

Index for Operation Manual

(Volume I)

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

Chapter	Title
701	Safety Precautions and Engine Data
702	Checks during Standstill Periods
703	Starting, Manoeuvring and Running
704	Special Running Conditions
705	Fuel and Fuel Treatment
706	Performance Evaluation & General Operation
707	Cylinder Condition
708	Bearings and Circulating Oil
709	Water Cooling Systems
710	Index

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.



Instruction Book 'Operation'

for 46-98MC Engines

General Edition 40E

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:

46 - 98 MC

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 for guidance purposes only.

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

Example: Instruction book OPERATION, Edition 40E, page 701.09-40D.

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

for the engine concerned.

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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.

Think out beforehand 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.

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.

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.

Fire

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: 'Fire in scavenge air box' and 'Ignition in Crankcase', [Chapter 704](#), and 'Sealing Materials' in this Chapter.

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.

Check and Maintain

Measuring equipment, filter elements, and lubricating oil condition.

Entering the Crankcase or Cylinder

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 [Chapter 704](#) `Ignition in Crankcase')

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.

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 [Chapter 703](#), Item 3.2, `Check 9') 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 [Chapter 703](#), Item 3.2, `Check 9'.

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.

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



General Basis for Guidance Values

*The values stated in this list 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. 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 engine Instruction Book.

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.

NB: Attention must be paid to the temperature levels stated under Nos. 340 to 348 (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.



The list applies to all MC/MC-C Engines

For items marked with an '★', further details are given in a footnote.

Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
300	p	Fuel pump roller guide gear activated ★		0	2.0			
301	l	Leakage from high pressure pipes			★			
302	v/t	Fuel oil inlet engine		T ★				
303	v	Fuel oil inlet engine		10-15 cSt ★				
303A	v	Fuel oil inlet engine			20 ★			
304	v	Fuel oil inlet engine				7 ★		
305	p	Fuel oil inlet engine ★		7-8				
306	p	Fuel oil inlet engine ★				6.5		
307	p	Fuel oil before filter ★				6.5		
308	Δp	Pressure drop across fuel oil filter		0.2-0.5				
309	t	Fuel oil inlet fuel pumps		T ★				
311	t	Lub. oil inlet (system oil)		40-50				
312	t	Lub. oil inlet (system oil)			55			
313	t	Lub. oil inlet (system oil)				35		
314	t	Lub. oil inlet (system oil)					60	
315	t	Lub. oil outlet from engine (lub. oil inlet to oil cooler)		50-60				
316	t	Lub. oil outlet from engine (lub. oil inlet to oil cooler)			65			
300 Only 80-98MC/MC-C type engines 301 See Vol. III, Chapter 909, 'Fuel oil leakage alarm'. 302, 309 The functioning of the viscorator can be checked by measuring the temperature. Regarding temperature in relation to viscosity, see Plate 70506. 303, 303A, 304 Viscosity to be monitored and alarm given off by sensor built into the viscorator. For viscorator without built-in alarm for max./min. viscosity, temperature switches can be used instead. The temperature switches can be preset by adjusting the viscorator to 20 and 7 cSt, respectively. 305, 306 Fuel viscosity max. 700 cSt at 50 °C measured at camshaft level. 307 Fuel viscosity max. 700 cSt at 50 °C.								



The list applies to all MC/MC-C Engines

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Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δ p = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
317	t	Piston cooling oil outlet (except K90-98MC/MC-C) K90-98MC/MC-C		50-65 55-65				
318	t	Piston cooling oil outlet			70			
319	t	Piston cooling oil outlet					75	
320	fl	Piston cooling oil outlet				no flow		
321	fl	Piston cooling oil outlet					no flow	
323	t	Oil pan temperature on ABB turbocharger, turbine side		70-115				
325	p	Engine room pressure		0.95-1.05				
326	p	Piston cooling oil inlet ★ (35-46 engines: also inlet to camshaft At stopped engine: S80, L90, K90-98MC/MC-C S70, S70MC-C, L80, K80MC-C S50-60, K/L50-60-70, S50-60MC-C, S46MC-C, S/L42MC, S/L35MC S26MC At running engine: (MCR) S80, L90, K90-98MC/MC-C S70, S70MC-C, L80, K80MC-C S50-60, K/L50-60-70, S50-60MC-C, S46MC-C, S/L42MC, S/L35MC S26MC		2.1 1.9 1.6 1.6 2.0 2.7 2.5 2.2 2.2 2.2				
326		Measured by pressure gauge placed 1800 mm 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).						



Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
327	p	Piston cooling oil inlet ★ 35-46 engines: also inlet to camshaft S80, L90, K90-98MC/MC-C S70, S70MC-C, L80, K80MC-C S50-60, K/L50-60-70, S50-60MC-C, S46MC-C, S/L42MC, S/L35MC S26MC				1.9 1.7 1.4 1.4 1.8		
328	p	Piston cooling oil inlet ★ 35-46 engines: also inlet to camshaft S80, L90, K90-98MC/MC-C S70, S70MC-C, L80, K80MC-C S50-60, K/L50-60-70, S50-60MC-C, S46MC-C, S/L42MC, S/L35MC S26MC					1.5 1.3 1.0 1.2 1.6	
330	p	Lub. oil inlet to main bearings and thrust bearing★ At stopped engine: S80, L90, K90-98MC/MC-C S70, S70MC-C, L80, K80MC-C S50-60, K/L50-60-70, S50-60MC-C, S46MC-C, S/L42MC, S/L35MC S26MC At running engine: (MCR) S80, L90, K90-98MC/MC-C S70, S70MC-C, L80, K80MC-C S50-60, K/L50-60-70, S50-60MC-C, S46MC-C, S/L42MC, S/L35MC S26MC		2.1 1.9 1.6 1.6 1.7 2.7 2.5 2.2 2.2 2.0				
327, 328		Measured by pressure gauge placed 1800 mm above crankshaft centreline.						
330		Measured by pressure gauge placed 1800 mm 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).						



The list applies to all MC/MC-C Engines

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Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δ p = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
331	p	Lub. oil inlet to main bearings and thrust bearing ★ K90-98MC/MC-C S80, L90 S70, S70MC-C, L80, K80MC-C S50-60, K/L50-60-70MC, S50-60MC-C, S46MC-C, S/L42MC, S/L35MC S26MC				1.9 1.7 1.5 1.2 1.2 1.6		
334	p	Lub. oil inlet to main bearings and thrust bearing ★ K90-98MC/MC-C S80, L90 S70, S70MC-C, L80, K80MC-C S50-60, K/L50-60-70MC, S50-60MC-C, S46MC-C, S/L42MC, S/L35MC S26MC					min. 1.7 1.5 1.3 1.0 1.0 1.4	
335	p	Lub. oil inlet to main bearings and thrust bearing ★ K90-98MC/MC-C S80, L90 S70, S70MC-C, L80, K80MC-C S50-60, K/L50-60-70MC, S50-60MC-C, S46MC-C, S/L42MC, S/L35MC S26MC If turbocharger bearings are fed by main engine system oil or separate lub. oil system, simultaneous stop of aux. blowers is to be arranged to occur at lub. oil shut down.						min. 1.5 1.3 1.1 0.8 0.8 1.2
336	t	Compressor inlet temperature,		-10 - +45				
331, 334, 335 Measured by pressure gauge placed 1800 mm above crankshaft centreline.								



The list applies to all MC/MC-C Engines

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Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
337	p	Compressor spiral housing pressure at outlet diameter (except K90-98MC/MC-C) K90-98MC/MC-C		0 -3 0 -4				
338	Δp	Diff. pressure across compressor spiral housing		0 -0.3				
340	t	Main bearing metal temperature. Main bearing oil outlet temperature		50-60 ★ ★				
341	t	Main bearing metal temperature. Main bearing oil outlet temperature Main bearing oil outlet temperature, deviation from average			70 60 + 5	- 5		
342	t	Main bearing metal/oil outlet temp. Main bearing oil outlet temperature, deviation from average.					Max. 70 ±7	
343	t	Crankpin bearing metal temperature Crankpin bearing oil outlet temperature		50-60 ★ ★				
344	t	Crankpin bearing metal temperature Crankpin bearing oil outlet temperature Crankpin bearing oil outlet temperature, deviation from average			70 60 + 5	- 5		
345	t	Crankpin bearing metal/oil outlet temp. Crankpin bearing oil outlet temperature, deviation from average					Max. 70 ±7	
346	t	Crosshead bearing metal temperature Crosshead bearing oil outlet temperature		50-60 ★ ★				

340, 343,
346

To be stated at seatrial.



The list applies to all MC/MC-C Engines

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347	t	Crosshead bearing metal temperature Crosshead bearing oil outlet temperature Crosshead bearing oil outlet temperature, deviation from average			70 60 + 5	- 5		
348	t	Crosshead bearing metal/oil outlet temp. Crosshead bearing oil outlet temperature, deviation from average					Max. 70 ±7	
349	t	Thrust bearing segment		60-70				
350	t	Thrust bearing segment			75			
351	t	Thrust bearing segment					max. 80	
352	t	Thrust bearing segment						max. 90
355	t	Lub. oil inlet ★		40-45				
356	t	Lub. oil inlet ★			55			
357	p	Lub. oil inlet ★ (except K90-98MC/MC-C) K90-98MC/MC-C		2.5-3.0 2.1				
358	p	Lub. oil inlet ★ (except K90-98MC/MC-C) K90-98MC/MC-C				2.0 1.4		
359	p	Lub. oil inlet ★ (except K90-98MC/MC-C) K90-98MC/MC-C						1.5 1.0
360	t	Lub. oil outlet from camshaft		★				
360A	t	Lub. oil outlet from camshaft ★			70			
355, 356 26, 50-98 types: To camshaft. 35-42, S46-70MC-C types: To exhaust valve actuator. 357, 358, 359 26, 50-98 types: To camshaft. 35-42, S46-70MC-C types: To exhaust valve actuator. Measured at camshaft level. 360 Inlet temperature + 5-6 °C (not relevant for engines with Uni. lub.) 360A Not relevant for engines with Uni. lub.								



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Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
361	t	Lub. oil inlet ★					60	
362	p	Exhaust gas pressure after turbine		0-350mmWC				
363	t	Exhaust gas receiver temperature		100-500				
364		Exhaust gas bypass valve, angle position (DEGREES)		0-90				
365	l	Cylinder lubricators				level	low	
366	fl	Cylinder lubricators					no flow	
366A flow	fl	Cylinder lubricators						no
367	l	Lub. oil inlet to turbocharger				low level		
368	p	Lub. oil inlet to turbocharger					1.0	
369	t	Lub. oil outlet from turbocharger: MAN B&W turbocharger ABB TPL-turbocharger, interval of the difference between inlet and outlet		70-90 20-45				
370	t	Lub. oil outlet from turbocharger: MAN B&W turbocharger Mitsubishi turbocharger ABB TPL-turbocharger, the difference should not exceed			95 85 50			
370A	t	Lub. oil outlet from turbocharger: ABB TPL-turbocharger, the difference should not exceed					55	
361 26, 50-98 types: To camshaft. 35-42, S46-70MC-C types: To exhaust valve actuator.								



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Item No.	Symbol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
371	p	Lub. oil inlet to turbocharger		1.5-2.2				
		If turbocharger bearings are fed by engine system oil or separate lub. oil system, simultaneous stop of auxiliary blowers is to be arranged to occur at lub. oil shut down.						
372	p	Lub. oil inlet to turbocharger				1.2		
373	t	Lub. oil inlet to turbocharger			55			
374	p	Lub. oil inlet to turbocharger						0.8
375	t	Cooling water inlet air cooler		10-32				
375A	t	Cooling water inlet air cooler: Conv. seawater cooling system (except K90-98MC/MC-C) K90-98MC/MC-C Central cooling water system (except K90-98MC/MC-C) K90-98MC/MC-C		5-32 10-32 5-36 10-36				
376	t	Cooling water inlet air cooler			40			
377	p	Cooling water inlet air cooler			3.5			
378	p	Cooling water inlet air cooler				1.0		
379	t	Cooling water outlet from air cooler		★				
380	t	Cooling water to lub. oil cooler(s)		10-32				
381	t	Cooling water to lub. oil cooler(s)				10		
382	p	Cooling water inlet air cooler		2.0-2.5				
379	Temperature difference across cooler should not exceed: Conv. sea water cooling system: 20 °C Central cooling water system: 27 °C							



The list applies to all MC/MC-C Engines

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Item No.	Sym-bol	t = temperature in °C p = "Gauge" pressure in bar Δ p = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
383	p	Jacket cooling water inlet (except K90-98MC/MC-C) K90-98MC/MC-C				0.5 ★ 2.0 ★		
384	p	Jacket cooling water inlet manifold (except K90-98MC/MC-C) K90-98MC/MC-C					0.3 ★ 1.5 ★	
384B	p	Jacket cooling water inlet: K90-98MC/MC-C						0.1 ★
385	t	Jacket cooling water inlet manifold		65-70				
385A	t	Jacket cooling water inlet manifold				57		
386	p	Jacket cooling water inlet manifold		3.5-4.5 ★				
387A	t	Jacket cooling water outlet/cyl.		80-85				
387B	t	Jacket cooling water outlet exhaust valve/cyl.		80-85				
388	t	Jacket cooling water outlet/cyl.			90			
389	t	Jacket cooling water outlet/cyl.					95	
390	Δp	Jacket cooling water across engine ★		0.8-1.4				
391	Δp	Jacket cooling water across engine ★				0.2		
392	Δp	Jacket cooling water across engine ★					0.4	
393	t	Jacket cooling water outlet TC		80-85				
394	t	Jacket cooling water outlet TC			90			

383, 384,
384B

With stopped cooling water pump, the set point for the sensor is the static pressure plus the stated value.

386

If the expansion tank is located more than 5 metres above the engine outlet, add the resulting increase in the static pressure to the 'normal service value'.

390

To be stated at sea trial.

391, 392

Lower than the "normal service value".



