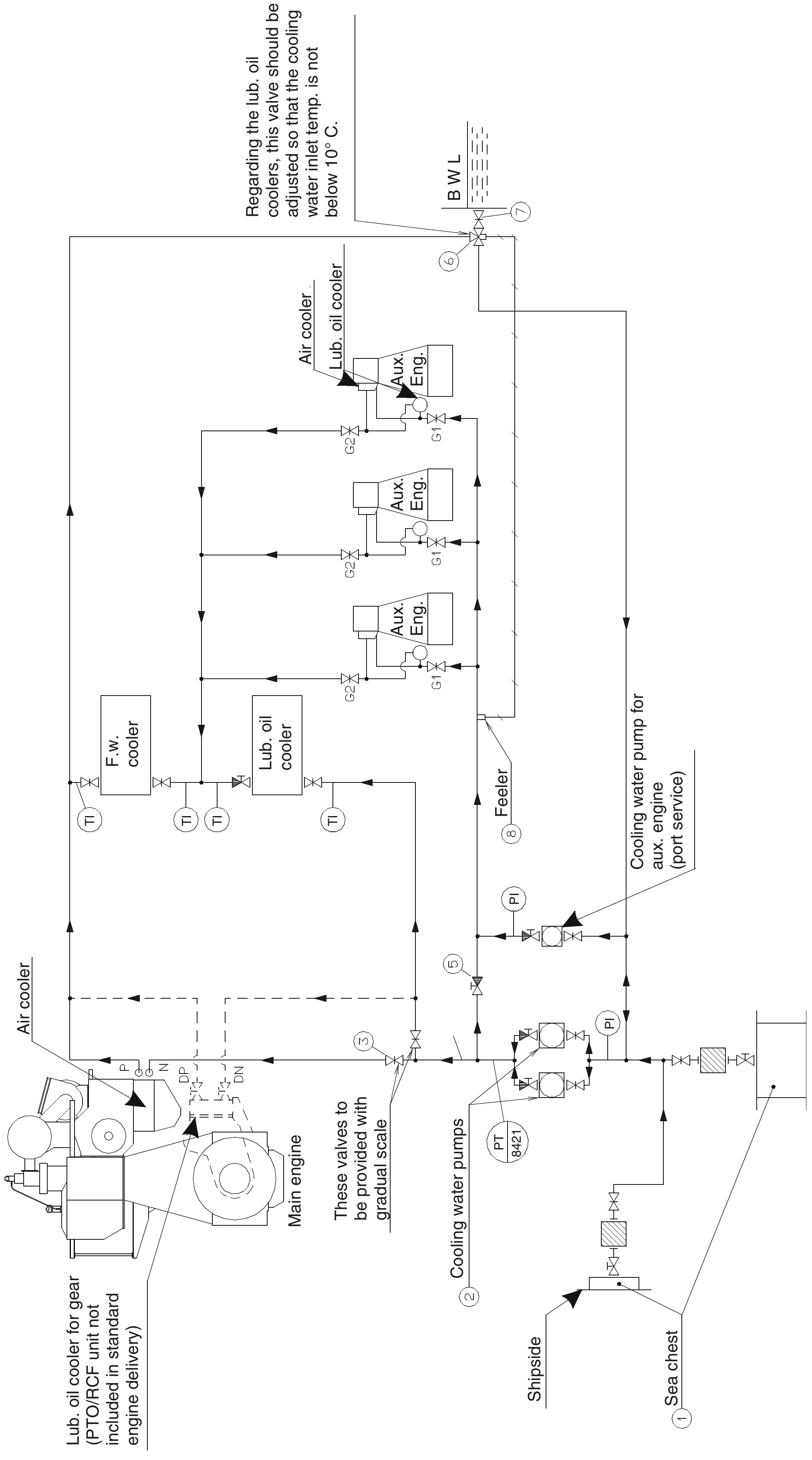
5.2 Non Nitrite-borate Corrosion Inhibitors for Fresh Cooling Water Treatment

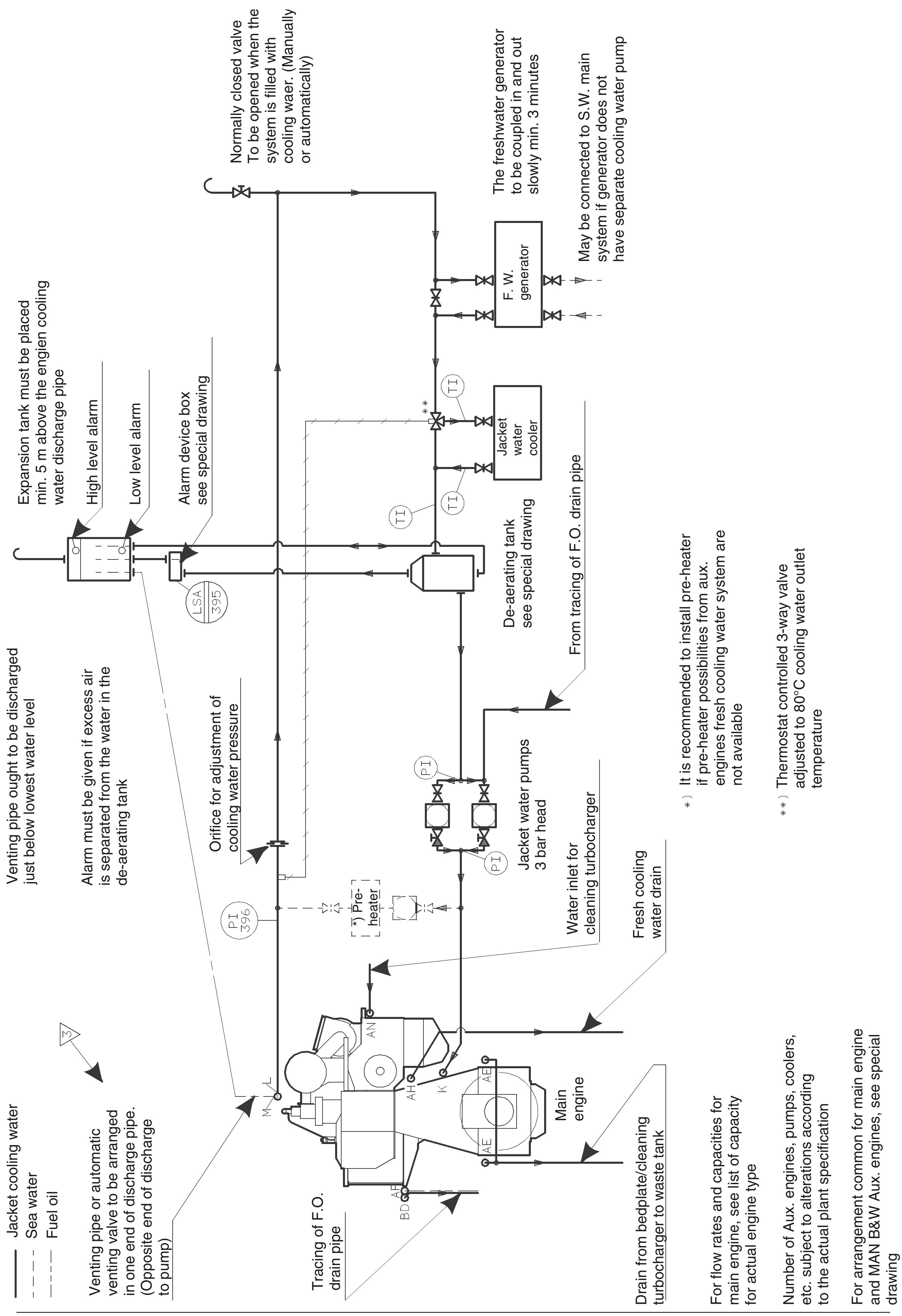
Company	Name of Inhibitor	Delivery Form	Maker's min. Recommended Dosage (*)
Chevron, Houston USA	Havoline XLI Havoline XLC	Liquid	50 l / 1000 l 350 l / 1000 l
Wilhelmsen Ships Service AS Lysaker, Norway	Unitor Cooltreat AL	Liquid	50 l / 1000 l