The list applies to all MC/MC-C Engines

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Item No.	Sym-bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
395	l	Jacket cooling water, deaerating				at low level		
396	p	Fresh cooling water, outlet common pipe		2.7-3.1 ★				
398	p	Cooling water inlet pressure, air cooler		0.25-0.50				
401	p	Starting air to main starting valve		30				
402	p	Starting air to main starting valve				15		
403	p	Control air pressure		7.0				
404	p	Control air pressure				5.5		
405	p	Safety air pressure		7.0				
406	p	Safety air pressure				5.5		
407	p	Air supply to air cylinder, for exhaust valve		7.0				
408	p	Air supply to air cylinder, for exhaust valve				5.5		
409	p	Control air supply			0.5 ★			
410	p	Safety air supply			0.5 ★			
411	t	Scavenge air before air cooler		170-210 ★				
412	t	Scavenge air after air cooler		★				
413	t	Scavenge air receiver		15 ★				
414	t	Scavenge air receiver ★			55			
414A	t	Scavenge air receiver ★					65	
396 If the expansion tank is located more than 5 metres above the engine outlet, add the resulting increase in the static pressure to the 'normal service value'. 409, 410, Finished with engine. (Stopped engine, air supply system - vented) 411 MCR value, engine load and ambient condition dependent. 412 Coolant inlet +12 °C. 413 Above water inlet temperature. 414, 414A To be cut out during STOP. To remain cut out until 3-5 min. after START.								



The list applies to all MC/MC-C Engines

For items marked with an '★', further details are given in a footnote.

Item No.	Sym-bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
415	t	Scavenge air boxes (fire alarm)			80			
416	t	Scavenge air boxes (fire alarm)					120	
417 & 417A	p	Scavenge air receiver (bar abs) ★ S50-60-70-80-90MC L50-60-70-80-90MC K80-98MC and MC-C, S/L42MC, L35MC S50-70MC-C S46MC-C, S35MC S26MC, Mark V		3.55 3.50 3.60 3.65 3.70 3.80				
418	p	Scavenge air receiver ★ For S26MC, S/L35MC, S/L42MC, S46MC-C, S50MC-C	Makes Breaks Makes Breaks	0.55 0.70 0.45 0.70				
419	p	Scavenge air, aux. blower failure ★ For S26MC, S/L35MC, S/L42MC, S46MC-C, S50MC-C			0.39	0.45		
420	Δp	Pressure drop across air cooler(s)		★				
421	Δp	Pressure drop across air cooler(s)			★			
422	Δp	Pressure drop of air across blower filter/TC		★				
423	Δp	Pressure drop of air across blower filter/TC			★			
424	p	Exhaust gas receiver ★ (bar abs) S50-60-70-80-90MC L50-60-70-80-90MC K80-98MC and MC-C, S46MC-C, S/L42MC, L35MC		3.35 3.30 3.40 3.40				
417, 417A, 424 Values for nominal MCR. Layout and load dependent. 418 Controls the auxiliary blowers. 419 Alarm switch breaks at 0.45 bar, respective 0.39 bar, falling pressure and makes at 0.56 bar, respective 0.50 bar, rising pressure. 420, 422 According to shop trial results. 421, 423 At 50% increase compared to the 'normal service value'.								



The list applies to all MC/MC-C Engines

For items marked with an '★', further details are given in a footnote.

Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
		S50-60-70MC-C S35MC S26MC, Mark V		3.45 3.50 3.60				
425	t	Exhaust gas before turbine ★		380-430				
425A	t	Exhaust gas before turbine			★			
425B	t	Exhaust gas before turbine					★	
426	t	Exhaust gas after exhaust valves ★		320-390				
427	t	Exhaust gas after exhaust valves			430			
428	t	Exhaust gas after exhaust valves					450	
429	t	Exhaust gas after valves ★			+50			
430	t	Exhaust gas after valves ★				-50		
431	t	Exhaust gas after valves ★					±60	
432	t	Exhaust gas after turbocharger ★		220-300				
433	t	Exhaust gas after turbocharger			320			
433A	p	Exhaust gas after turbocharger ★		300 mmWC				
434	l	Water level at water mist catcher drain ★			at max level			
435A	p	Air inlet for dry cleaning of TC		4.5-10				
435B	p	Cleaning water inlet to TC		min. 0.5 ★				
425 Values for nominal MCR. Layout and load dependent. 425A, 425B T/C dependent. 426, 432 The service values apply under the following conditions: Ambient temperature in engine room: 25 °C. Scavenge air temperature in receiver: (except K90-98MC/MC-C) 35 °C; K90-98MC/MC-C: 37 °C. 429, 430, 431 Deviation from average. When operating below 200 °C average temperature, deviation alarm is cut off. 433A Back-pressure measured at MCR. Alarm max.: 1.5 × MCR value. 434 Below the water mist catcher, in the air cooler housing. 435B Higher than exhaust gas pressure.								



The list applies to all MC/MC-C Engines

For items marked with an '★', further details are given in a footnote.

Item No.	Sym-bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
436	mg/l	Oil mist in crankcase			high ★ density			
437	mg/l	Oil mist in crankcase					high ★ density	
437A		Oil mist detector, failure (No value)						
438	sp	Engine overspeed						★
439	sp	Turbocharger overspeed			★			
440		Vibration of turbocharger			★			
441	Δp	Pressure drop across exhaust gas boiler		150 mm WC				
443	p	Air inlet jet assistance TC (only for S26MC) MAN B&W TC ABB TC		3.5-5.5 ★ 3.5-6.0 ★				
470	p	Speed setting air pressure to governor		0.5-5.0				
436, 437 <i>Preadjusted by the producer. See also the producer's special instructions.</i> 438 <i>Nominal MCR rpm × 1.09.</i> 439 <i>Specified by manufacturer.</i> 440 <i>Not standard equipment.</i> <i>At max. vibration level according to the TIC producer's recommendations.</i> 443 <i>Absolute pressures.</i>								



The list applies to all MC/MC-C Engines

For items marked with an `★', further details are given in a footnote.

Item No.	Sym- bol	t = temperature in °C p = ``Gauge" pressure in bar Δ p = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
471, 472, 473	mm	Axial vibration monitor (peak to peak) ★ :						
		4K50MC		0-0.81	1.08		1.35	
		5K50MC		0-1.01	1.34		1.68	
		6K50MC		0-1.20	1.60		2.00	
		7K50MC		0-1.41	1.88		2.35	
		8K50MC		0-1.61	2.14		2.68	
		9K50MC		0-1.82	2.42		3.03	
		10K50MC		0-2.01	2.68		3.35	
		11K50MC		0-2.21	2.94		3.68	
		12K50MC		0-2.42	3.22		4.03	
		4K60MC		0-0.96	1.28		1.60	
		5K60MC		0-1.20	1.60		2.00	
		6K60MC		0-1.43	1.90		2.38	
		7K60MC		0-1.67	2.22		2.78	
		8K60MC		0-1.91	2.54		3.18	
		9K60MC		0-2.13	2.84		3.55	
		10K60MC		0-2.37	3.16		3.95	
		11K60MC		0-2.60	3.46		4.33	
		12K60MC		0-2.84	3.78		4.73	
		4K70MC		0-1.13	1.50		1.88	
		5K70MC		0-1.40	1.86		2.33	
		6K70MC		0-1.68	2.24		2.80	
		7K70MC		0-1.95	2.60		3.25	
		8K70MC		0-2.24	2.98		3.73	
		9K70MC		0-2.51	3.34		4.18	
		10K70MC		0-2.79	3.72		4.65	
		11K70MC		0-3.06	4.08		5.10	
		12K70MC		0-3.35	4.46		5.58	

471, 472,
473

For engines marked with an `★', the correct functioning of the axial vibration damper is of special importance for the crankshaft's safe operation.

Consequently, these engines, and engines fitted with PTO in the fore end, are as standard fitted with an electronic axial vibration monitor, for condition check.

Furthermore, for engines marked with an `★', the device is connected to alarm and SLOW-DOWN functions.

Concerning the electronic device, refer to the maker's instructions.

Other engines are fitted with a mechanical measuring device, see Vol. II, Procedure 905-6.



The list applies to all MC/MC-C Engines

For items marked with an '★', further details are given in a footnote.

Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δ p = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
471, 472, 473	mm	(Cont.)						
		4K90MC		0-1.44	1.92		2.40	
		5K90MC		0-1.80	2.40		3.00	
		6K90MC		0-2.16	2.88		3.60	
		7K90MC		0-2.54	3.38		4.23	
		8K90MC		0-2.90	3.86		4.83	
		9K90MC		0-3.26	4.34		5.43	
		10K90MC		0-3.62	4.82		6.03	
		11K90MC		0-3.98	5.30		6.63	
		12K90MC		0-4.34	5.78		7.23	
		6K98MC		0-2.28	3.05		3.81	
		7K98MC		0-2.66	3.55		4.43	
		8K98MC		0-3.03	4.05		5.06	
		9K98MC		0-3.41	4.55		5.68	
		10K98MC		0-3.78	5.05		6.31	
		11K98MC		0-4.16	5.55		6.93	
		12K98MC		0-4.54	6.06		7.57	
		6K80MC-C		0-1.73	2.30		2.88	
		7K80MC-C		0-2.03	2.70		3.38	
		8K80MC-C		0-2.31	3.08		3.85	
		9K80MC-C		0-2.61	3.48		4.35	
		10K80MC-C		0-2.90	3.86		4.83	
		11K80MC-C		0-3.18	4.24		5.30	
		12K80MC-C		0-3.47	4.62		5.78	
		6K90MC-C		0-1.95	2.60		3.25	
		7K90MC-C		0-2.28	3.04		3.80	
		8K90MC-C		0-2.61	3.48		4.35	
		9K90MC-C		0-2.94	3.92		4.90	
		10K90MC-C		0-3.26	4.34		5.43	
		11K90MC-C		0-3.59	4.78		5.98	
		12K90MC-C		0-3.92	5.22		6.53	

Guidance Alarm Limits and Measuring Values

(at max. continuous rating with engine running steadily)

701.19-40F

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The list applies to all MC/MC-C Engines

For items marked with an '★', further details are given in a footnote.

Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δ p = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
471, 472, 473	mm	(Cont.)						
		6K98MC-C		0-1.88	2.51		3.13	
		7K98MC-C		0-2.19	2.92		3.65	
		8K98MC-C		0-2.49	3.33		4.16	
		9K98MC-C		0-2.80	3.74		4.67	
		10K98MC-C		0-3.11	4.15		5.18	
		11K98MC-C		0-3.42	4.56		5.70	
		12K98MC-C		0-3.72	4.97		6.21	
		4L35MC		0-0.65	0.86		1.08	
		5L35MC		0-0.80	1.06		1.33	
		6L35MC		0-0.96	1.28		1.60	
		7L35MC		0-1.13	1.50		1.88	
		8L35MC		0-1.29	1.72		2.15	
		9L35MC		0-1.44	1.93		2.41	
		10L35MC		0-1.60	2.14		2.68	
		11L35MC		0-1.76	2.35		2.94	
		12L35MC		0-1.93	2.57		3.21	
		4L42MC		0-0.77	1.02		1.28	
		5L42MC		0-0.96	1.28		1.60	
		6L42MC		0-1.14	1.52		1.90	
		7L42MC		0-1.34	1.78		2.23	
		8L42MC		0-1.53	2.04		2.55	
		9L42MC		0-1.71	2.29		2.86	
		10L42MC		0-1.91	2.54		3.18	
		11L42MC		0-2.10	2.79		3.49	
		12L42MC		0-2.29	3.05		3.81	
		4L50MC		0-0.92	1.22		1.53	
		5L50MC		0-1.14	1.52		1.90	
		6L50MC		0-1.37	1.82		2.28	
		7L50MC		0-1.59	2.12		2.65	
		8L50MC		0-1.82	2.42		3.03	



Guidance Alarm Limits and Measuring Values

(at max. continuous rating with engine running steadily)

701.20-40F

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The list applies to all MC/MC-C Engines

For items marked with an '★', further details are given in a footnote.

Item No.	Sym-bol	t = temperature in °C p = "Gauge" pressure in bar Δ p = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
471, 472, 473	mm	(Cont.)						
		4L60MC		0-1.08	1.44		1.80	
		5L60MC		0-1.35	1.80		2.25	
		6L60MC		0-1.62	2.16		2.70	
		7L60MC		0-1.89	2.52		3.15	
		8L60MC		0-2.16	2.88		3.60	
		4L70MC		0-1.28	1.70		2.13	
		5L70MC ★		0-1.59	2.12		2.65	
		6L70MC ★		0-1.91	2.54		3.18	
		7L70MC		0-2.22	2.96		3.70	
		8L70MC		0-2.54	3.38		4.23	
		4L80MC		0-1.44	1.92		2.40	
		5L80MC		0-1.80	2.40		3.00	
		6L80MC		0-2.16	2.88		3.60	
		7L80MC		0-2.52	3.36		4.20	
		8L90MC		0-2.90	3.86		4.83	
		9L80MC		0-3.26	4.34		5.43	
		10L80MC		0-3.62	4.82		6.03	
		11L80MC		0-3.98	5.30		6.63	
		12L80MC		0-4.34	5.78		7.23	
		4L90MC		0-1.64	2.18		2.73	
		5L90MC		0-2.04	2.72		3.40	
		6L90MC		0-2.45	3.26		4.08	
		7L90MC		0-2.85	3.80		4.75	
		8L90MC		0-3.26	4.34		5.43	
		9L90MC		0-3.68	4.90		6.13	
		10L90MC		0-4.08	5.44		6.80	
		11L90MC		0-4.49	5.98		7.48	
		12L90MC		0-4.89	6.52		8.15	



Guidance Alarm Limits and Measuring Values

(at max. continuous rating with engine running steadily)

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The list applies to all MC/MC-C Engines

For items marked with an '★', further details are given in a footnote.