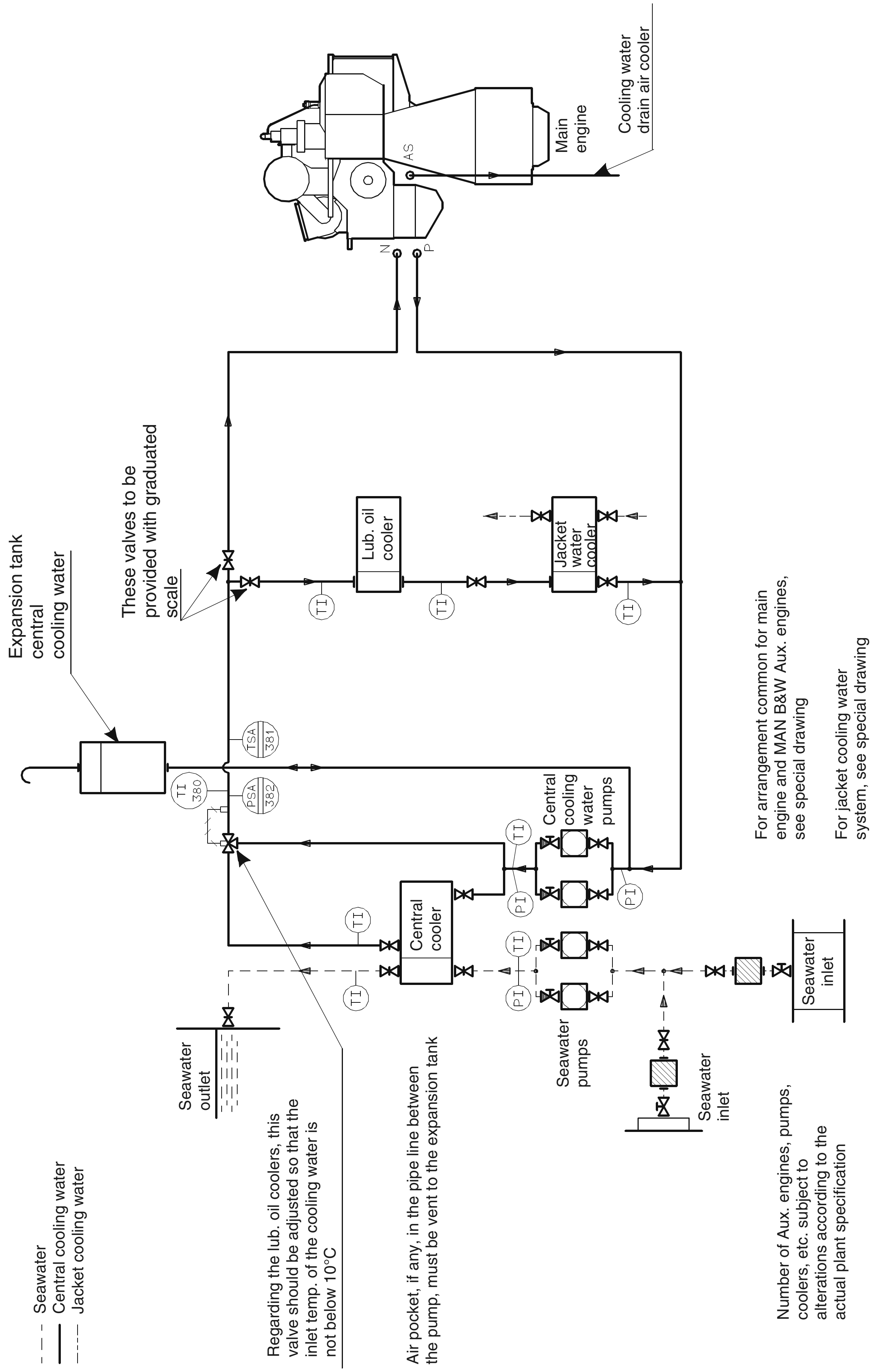
(*) Initial dosage may be larger.

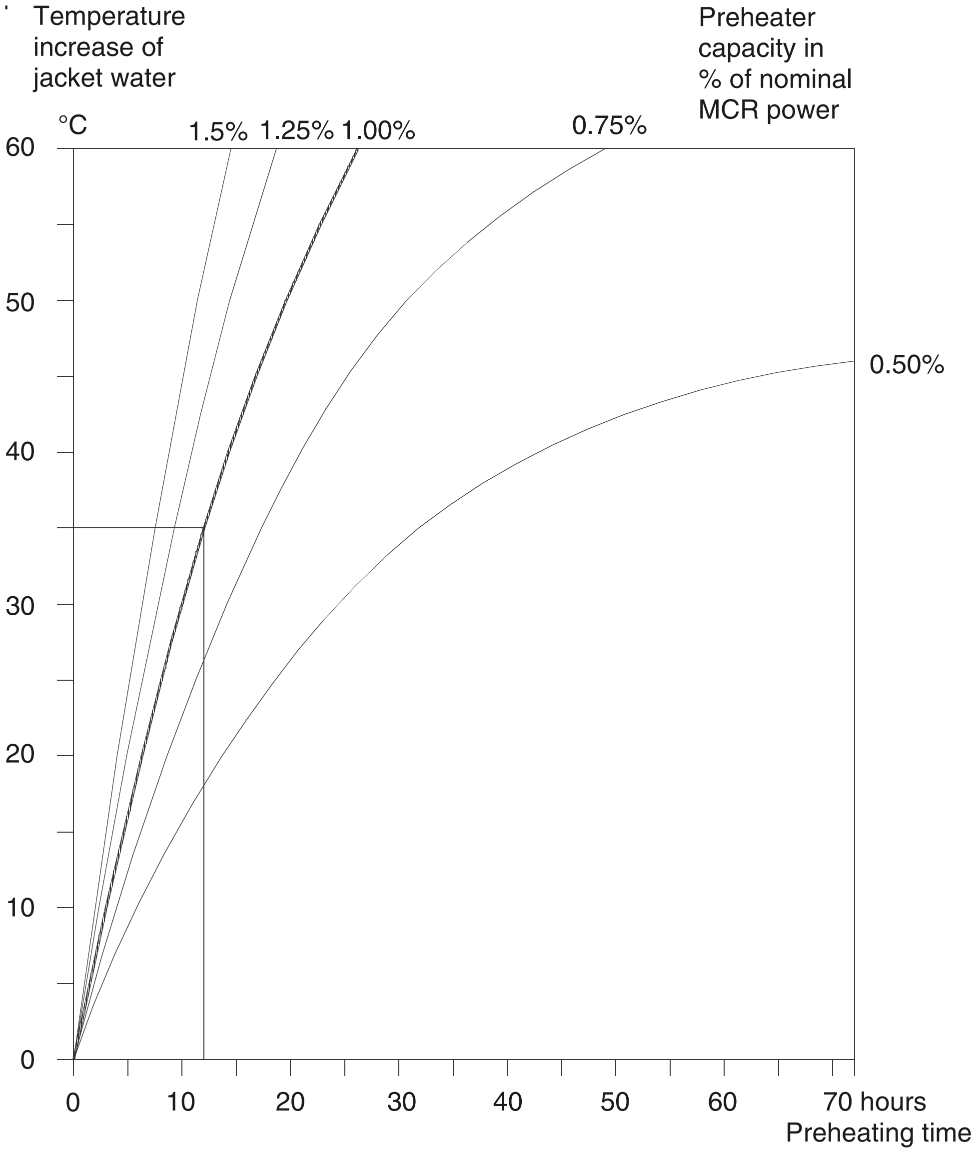
These lists are for guidance only and must not be considered complete. We undertake no responsibility for difficulties that might be caused by these or other water inhibitors/chemicals.