Item No.	Sym-bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
471, 472, 473	mm	(Cont.)						
		4S26MC		0-0.62	0.82		1.03	
		5S26MC ★		0-0.77	1.02		1.28	
		6S26MC ★		0-0.92	1.22		1.53	
		7S26MC		0-1.08	1.44		1.80	
		8S26MC		0-1.23	1.64		2.05	
		9S26MC		0-1.38	1.84		2.31	
		10S26MC		0-1.54	2.05		2.56	
		11S26MC		0-1.69	2.25		2.82	
		12S26MC		0-1.84	2.46		3.07	
		4S35MC		0-0.94	1.25		1.56	
		5S35MC ★		0-1.17	1.56		1.95	
		6S35MC ★		0-1.40	1.87		2.34	
		7S35MC		0-1.64	2.18		2.73	
		8S35MC		0-1.88	2.50		3.13	
		9S35MC		0-2.11	2.81		3.51	
		10S35MC		0-2.34	3.12		3.90	
		11S35MC		0-2.57	3.43		4.29	
		12S35MC		0-2.81	3.74		4.68	
		4S42MC		0-1.15	1.53		1.91	
		5S42MC ★		0-1.44	1.92		2.40	
		6S42MC ★		0-1.73	2.30		2.88	
		7S42MC		0-2.01	2.68		3.35	
		8S42MC		0-2.30	3.07		3.84	
		9S42MC		0-2.59	3.45		4.31	
		10S42MC		0-2.87	3.83		4.79	
		11S42MC		0-3.16	4.22		5.27	
		12S42MC		0-3.45	4.60		5.75	
		4S46MC-C		0-1.23	1.64		2.05	
		5S46MC-C ★		0-1.52	2.03		2.53	
		6S46MC-C ★		0-1.82	2.43		3.03	
		7S46MC-C		0-2.11	2.82		3.52	
		8S46MC-C		0-2.50	3.34		4.17	



Guidance Alarm Limits and Measuring Values

(at max. continuous rating with engine running steadily)

701.22-40F

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The list applies to all MC/MC-C Engines

For items marked with an '★', further details are given in a footnote.

Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
471, 472, 473	mm	(Cont.)						
		4S50MC		0-1.23	1.64		2.05	
		5S50MC ★		0-1.55	2.06		2.58	
		6S50MC ★		0-1.85	2.46		3.08	
		7S50MC		0-2.16	2.88		3.60	
		8S50MC		0-2.46	3.28		4.10	
		4S50MC-C		0-1.26	1.69		2.11	
		5S50MC-C ★		0-1.56	2.09		2.61	
		6S50MC-C ★		0-1.87	2.50		3.12	
		7S50MC-C		0-2.17	2.90		3.62	
		8S50MC-C		0-2.55	3.41		4.26	
		4S60MC		0-1.47	1.96		2.45	
		5S60MC ★		0-1.85	2.46		3.08	
		6S60MC ★		0-2.21	2.94		3.68	
		7S60MC		0-2.58	3.44		4.30	
		8S60MC		0-2.94	3.92		4.90	
		4S60MC-C		0-1.52	2.03		2.53	
		5S60MC-C ★		0-1.88	2.51		3.13	
		6S60MC-C ★		0-2.25	3.00		3.75	
		7S60MC-C		0-2.61	3.49		4.36	
		8S60MC-C		0-3.07	4.10		5.12	
		4S70MC		0-1.71	2.28		2.85	
		5S70MC ★		0-2.15	2.86		3.58	
		6S70MC ★		0-2.57	3.42		4.28	
		7S70MC		0-3.00	4.00		5.00	
		8S70MC		0-3.42	4.56		5.70	
		4S70MC-C		0-1.77	2.36		2.95	
		5S70MC-C ★		0-2.19	2.92		3.65	
		6S70MC-C ★		0-2.62	3.50		4.37	
		7S70MC-C		0-3.05	4.07		5.08	
		8S70MC-C		0-3.58	4.78		5.97	

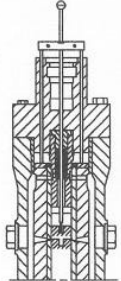
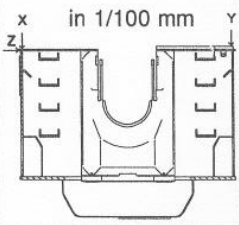
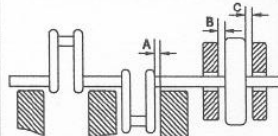


The list applies to all MC/MC-C Engines

For items marked with an '★', further details are given in a footnote.

Item No.	Sym- bol	t = temperature in °C p = "Gauge" pressure in bar Δp = dif. pressure in bar	sp = speed in r/min fl = flow l = level	Normal service value	Alarm max.	Alarm min.	Slow down	Shut down
471, 472, 473	mm	(Cont.)	4S80MC 5S80MC ★ 6S80MC ★ 7S80MC 8S80MC 9S80MC 10S80MC 11S80MC 12S80MC 5S90MC ★ 6S90MC ★ 7S90MC	0-1.95 0-2.45 0-2.93 0-3.42 0-3.90 0-4.40 0-4.88 0-5.37 0-5.87 0-2.42 0-2.91 0-3.39	2.60 3.26 3.90 4.56 5.20 5.86 6.50 7.16 7.82 3.23 3.88 4.52		3.25 4.08 4.88 5.70 6.50 7.33 8.13 8.95 9.78 4.04 4.85 5.65	
476	p	p_{max} control pressure		0-5.0				
477		Fuel pump index		★				
478		VIT index		★				
479		Governor index		★				
480		Engine torque		★				
477, 478, 479, 480 Engine and load dependent								



M/V	Engine Type:		Engine Layout:		Checked by:																																																																																																										
Yard:	Builder:	Engine	BHP:																																																																																																												
No.:	Built year:	No.:	r/min:		Date:																																																																																																										
Fuel valve nozzle	Marked: holes of mm				Governor																																																																																																										
Fuel valve	Opening pressure bar				Make:																																																																																																										
Exhaust cam	Lead angle degrees				Type :																																																																																																										
Fuel pump	K= Injection timing positioner 'Break-point' at average fuel index				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 tight Camshaft side Exhaust side  in 1/100 mm Crossgirder No. <table border="1"> <tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr> <tr><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>Y</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>Z</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> </table> Optical measurements Piano wire d = 0.5 mm load 40 kg <table border="1"> <tr><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>Y</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>Z</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> </table>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	X														Y														Z														X														Y														Z														Crank No.	1	2	3	4	5	6	7	8	9	10	11	12
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	Crank in bottom port side. Dial gauge set to 'Zero' in bottom port side. Deflection to be measured in cold cond.																																																																																																														
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	Crank in top																																																																																																														
	Crank in starboard side																																																																																																														
	Crank in bottom starboard side																																																																																																														
	Total clearance at thrust bearing B+C = mm (max. mm)				Sheet No.:																																																																																																										
	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																																																																																																										

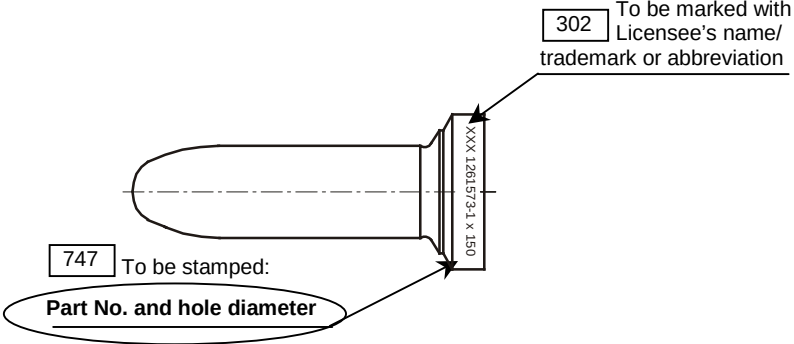
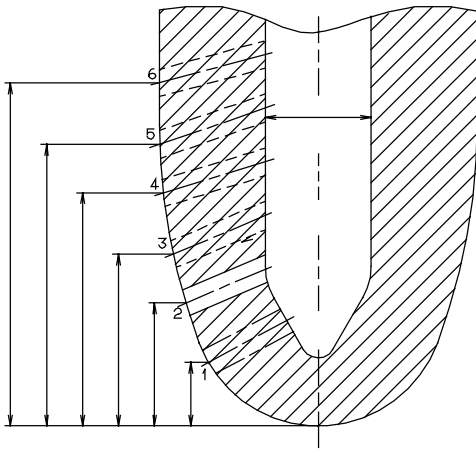
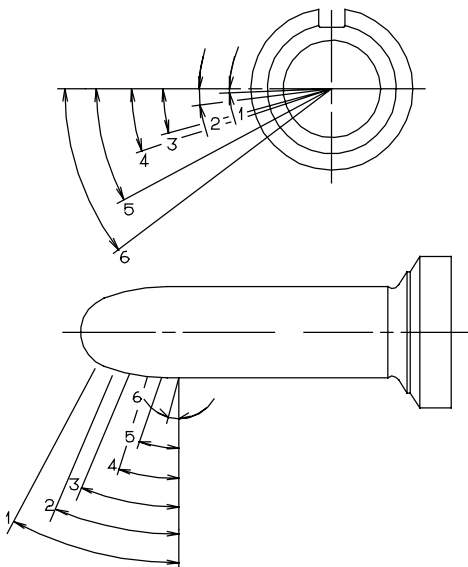


IMO Emission Certification Markings on Components

The components described in Items 1 to 8 have been marked with unambiguous identification numbers to enable the relevant drawing and certificate to be traced.
(The circled part of the number is the only part of the entire number that is to be defined as the "IMO number").

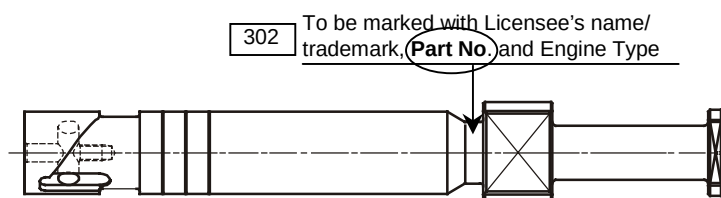
See also Drawing No. 0741260-8 regarding marks and stamps on components for MAN B&W two-stroke diesel engines.

1. Fuel Valve Nozzle

	Certified markings: Part No. and hole diameter. Marking instruction: No. 0742639-1
Checking the dimensions of the certified component: 1. Remove the fuel valve, see <i>instruction manual VOL II, Procedure 901-2</i>. 2. Disassemble the fuel valve, see <i>instruction manual VOL II, Procedure 909-6</i>.   <i>Fig. 1 Fuel valve nozzle</i>	



2. Fuel Pump Plunger



Certified markings:

Part No.

Marking instruction:

No. 0742845-1

Checking the dimensions of the certified component.

1. Remove the fuel pump top cover, see *VOL II, Procedure 909-3*.
2. Remove the plunger/barrel assembly, see *VOL II, Procedure 909-3*.

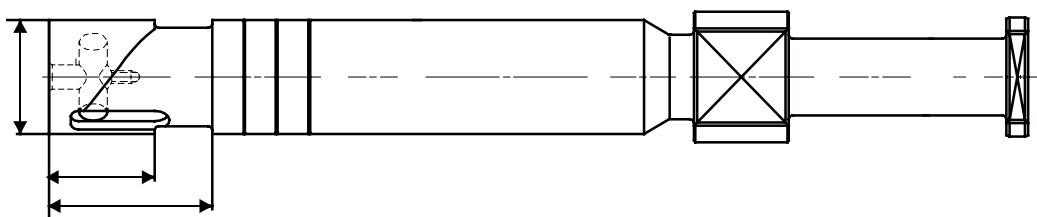
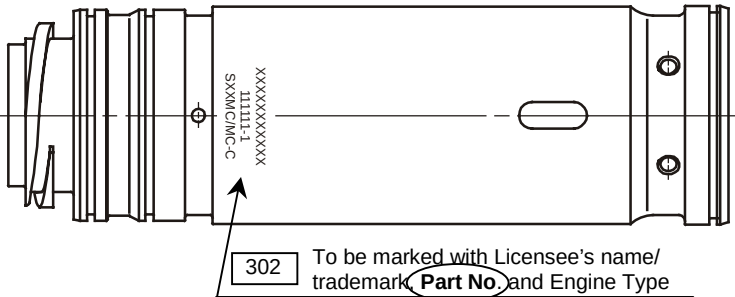


Fig. 2 Fuel pump plunger

3. Fuel Pump Barrel

	Certified markings: Part No.
	Marking instruction: No. 0742843-8

Checking the dimensions of the certified component.

1. Remove the fuel pump top cover, see *VOL II, Procedure 909-3*.
2. Remove the plunger/barrel assembly, see *VOL II, Procedure 909-3*.

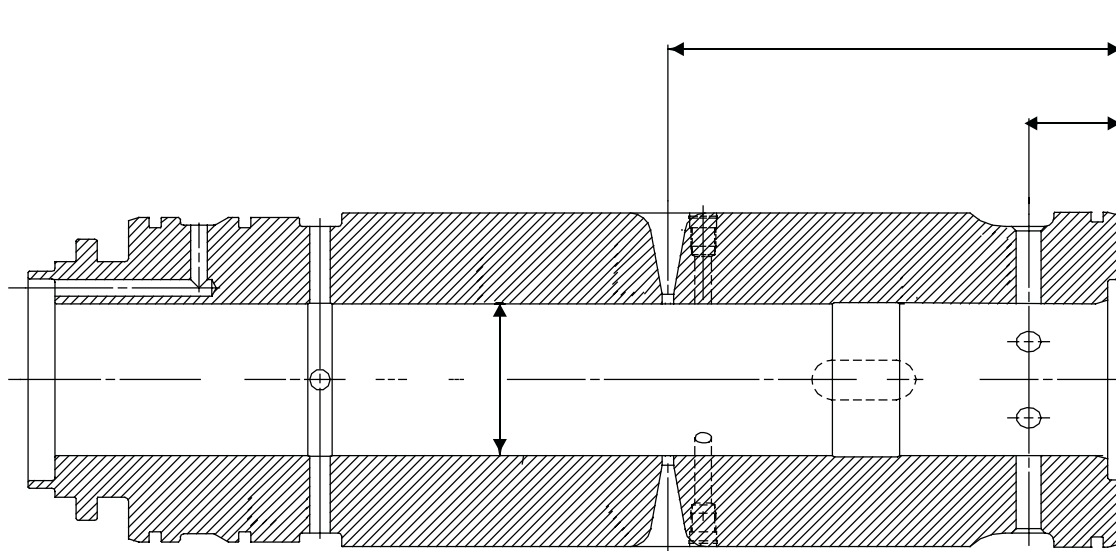
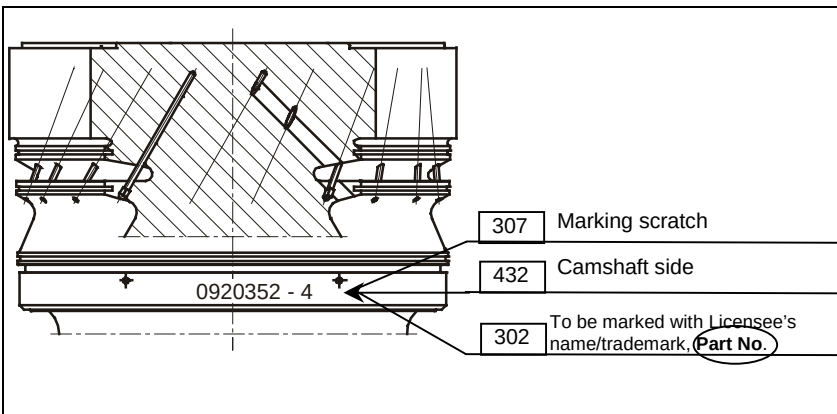


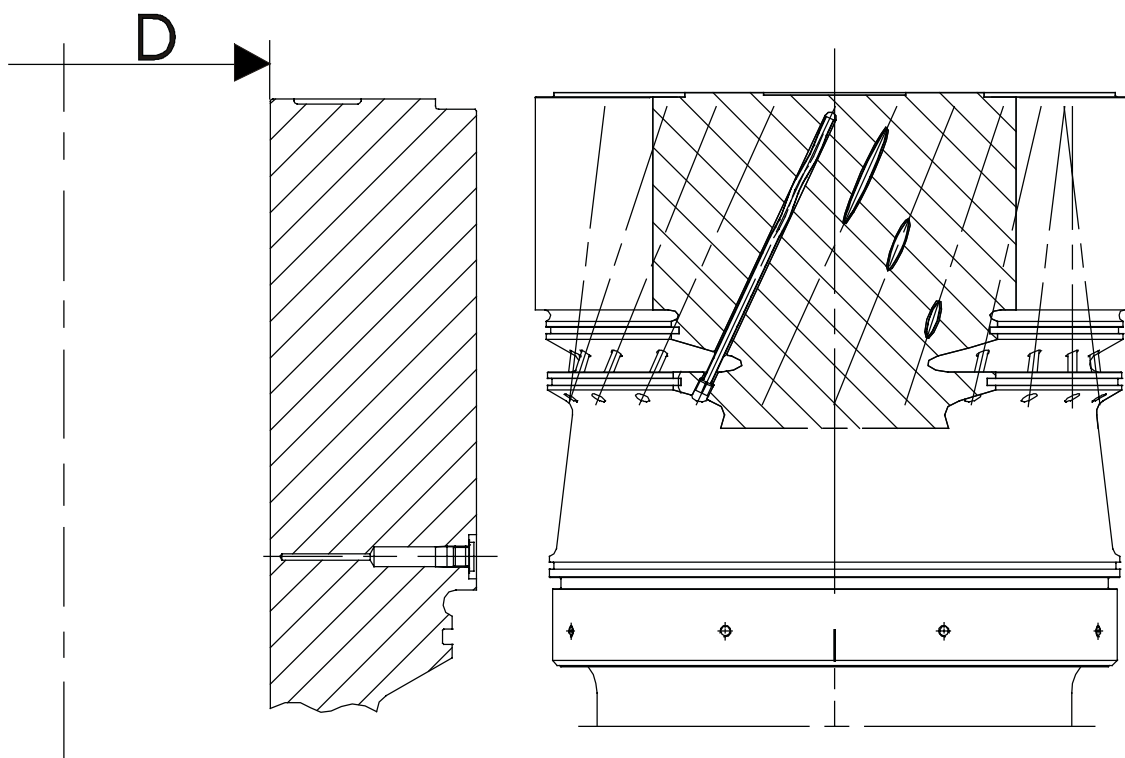
Fig. 3 Fuel pump barrel

4. Cylinder Liner

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

Checking the dimensions of the certified component:

1. Remove the cylinder cover, see *VOL II, Procedure 901-1*.
2. Remove the piston, see *VOL II, Procedure 902-2*.
3. Remove the liner and remove the cooling jacket, see *VOL II, Procedure 903-3*.



Liner diameter, D: _____
Number of cooling water bores: _____
Number of lubricating oil quills: _____

Fig. 4 Cylinder liner

5. Cylinder Cover

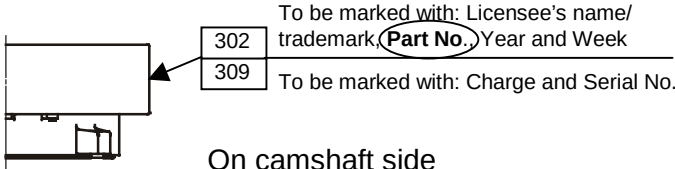
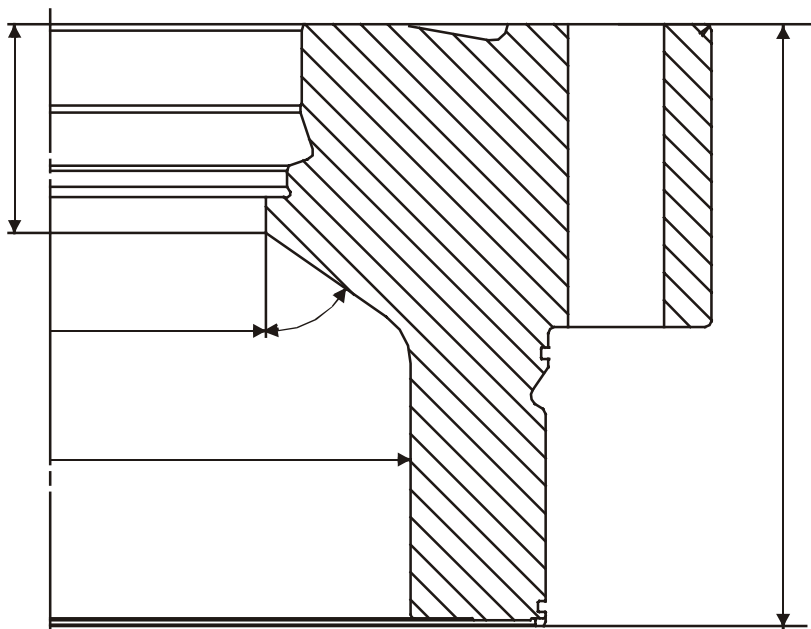
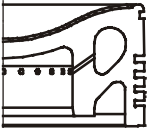
 To be marked with: Licensee's name/ trademark, (Part No.) Year and Week To be marked with: Charge and Serial No. On camshaft side	Certified markings: Part No. Marking instruction: No. 0742634-2
Checking the dimensions of the certified component: 1. Remove the cylinder cover, see <i>VOL II, Procedure 901-1.</i> 2. Remove the cooling jacket, see <i>VOL II, Procedure 901-3.</i> 	

Fig. 5 Cylinder cover

6. Piston Crown

	To be marked with: Licensee's name/ trademark Part No. Year and Week To be marked with: Charge and Serial No.	Certified markings:	Part No.
On camshaft side		Marking instruction:	
		No. 0742392-0	

Checking the dimensions of the certified component:

1. Remove the cylinder cover, see *VOL II, Procedure 901-1*.
2. Measure the piston bowl, see *VOL II, Procedure 902-3*.
3. Measure the heights (A and B) through the scavenge air ports.

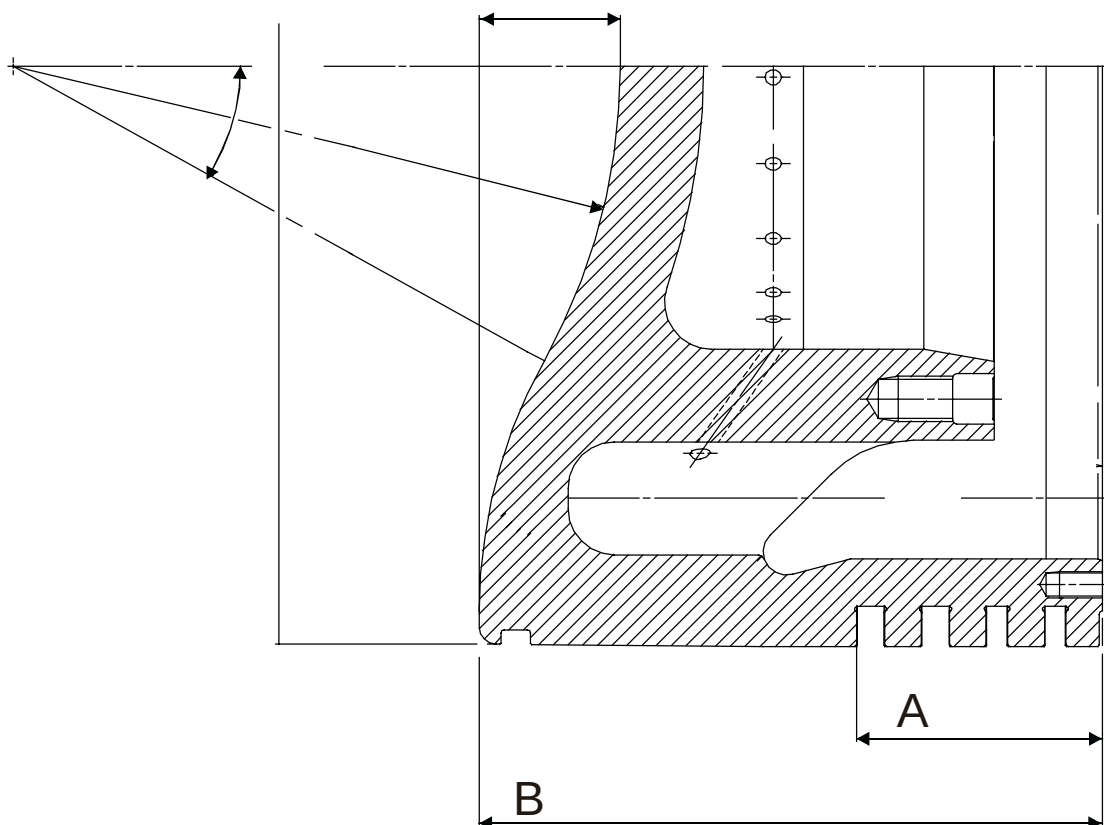
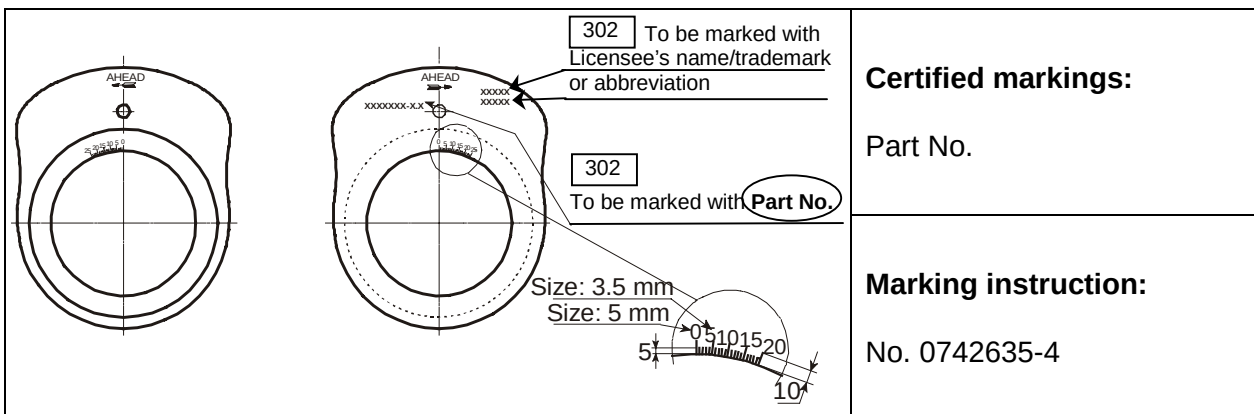


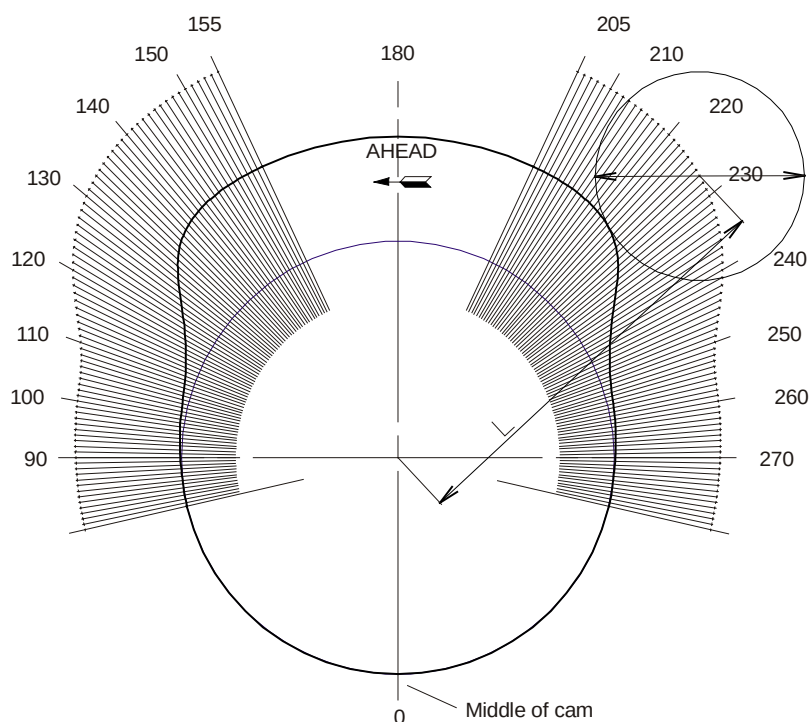
Fig. 6 Piston crown

7. Exhaust Cam



Checking the dimensions of the certified component:

1. Remove the cover for the exhaust roller guide, see *VOL II, Procedure 908-4*.
2. Locate the middle of the cam, see *VOL II, Procedure 908-7*.
3. Check the distance 'L' according to the table below.