The suppliers are listed in alphabetical order.
Suitable cleaners can normally also be supplied by these firms.


Regarding the lub. oil coolers, this valve should be adjusted so that the cooling water inlet temp. is not below 10° C.
B W L
7
6
Air cooler
Lub. oil cooler
Aux. Eng.
Aux. Eng.
Aux. Eng.
G1
G2
F.w. cooler
Lub. oil cooler
TI
PI
Feeler
8
Cooling water pump for aux. engine (port service)
5
PI
Air cooler
P
N
DP
DN
3
These valves to be provided with gradual scale
Main engine
Cooling water pumps
2
PT 8421
Lub. oil cooler for gear (PTO/RCF unit not included in standard engine delivery)
Shipside
Sea chest
1


Jacket cooling water
Sea water
Fuel oil
Venting pipe or automatic venting valve to be arranged in one end of discharge pipe. (Opposite end of discharge to pump)
Venting pipe ought to be discharged just below lowest water level
Alarm must be given if excess air is separated from the water in the de-aerating tank
Expansion tank must be placed min. 5 m above the engien cooling water discharge pipe
High level alarm
Low level alarm
Alarm device box see special drawing
LSA 395
Orifice for adjustment of cooling water pressure
PI 396
*) Pre-heater
Normally closed valve To be opened when the system is filled with cooling waer. (Manually or automatically)
TI
TI
TI
**
Jacket water cooler
F. W. generator
The freshwater generator to be coupled in and out slowly min. 3 minutes
May be connected to S.W. main system if generator does not have separate cooling water pump
De-aerating tank see special drawing
From tracing of F.O. drain pipe
PI
PI
Jacket water pumps 3 bar head
Water inlet for cleaning turbocharger
Fresh cooling water drain
Tracing of F.O. drain pipe
Drain from bedplate/cleaning turbocharger to waste tank
Main engine
M
L
AN
AH
K
AE
AE
AF
BD
3
*) It is recommended to install pre-heater if pre-heater possibilities from aux. engines fresh cooling water system are not available
**) Thermostat controlled 3-way valve adjusted to 80°C cooling water outlet temperature
For flow rates and capacities for main engine, see list of capacity for actual engine type
Number of Aux. engines, pumps, coolers, etc. subject to alterations according to the actual plant specification
For arrangement common for main engine and MAN B&W Aux. engines, see special drawing


Main engine
Cooling water drain air cooler
AS
N
P
Expansion tank central cooling water
These valves to be provided with graduated scale
Lub. oil cooler
Jacket water cooler
TI
TSA 381
TI 380
PSA 382
Central cooling water pumps
PI
Central cooler
Seawater inlet
Seawater pumps
Seawater inlet
Seawater outlet
For arrangement common for main engine and MAN B&W Aux. engines, see special drawing
For jacket cooling water system, see special drawing
Regarding the lub. oil coolers, this valve should be adjusted so that the inlet temp. of the cooling water is not below 10°C
Air pocket, if any, in the pipe line between the pump, must be vent to the expansion tank
Number of Aux. engines, pumps, coolers, etc. subject to alterations according to the actual plant specification
Seawater
Central cooling water
Jacket cooling water



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 *Section 703-07.*