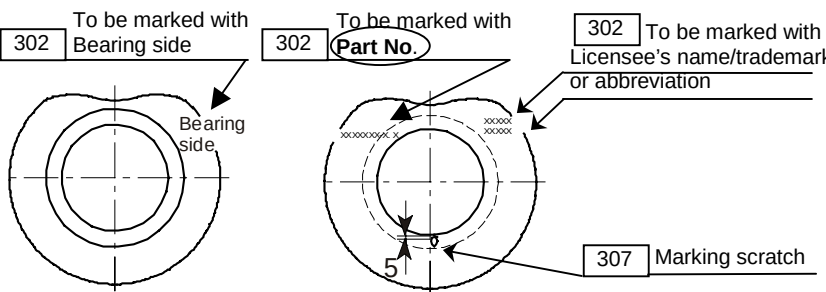
Angle (°)	Angle (°)	L *) (mm)	Angle (°)	Angle (°)	L *) (mm)	Angle (°)	Angle (°)	L *) (mm)
0.0	360.0		105.0	255.0		135.0	225.0	
80.0	280.0		110.0	250.0		140.0	220.0	
85.0	275.0		115.0	245.0		145.0	215.0	
90.0	270.0		120.0	240.0		150.0	210.0	
95.0	265.0		125.0	235.0		155.0	205.0	
100.0	260.0		130.0	230.0				

*) Specific for an individual engine type

Fig. 7 Exhaust cam



8. Fuel Cam



Certified markings:

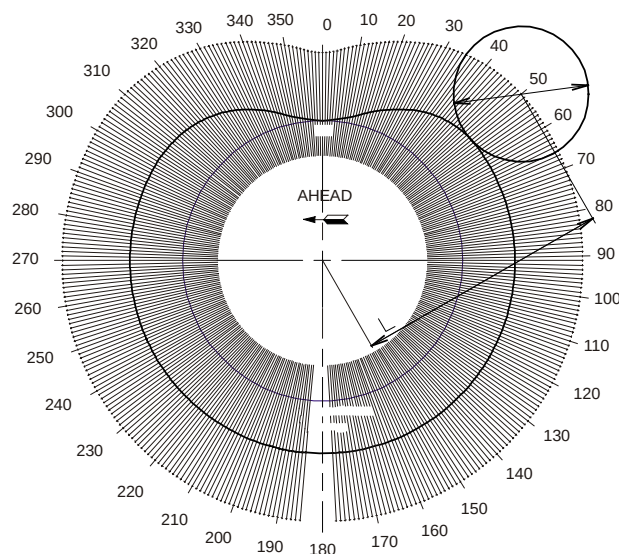
Part No.

Marking instruction:

No. 0742636-6

Checking the dimensions of the certified component:

1. Remove the covers for the fuel pump roller guide, see *VOL II, Procedure 909-2*.
2. Locate the lowermost position of the cam, see *VOL II, Procedure 909-1*.
3. Check the distance 'L' according to the table below.



Angle (°)	L *) (mm)	Angle (°)	L *) (mm)	Angle (°)	L *) (mm)
0.0		120.0		245.0	
5.0		125.0		250.0	
10.0		130.0		255.0	
15.0		135.0		260.0	
20.0		140.0		265.0	
25.0		145.0		270.0	
30.0		150.0		275.0	
35.0		155.0		280.0	
40.0		160.0		285.0	
45.0		165.0		290.0	
50.0		170.0		295.0	
55.0		175.0		300.0	
60.0		180.0		305.0	
65.0		185.0		310.0	
70.0		190.0		315.0	
75.0		195.0		320.0	
80.0		200.0		325.0	
85.0		205.0		330.0	
90.0		210.0		335.0	
95.0		215.0		340.0	
100.0		220.0		345.0	
105.0		225.0		350.0	
110.0		230.0		355.0	
115.0		235.0		360.0	
		240.0			

Fig. 8 Fuel cam

*) Sprężynki do pomiaru i kontrolowania



9. Checking the VIT-adjustments (Engines with VIT)

9.1 Load the engine

- Loading to 75% MCR or 100% MCR:
see VOL I, [Chapter 706](#), Appendix 2 or Appendix 5.
- Loading to the 'break-point':

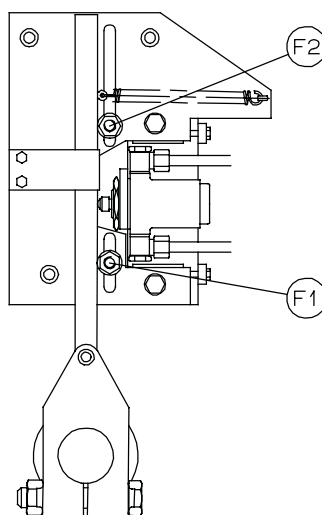
Electronically controlled VIT:

Follow the instructions from the supplier of the engine control system

Mechanically controlled VIT:

Load the engine until the steel bar touches the pivoting points (F1 and F2) simultaneously, see Fig. 9.1.

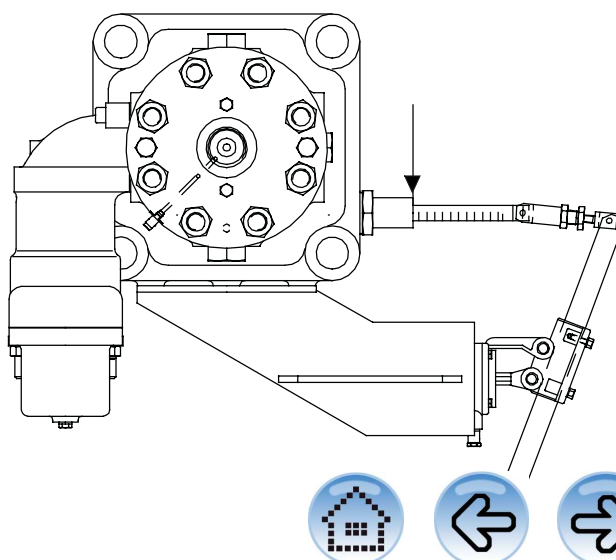
Fig. 9.1



9.2 Read the actual VIT-index

Read the actual VIT-index on the scale of the fuel pump timing racks, see Fig. 9.2.

Fig. 9.2

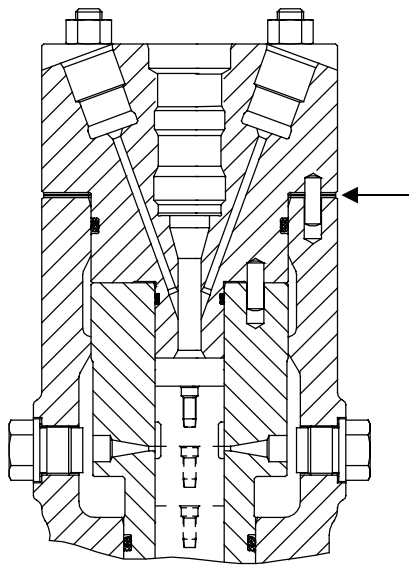


10. Checking the Shims

10.1 Number of shims in fuel pump (Injection timing)

For engines without VIT, visually check the number of shims between the fuel pump top cover and the pump housing. See Fig. 10.1.

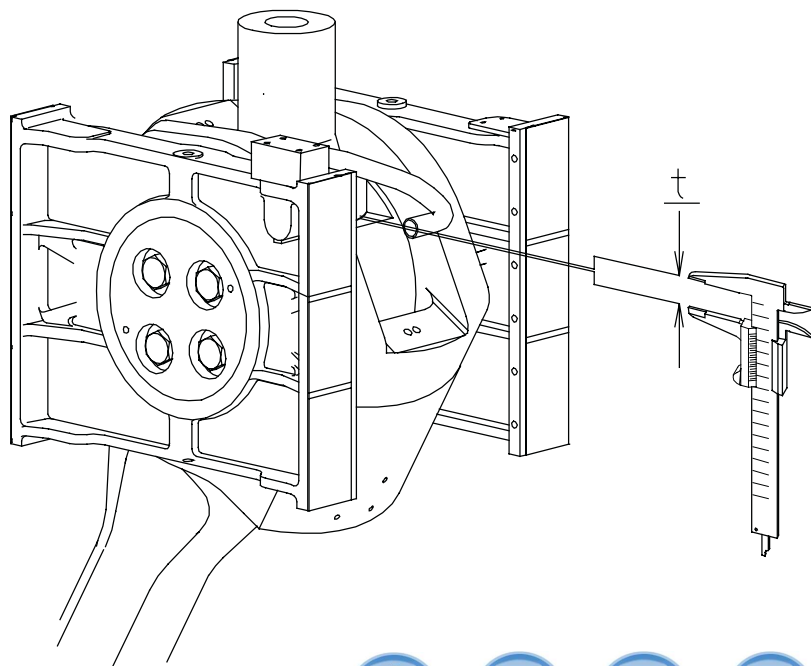
Fig. 10.1



10.2 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 Fig. 10.2.

Fig. 10.2



The measuring instruments are identified by a combination of symbols followed by a position number, the symbols represent:

DSA	Density switch for alarm (oil mist)	TEA	Temperature sensor for alarm (analogue)
DS-SLD	Density switch for slow-down	TEI	Temperature sensor for remote indication (analogue)
E	Electric devices	TE-SLD	Temperature sensor for slow-down (analogue)
EV	Solenoid valve	VE	Viscosity sensor (analogue)
ESA	Electrical switch for alarm	VI	Viscosity indicator
FSA	Flow switch for alarm	ZE	Position sensor
FS-SLD	Flow switch for slow-down	ZS	Position switch
LSA	Level switch for alarm	WEA	Vibration signal for alarm (analogue)
PDI	Pressure difference indicator	WI	Vibration indicator
PDSA	Pressure difference switch for alarm	WS-SLD	Vibration switch for slow down
PDT	Pressure difference transmitter		
PI	Pressure indicator		
PS	Pressure switch		
PS-SHD	Pressure switch for shut-down		
PS-SLD	Pressure switch for slow-down		
PSA	Pressure switch for alarm		
PSC	Pressure switch for controlling		
PE	Pressure sensor (analogue)		
PEA	Pressure sensor for alarm (analogue)		
PEI	Pressure sensor for remote indication (analogue)		
PE-SLD	Pressure sensor for slow-down (analogue)		
SE	Speed sensor (analogue)		
SSA	Speed switch for alarm		
SS-SHD	Speed switch for shut-down		
TI	Temperature indicator		
TSA	Temperature switch for alarm		
TSC	Temperature switch for control		
TS-SHD	Temperature switch for shut-down		
TS-SLD	Temperature switch for slow down		
TE	Temperature sensor (analogue)		

The symbols are shown in a circle indicating



Instrument locally mounted



Instrument mounted in panel on engine



Control panel mounted instrument



<u>Symbol</u>	<u>Description</u>	<u>Position</u>
Fuel Oil System		
PSA	Gives signal when lifting gear for fuel pumps are activated (option)	300
LSA	Leakage from high pressure pipes (option)	301
TI	Fuel oil after filter	302
PI	Fuel oil after filter	305
Lub. Oil System		
TI	Lub. oil inlet system oil	311
TI	Piston cooling oil outlet/cylinder	317
TSA	Piston cooling oil outlet/cylinder	318
FSA	Piston cooling oil outlet/cylinder	320
PI	Piston cooling oil inlet	326
PSA	Piston cooling oil inlet	327
PI	Lub. oil inlet to main bearings and thrust bearing	330
PSA	Lub. oil inlet to main bearings and thrust bearing	331
PS-SHD	Lub. oil inlet to main bearings and thrust bearing	335
TI	Thrust bearing segment	349
TSA	Thrust bearing segment	350
TS-SHD	Thrust bearing segment	352
TI	Lub. oil inlet to camshaft	355
PI	Lub. oil inlet to camshaft	357
PSA	Lub. oil inlet to camshaft	358
PS-SHD	Lub. oil inlet to camshaft	359
TI	Lub. oil outlet from camshaft/cylinder	360
LSA	Lub. oil cyl. lubricators (built-in switches)	365
FSA	Lub. oil cyl. lubricators (built-in switches)	366
TI	Lub. oil outlet from MAN B&W turbocharger with slide bearings	369
PI	Lub. oil inlet from MAN B&W turbocharger with slide bearings/turbocharger	371
DSA	Oil mist detector	436
WI	Axial vibration monitor	471
WEA	Axial vibration monitor <i>only 5-cyl. S-engines</i>	472

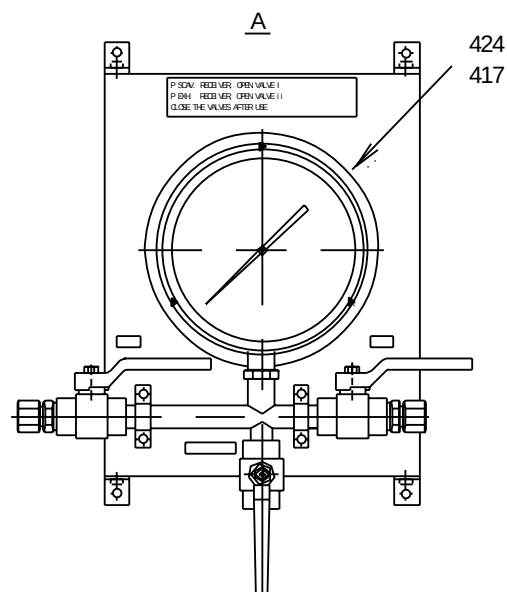
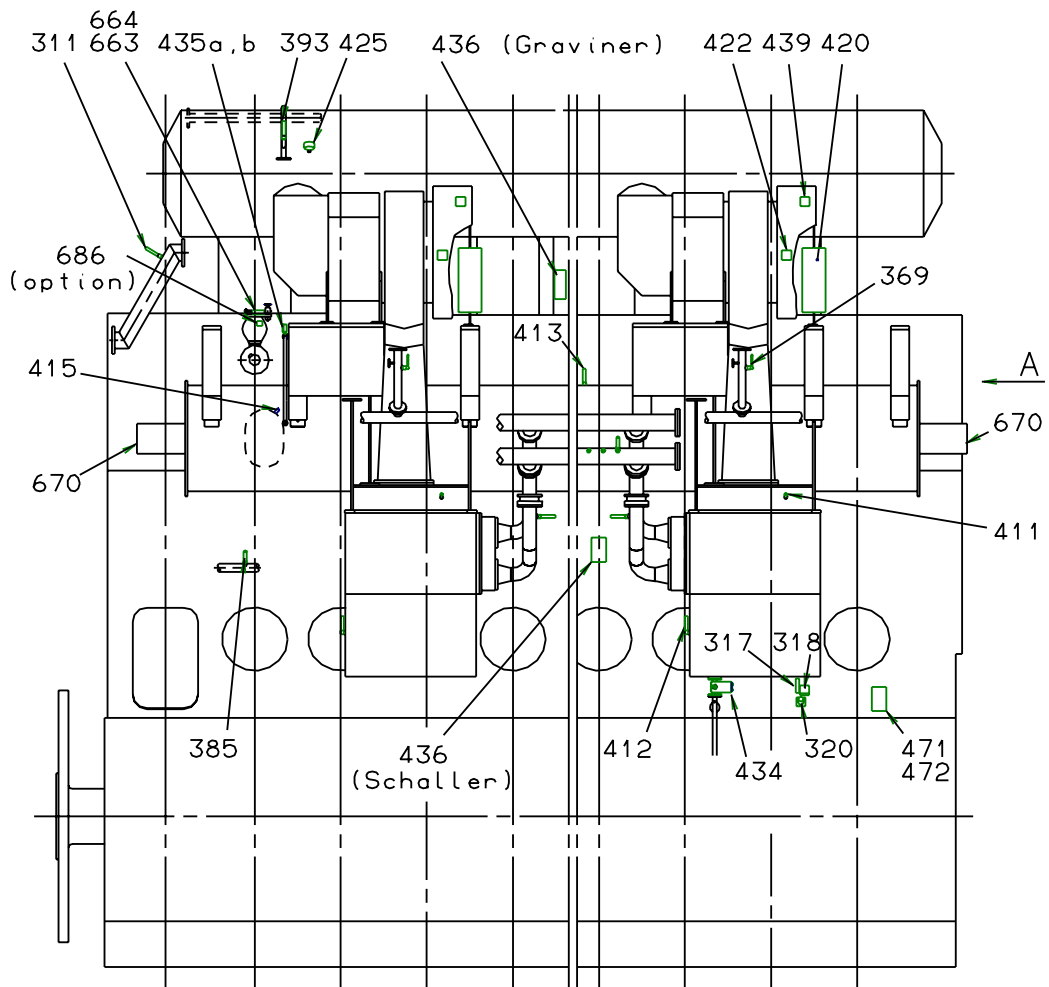


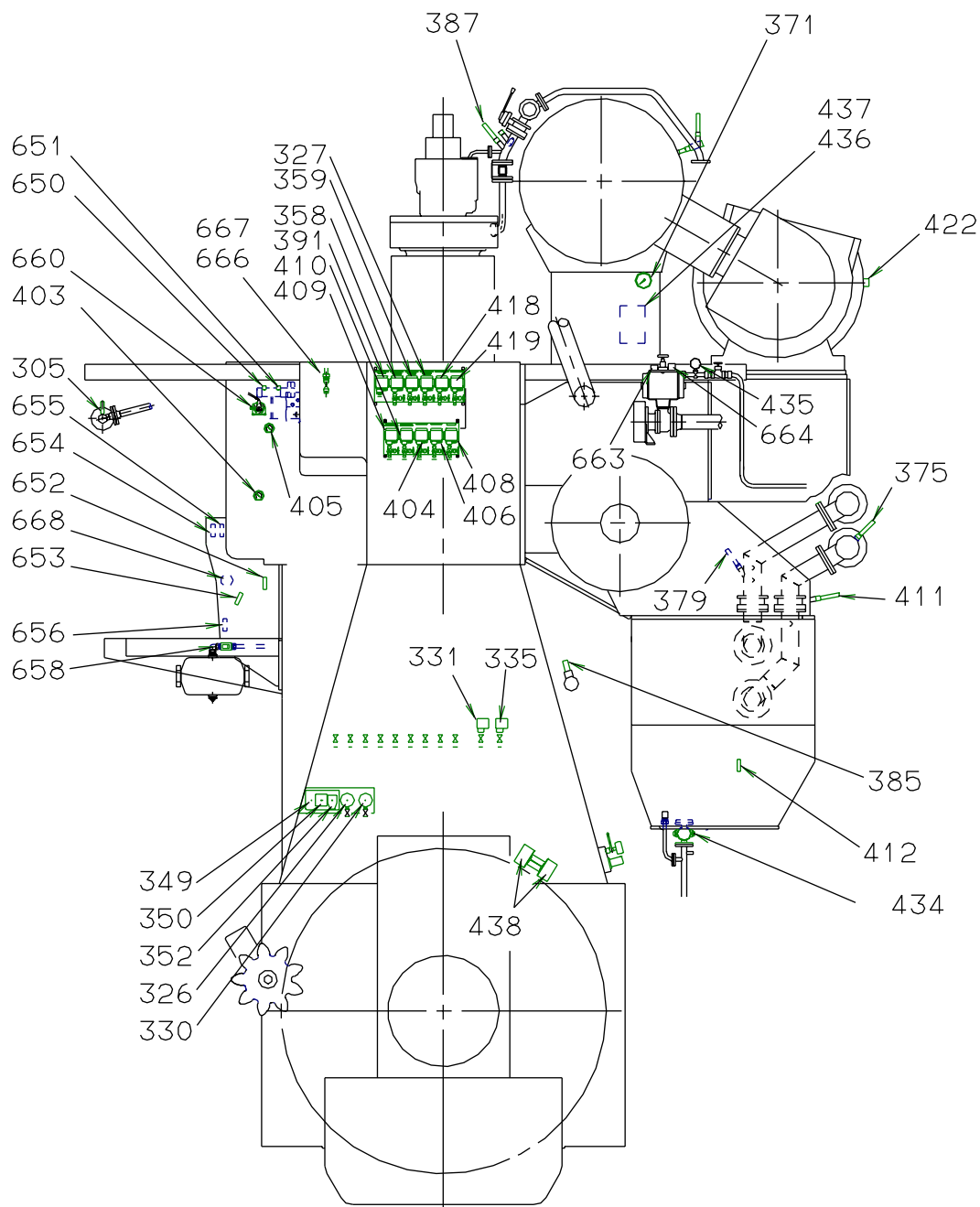
<u>Symbol</u>	<u>Description</u>	<u>Position</u>
Cooling Water System		
TI	Sea cooling water inlet	375
TI	Sea cooling water outlet/air cooler	379
TI	Fresh cooling water inlet	385
PI	Fresh cooling water inlet	386
TI	Fresh cooling water outlet/cylinder	387
PDSA	Fresh cooling water across engine	391
TI	Fresh cooling water outlet/turbocharger	393
Air and Gas System		
PI	Starting air to main starting valve	401
PI	Control air inlet	403
PSA	Control air inlet	404
PI	Safety air inlet	405
PSA	Safety air inlet	406
PSA	Air inlet to exhaust valve	408
PSA	Control air inlet, finished with engine	409
PSA	Safety air inlet, finished with engine	410
TI	Scavenge air before air cooler/air cooler	411
TI	Scavenge air after air cooler/air cooler	412
TI	Scavenge air receiver	413
TSA	Scavenge air box fire/cylinder	415
PI	Scavenge air receiver	417
PSC	Scavenge air receiver (auxiliary blower) control	418
PSA	Scavenge air receiver (auxiliary blower)	419
PDI	Pressure drop across air cooler/air cooler	420
PDI	Pressure drop across blower filter/turbocharger only for ABB-turbocharger	422
PI	Exhaust gas receiver	424
TI	Exhaust gas before turbocharger/turbocharger	425
TI	Exhaust gas after valves	426
LSA	Scavenge air, water level	434
PI	Cleaning turbocharger, air supply	435a
PI	Cleaning turbocharger, water supply	435b
Tacho System		
E	Engine, r/min	438
E	Turbocharger, r/min	439

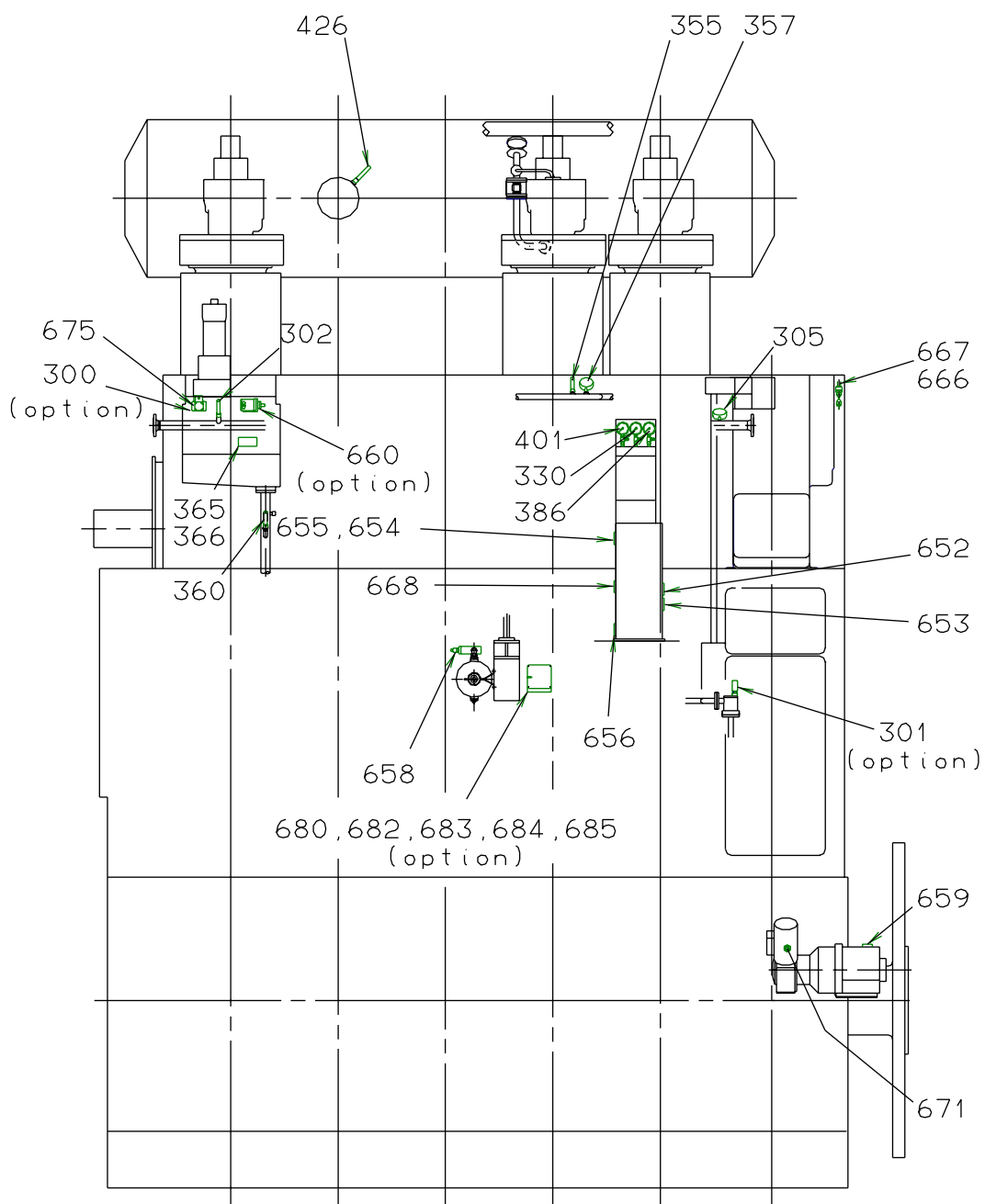


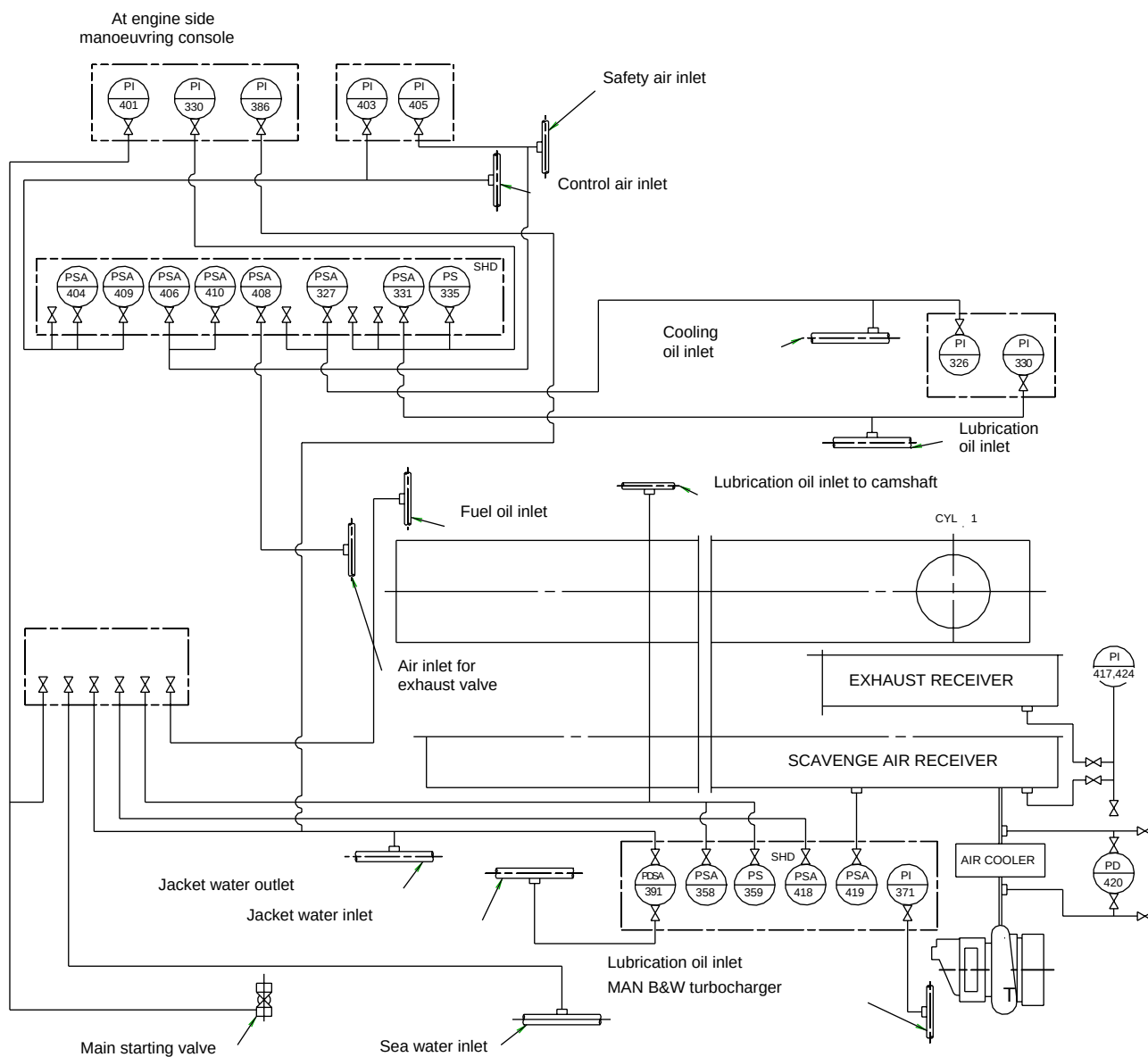
<u>Symbol</u>	<u>Description</u>	<u>Position</u>
Manoeuvring System		
ZS	Reversing astern/cylinder	650
ZS	Reversing ahead/cylinder	651
ZS	Resets shut-down function during engine side control	652
ZS	Gives signal when change-over mechanism is in remote control mode	653
PSC	Gives signal to manoeuvring system when on engine side control	654
PSC	Disconnect reset and cancel remote control system from safety system during engine side control	655
EV	Solenoid valve for cancel V.I.T. system in stop and astern	656
EV	Solenoid for automatic shut-down ME	658
ZS	Turning gear engaged indication	659
E	Fuel rack transmitter (option)	660
ZS	Main starting valve - blocked	663
ZS	Main starting valve - in service	664
ZS	Air inlet starting air distributor, open	666
ZS	Air inlet starting air distributor, closed	667
PI	Pilot pressure to actuator for V.I.T. system	668
E	Electric motor, auxiliary blower	670
E	Electric motor, turning gear	671
PSC	Cancel of tacho alarm from safety system, when stop is ordered	675
PSC	Gives signal when on bridge control (option)	680
EV	Gives signal when stop is ordered from bridge control (option)	682
EV	Gives signal when ahead is ordered from bridge control (option)	683
EV	Gives signal when start is ordered from bridge control (option)	684
EV	Gives signal when astern is ordered from bridge control (option)	685
EV	Prevent opening of main starting valve during slow turning (option)	686











The panels shown are mounted on the engine

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D. Laid-up Vessels	702.04

BLANK



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.

- A. Checks A1-A9
should be made regularly at engine standstill during normal service.

Checks A1 to A9 should be coordinated and evaluated together with the measurements described in [Chapter 706](#), 'Engine Synopsis'.

- B. Checks B1-B5
should be made at engine standstill *during* the repairs.

- C. Checks C1-C7
should be made at engine standstill *after* the repairs.

If repair or alignment of bearings, crankshaft, camshaft or pistons has been carried out, repeat checks A1, A2 and A6.

Checks to be made just before starting the engine are mentioned in [Chapter 703](#).

A. 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 A1-A9, combined with performance observations, it is determined if extra maintenance work (other than that scheduled) is necessary.

Check A1: 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 Chapter 708, Item 7.1](#).

Check also that oil is flowing freely from bearings, spray pipes and spray nozzles in the chain drive.

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 camshaft lubrication.

NB: After a major overhaul of pistons, bearings, etc., this check should be repeated before starting the engine.

Check A2: 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 [Chapter 708](#), Item 7.12.

Refer to [Chapter 708](#), Item 7.1 for further information.

Check A3: 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 A4: Scavenge Port Inspection

Inspect the condition of the piston rings, cylinder liners, pistons, and piston rods, as detailed in [Chapter 707](#), Item 3.

Note down the conditions as described in [Chapter 707](#), Item 3.2.

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 C2).

Check A5: 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 A6: Crankshaft

Take deflection measurements as described in [Chapter: 708](#) 'Alignment of main bearings'.

Check A7: Circulating Oil Samples

Take an oil sample and send it to a laboratory for analysis and comments.

(See [Chapter 708](#) 'Maintenance of the circulating oil').

Check A8: 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 C4](#) regarding precautions to avoid turbocharger bearing damage during engine standstill.

Check A9: Manoeuvring Gear

Frequently check the movability of the system.

Disconnect the governor from the regulating gear by means of the impact handwheel in the engine side control console. Move the rod connections by means of the regulating handle to check that the friction in the regulating gear is sufficiently low.

Lubricate the system (bearings and rod connections) at intervals of about 4000 hours.

Use grease of a good quality, and with a "melting" point of about 120°C.

For the governor, use an anti-corrosive oil, with additives against: foam, sludge formation, and damage to gaskets and paint.

The viscosity index should be high and the viscosity be in the range 22-68 cSt at 40°C.

Regarding check of the governor, see the producer's special instructions.



Check A10: Timing Guide

(Only for engines with VIT, Variable Injection Timing)

In order to keep the timing guide in an optimum service condition with regard to movability, we recommend that you twice a year apply diesel oil via the plug screw hole at the base of the fuel pump housings.

When the diesel oil has drained off, apply lube oil and reinstall the plug screw.

B. Checks at Engine Standstill during Repairs**Check B1: Bolts, Studs and Nuts**

Check all bolts, studs and nuts in the crankcase and chain casing to make sure that they have not worked loose.

The same applies to the holding-down bolts in the bedplate. Check that side and end chocks are properly positioned, *see also Vol. II 'Maintenance', Chapter 912.*

Check all locking devices.

Check B2: Chain Casing

Inspect the chains, wheels, bearings and rubber-bonded guide bars.

Check the hydraulic damper of the chain tightener, *see also Vol. II 'Maintenance', Chapter 906-2.1.*

Check B3: Leakages and Drains

Remedy any water or oil leakages. Clean drain and vent pipes of possible blockages by blowing-through.

Check B4: Pneumatic Valves in the Control Air System

Clean the filters.

Check B5: 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.

C. Checks at Engine Standstill after Repairs

If repair or alignment of bearings, crankshaft, camshaft or pistons has been carried out, repeat Checks A1, A2 and A6.

Check C1: 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 by-passing the bearings, as described in [Chapter 708](#).

Continue the flushing until all dirt is removed.

Check C2: 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 C3: Turning

After restoring normal oil circulation, check the movability of the engine by turning it one or more revolutions using the turning gear.

Note: Before leading oil to the exhaust valve actuators:

- Engines without Unilub:
via the camshaft oil pump,
- Engines with Unilub:
via the main lube oil pump,
and camshaft booster pumps,

check that air supply is connected to the pneumatic pistons of the exhaust valves, and that the exhaust valves are closed.

See also Chapter 703, page 703.01.

Check C4: 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 C5: Cylinder Lubricators

See also Plate 70716.

Manually operate the “button pumps” until the cylinder oil is known for certain to be flowing from all the cylinder liner lubricating orifices:

Check that all steel balls are moving in the sight tubes, indicating oil flow.

Turn each main piston to BDC in turn, and check, via the scavenge ports, the lube oil flow to the cylinder liner. *See Plate 70701.*

Check that all pipe connections and valves are tight.

Check C6: Manoeuvring Gear

See Check A9, earlier in this Chapter.

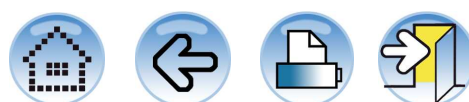
Check C7: Air Cooler

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.

D. 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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The following descriptions cover the standard manoeuvring system for the 50-98MC engines.

Since the manoeuvring system supplied for a specific engine may differ from the standard system, *Chapter 907 in Volume III and 'Plant Installation Drawings'* should always be consulted when dealing with questions regarding a specific plant.

1. Preparations for Starting

See [Chapter 705](#), Item 3.3 regarding correct fuel oil temperature before starting.

Regarding checks to be made before starting, when cylinders are out of operation, see [Chapter 704](#), 'Running with Cylinders or Turbochargers out of Operation', Item 3.

1.1 Air Systems

- Drain water, if any, from the starting air system. See also [Plate 70304](#), 'Starting Air System'.
- Drain water, if any, from the control air system at the receivers.
- Pressurise the air systems.
Check the pressures.
See also [Chapter 701](#), 'Alarm Limits'.
- Pressurise the air system to the pneumatic exhaust valves.

Note: 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 [Chapter 702](#), Check C3.

- Engage the lifting/rotation check rod mounted on each exhaust valve, and check that the exhaust valves are closed.

1.2 Lube Oil Systems

- Start the lube oil pumps for:
 - Engine

- Camshaft
 - Engines without Unilub: camshaft lube oil pumps,
 - Engines with Unilub: camshaft booster pumps.

- 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 [Chapter 701](#), 'Alarm Limits'.

- Check the oil flow, through the sight-glasses, for:

- Piston cooling oil

- Turbochargers

- Check that the cylinder lubricators are filled with the correct type of oil.
[See also Plate 70716](#).

- Operate the cylinder lubricators manually.

Check that oil is emitted.
[See also Chapter 702](#), Check C5.

Note: Check regularly during service that the Load Change Dependent lubricators function properly. See also the producer's special instructions.

1.3 Cooling Water Systems

Note: 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 Item 3.1 and Item 7 point 9.

- Start the cooling water pumps.
- Check the pressures.
See also Chapter 701, 'Alarm Limits'.

1.4 Slow-Turning the Engine

This must be carried out to prevent damage caused by fluid in one of the cylinders, and to check the reversing mechanism.

Before beginning the slow-turning, obtain permission from the bridge.

Note: Always carry out the slow-turning at the latest possible moment before starting and, under all circumstances, within the last 30 minutes.

Is the special slow turning device installed?	
YES	Follow procedure 1.4.A
NO	Follow procedure 1.4.B

1.4.A Slow-turn with Special 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 ENGAGED extinguishes.
2. 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.*
3. Open the indicator valves.

4. Turn the slow-turning switch to SLOW-TURNING position.
5. Move the regulating handle to START position.
Check to see if fluid flows out of any of the indicator valves.
Check that the individual air cylinders reverse the displaceable rollers for each fuel pump to the outer position.
6. When the engine has moved one revolution, move the handle back to STOP position.
7. Turn the reversing handle to the opposite direction of rotation.
Repeat points 5 and 6.
8. Turn the slow-turning switch back to NORMAL position.
9. Close the indicator valves.

1.4.B Slow-turn with Turning Gear

1. Open the indicator valves.
2. Give REVERSING order by moving the reversing handle to the opposite direction of rotation.
3. Turn the engine one revolution with the turning gear in the direction indicated by the reversing handle.
Check to see if fluid flows out of any of the indicator valves.
Check that the individual air cylinders reverse the displaceable rollers for each fuel pump to the outer position.
4. Repeat points 2 and 3 in the opposite direction of rotation.
5. Close the indicator valves.
6. Disengage the turning gear.
Check that it is locked in the OUT position.
Check that the indicator lamp for TURNING GEAR ENGAGED extinguishes.



7. 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.*

1.5 Fuel Oil System

Regarding fuel oil temperature before starting, [see Chapter 705](#), Items 3 and 3.3.

- 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 Chapter 701](#), 'Alarm Limits'.

1.6 Checking the Fuel Regulating Gear

- Close the shut-off valve of the starting air distributor to prevent the engine from turning. Check the indicator lamp.
- Switch over to control from the engine side control console.
See description of the procedure on [Plate 70302](#), Items 2-3.
- Turn the regulating handwheel to increase the fuel pump index, and check that all the fuel pumps follow to the FUEL SUPPLY position. With the regulating handwheel back in STOP position, check that all the fuel pumps show zero-index.
- Switch back to NORMAL control by following [Plate 70302](#), Items 1-2 in the reverse order.
- Open the shut-off valve of the starting air distributor.
Check that the indicator lamp extinguishes.

1.7 Miscellaneous

- Lubricate the bearings and rod connections in the regulating gear, etc., at the intervals stated in [Chapter 702](#), Check A9.
- Switch on the electrical equipment in the control console.
- Set switch for the auxiliary blowers in AUTO position.

The blowers will start at intervals of 6 sec.

Note: See the Warning of scavenge air box fire due to incorrectly working auxiliary blowers on page 704.01.

The engine is now ready to start.

2. Starting-Up

2.1 Starting

Start the engine as described under START-order in Item 8 for fixed pitch propeller plants and in Item 9 for controllable pitch propeller plants.

Note: 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.



2.2 Starting Difficulties

See also Chapter 703, Item 2.3, 'Supplementary Comments'

Difficulty	Point	Possible Cause	Remedy
Engine fails to turn on starting air after START order has been given	1	Pressure in starting air receiver too low.	Start the compressors. Check that they are working properly.
	2	Valve on starting air receiver closed.	Open the valve.
	3	Valve to starting air distributor closed.	Open the valve.
	4	No pressure in the control air system.	Check the pressure (normally 7 bar). If too low, change over to the other reducing valve and clean the filter.
	5	Main starting valve (ball valve) locked in closed position.	Lift locking plate to working position.
	6	Main starting valve (ball valve) does not function owing to activated turning gear locking device.	Release the turning gear locking device.
	7	Control selectors are wrongly set.	Correct the setting.
	8	The starting air distributor has not activated its end stop valve.	Lubricate and make the shaft movable so that the distributor moves easily. Check and adjust the air cylinder and end stop valves.
	9	Pistons in starting air distributor sticking.	Lubricate and make the pistons movable. Overhaul the starting air distributor.



Starting Difficulties cont. - See also Chapter 703, Item 2.3, 'Supplementary Comments'

Difficulty	Point	Possible Cause	Remedy
Engine does not reverse when order is given.	10	Distributor wrongly adjusted.	Check the timing marks, see Vol. II, Maintenance, proc. 907-2. Alternatively, with engine piston 1 in TDC, check that the starting air distributor piston for cyl. 1 is lifted to the same height (within a tolerance of about 0.2 mm) by, respectively, the AHEAD and ASTERN cam of the starting air distributor.
	11	Sticking control valve for starting air distributor.	Overhaul the control valve slide.
	12	Starting air valves in cylinder covers defective.	Pressure-test the valves. Replace or overhaul defective valves, see also Chapter 703, Item 7, 'Operations AFTER arrival in port'.
	13	Control air signal for starting does not reach the engine.	Find out where the signal has been stopped and correct the fault.
	13A	Propeller blades are not on zero-pitch (CPP-plants).	Set pitch to zero position.
	14	Coil of solenoid valve for the desired direction of rotation does not receive voltage.	See the 'Bridge Control' instruction book.
Engine turns too slowly (or unevenly) on starting air	15	Control air signal for the desired direction of rotation does not reach the engine.	By loosening one copper pipe at a time on the signal's route through the system, find the defective valve or pipe which stops the signal. Repair or replace the valve.
	16	'Slow-turning' (option) of engine adjusted too low.	Set the 'slow-turning' adjustment screw so that the engine turns as slowly as possible without faltering.



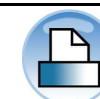
Starting Difficulties cont. - See also Chapter 703, Item 2.3, 'Supplementary Comments'

Difficulty	Point	Possible Cause	Remedy
Engine turns on starting air but stops, after receiving order to run on fuel.	17	'Slow-turning' (option) is not cancelled (automatic control).	See the 'Bridge Control' instructions.
	18	Faulty timing of starting air distributor.	Check the timing, see also point 10.
	19	Defective starting valves in cylinder covers.	Pressure-test the valves for leakages, see also Chapter 703, Item 7, 'Operations AFTER arrival in port'. Replace or overhaul the defective valves.
	20	Puncture valves not deaerated.	Find the cause of the stop-order and correct the fault.
	21	Shut-down of engine.	Check pressure and temperature. Reset 'shut-down'.
	22	Sluggishness in the manoeuvring gear.	Lubricate the manoeuvring gear. Ensure that the fuel pumps, rod connections and bearings are movable. See Chapter 702, Item 9.
	23	Faulty adjustment of manoeuvring gear.	Check the rod connections. Check that the fuel pump index corresponds to 'Adjustment on testbed', see under Chapter 701 .
	24	Governor air booster (Woodward) does not supply oil pressure to the governor during the starting air period. (Woodward governor only).	See the Governor instructions.
	25	The pre-set speed setting pressure to the governor (Woodward), is set too low, or for too short a period.	The pressure shall be set between 1.6 and 2.0 bar, and maintained for about 6 seconds.



Starting Difficulties cont. - See also Chapter 703, Item 2.3, 'Supplementary Comments'

Difficulty	Point	Possible Cause	Remedy
Engine turns on fuel, but runs unevenly (unstable) and will not pick-up rpm.	26	Engine runs too long on starting air, so the governor has time to regulate the pump index downwards, before running starts on fuel oil.	Automatic running: Adjust the starting level, see Plates 70305 and 70311 . Manual running: Shorten the starting air period.
	27	Fault in governor.	<u>Woodward governor</u> Check that the governor functions with the correct oil pressure. Check that the limiting functions in the governor are adjusted correctly. Deflection at the starting moment shall be about 6 on the terminal lever scale. For further fault-finding, see <i>the Governor instructions</i> . <u>Electronic governor</u> <i>See the Governor instruction book.</i> <i>See also 'Difficulties during Running', Point 28, further on in this Chapter.</i>
	28	Auxiliary blowers not functioning.	Start auxiliary blowers.
	29	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 shop or seatrial observations.



Starting Difficulties cont. - See also Chapter 703, Item 2.3, 'Supplementary Comments'

Difficulty	Point	Possible Cause	Remedy
	30	Fuel filter blocked.	Clean the filter.
	31	Too low fuel pressure.	Increase the pressure.
	32	One or more cylinders not firing.	Check suction valve and puncture valve in fuel pump. Check individual index, if no index, check the rod connections and the safety shut-down system. If fault not found, change fuel valves.



2.3 Supplementary Comments

Item 2.2, 'Starting Difficulties' gives some possible causes of starting failures, on which the following supplementary information and comments can be given.

Point 1

The engine can usually start when the starting air pressure is above 10 bar. The compressors should, however, be started as soon as the pressure in the starting air receiver is below 25 bar.

Points 12, 26 and 28

The testing procedure describing how to determine that all starting valves in the cylinder covers are closed and are not leaking is found in Chapter 703, Item 7, 'Operations AFTER arrival in port'. 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 12, 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 13

Examine whether there is voltage on the solenoid valve which controls the starting signal. *If not, see the special instruction book for the engine control system.*

If the solenoid valve is correctly activated or the engine is being manually controlled, trace the fault by loosening one copper pipe at a time on the route of the signal through the system, until the valve blocking the signal has been found. The failure can be due to a defective valve, or to the causes mentioned under points 8, 9, 10 and 21.

Point 21

If the shut-down was caused by over-speed, cancel the shut-down impulse by moving the regulating handle to the STOP position, whereby the cancellation switch closes, and the puncture valves are vented.

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.

In MANUAL control mode, the shut-down signal is reset by moving the regulating hand-wheel to STOP position.

2.4 Checks during Starting

Make the following checks **immediately after starting**:

Check 1: Direction of Rotation

Ensure that the direction of propeller rotation corresponds to the telegraph order.

Check 2: Exhaust Valves

See that all exhaust valves are operating correctly.

Disengage the lifting/rotation indicators after checking the functioning. Check that the slide valve spindles of the sealing air control units protrude through the covers to ensure sealing air supply.

Check 3: Turbochargers

Ensure that all turbochargers are running.

Check 4: Circulating Oil

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

Check 5: Cylinders

Check that all cylinders are firing.



Check 6: 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 7: Pressures and Temperatures

See that everything is normal for the engine speed. In particular: the circulating oil (bearing lubrication and piston cooling), camshaft lubricating oil (engines without Unilub), fuel oil, cooling water, scavenge air, and control and safety air.

Check 8: Cylinder Lubricators

Make sure that the lubricators are working, and with an even "drop height" level in all the sight glasses.

Check that the actuators on the Load Change Dependent lubricators are in the position for increased cyl. lub. oil dosage during starting and manoeuvring. *See the producer's special instructions.*

Check the oil levels in the centre glass, and the feeder tank.

See also Plate 70716.

NB: The lubricator pump stroke should be occasionally checked by measuring the free movement of the adjustment screw, which corresponds to the pump stroke.

See Chapter 707 regarding pre-calculating the pump stroke.

Follow the producer's special instructions for checking and adjusting the pump stroke.

3. Loading

3.1 Loading Sequence

Regarding load restrictions after repairs and during running-in, see Item 3.2.

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. <i>See also Plates 70305, 70311.</i>
NO	• See table below.

Is the cooling water temperature between 20°C and 50°C?	
YES	• Preferably, preheat to 50°C. • If you start with a cooling water temperature below 50°C, increase gradually to: - FPP-plants: 90% of MCR speed - CPP-plants: 80% pitch. • When the cooling water temperature reaches minimum 50°C, increase to 100% of MCR speed/pitch over a period of 30 minutes or more. • <i>The time it takes to reach 50 °C will depend on the amount of water in the system and on the engine load.</i> <i>See also Plates 70305, 70311.</i>
NO	• Do not start the engine. • Preheat to minimum 20°C, or preferably to 50°C. When 20°C, or preferably 50°C, has been reached, start and load the engine as described above. <i>See also Item 1.3, page 703.01.</i>



3.2 Checks during Loading

Check 9: Feel-over Sequence

If the condition of the machinery is uncertain (e.g. after repairs or alterations), the "feel-over sequence" should always be followed, i.e.:

- a) After 15-30 minutes' running on SLOW (depending on the engine size);
- b) again after 1 hour's running;
- c) at sea, after 1 hour's running at service speed;

stop the engine, open the crankcase, and feel-over the moving parts listed below (by hand or with a "Thermo-feel") on sliding surfaces where friction may have caused undue heating.

During feeling-over, the turning gear must be engaged, and the main starting valve and the starting air distributor must be blocked.

The starting air distributor is blocked by closing the cross-over valve.

Feel:

- Main, crankpin and crosshead bearings,
- Piston rods and stuffing boxes,
- Crosshead shoes,
- Telescopic pipes,
- Chains and bearings in the chain casing, and in the moment compensator chain drives (if mounted),
- Camshaft bearing housings,
- Thrust bearing / guide bearing,
- Axial vibration damper,
- Torsional vibration damper (if mounted).

After the last feel-over, repeat Check A1: 'Oil Flow', in [Chapter 702](#).

See also [Chapter 704](#): *Special Running Conditions*, 'Ignition in Crankcase'.

Check 10: Running-in

For a new engine, or after:

- repair or renewal of the large bearings,
- renewal or reconditioning of cylinder liners and piston rings,

allowance must be made for a running-in period.

Regarding bearings: increase the load slowly, and apply the feel-over sequence, see [Check 9](#).

Regarding liners/rings: See [Chapter 707](#), [Item 4.13](#).



4. Running

4.1 Running Difficulties - See also Chapter 703, Item 4.2, '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 Chapter 706: The section entitled 'Evaluation of Records', point 3, 'Air Cooler Synopsis'.
	2	Fouled air and gas passages.	Clean the turbine by means of dry cleaning/water washing. Clean the blowers and air coolers, see Chapter 706 'Cleaning of Turbochargers and Air Coolers'. 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 Chapter 705 'Fuel & Fuel Treatment'. ★)
	4	Wrong position of camshaft (Maladjusted or defective chain drive).	Check p_{max} . Check camshaft with pin gauge. Check chain tension.
	b) single cyl.	5	Defective fuel valves, or fuel nozzles. ★)
		6	Leaking exhaust valve ★)
		7	Blow-by in combustion chamber. ★)
		8	Wrongly adjusted, or slipped, fuel cam. ★)
Exhaust temperature decreases. a) all cyl.	9	Falling scavenge air temperature.	Check the fuel pump lead. Check that the seawater system thermostat valve is functioning correctly.

Running Difficulties cont. - See also Chapter 703, Item 4.2, 'Supplementary Comments'

Difficulty	Point	Possible Cause	Remedy
b) single cyl. Engine r/min decrease	10	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.
	11	Defective fuel pump suction valve.	Repair the suction valve.
	12	Fuel pump plunger or puncture valve sticking or leaking.	Replace the fuel pump or the puncture valve.
	13	Reversible roller guide in wrong position (reversible engines).	Check the roller guide mechanism for seized bearings, roller guide, roughened rollers or cam etc. In case of seizure being observed, check the cam shaft lub. oil filter as well as the by-pass filter for possible damage.
	14	Exhaust valve sticking in open position.	Replace the exhaust valve.
	15	Oil pressure before fuel pumps too low.	Raise the supply and circulating pump pressures to the normal level.
	16	Air/gas/steam in the fuel oil.	<i>See point 10.</i>
	17	Defective fuel valve(s) or fuel pump(s).	Replace and overhaul the defective valve(s) and pump(s).
	17a	Fuel index limited by torque/scavenge air limiters in the governor due to abnormal engine load.	<i>See Chapter 706 'Observations during Operation', Item 2.1 'Operating Range Load Diagram'.</i>

★) See Chapter 706, 'Evaluation of Records', in particular the



Running Difficulties cont. - See also Chapter 703, Item 4.2, 'Supplementary Comments'

Difficulty	Point	Possible Cause	Remedy
Smoky exhaust	18	One (or more) reversible roller guides in wrong position (reversible engines).	See point 13.
	19	Water in fuel oil.	Drain off the water and/or clean the fuel more effectively.
	20	Fire in scavenge air box.	See Chapter 704.
	21	Slow-down or shut-down.	Check pressure and temperature levels. If these are in order, check for faults in the slow-down equipment.
	22	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.
	23	Fouling of hull. Sailing in shallow water.	See Chapter 706, 'Observations during Operation', Item 2.1, 'Operating Range Load Diagram'.
	24	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 governor limiters setting.
	25	Air supply not sufficient.	See reference quoted under point 1. Check engine room ventilation.
	26	Defective fuel valves (incl. nozzles).	See point 5, and Chapter 706, Appendix 2 (incl. Plate 70618).
	27	Fire in scavenge air box.	See Chapter 704.
	28	Governor failure/erratic regulation.	See Item 4.2, 'Supplementary Comments'.



4.2 Supplementary Comments

Item 4.1, 'Difficulties when Running' gives some possible causes of operational disturbances, on which the following supplementary information and comments can be given.

Point 6

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, lift the fuel pump roller guide, [see Chapter 704](#) 'Running with Cylinders or Turbochargers out of Operation', Case A.

Point 7

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 Chapter 707](#), item 3, 'Scavenge Port Inspection'.

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 pump index for a few minutes and, at the same time, increasing the cylinder oil amount. If this is not effective, the fuel pump index and the $p_{\max}$ must be reduced until the blow-by ceases.

The pressure rise $p_{\text{comp}} - p_{\max}$ must not exceed the value measured on testbed at the reduced mean effective pressure or fuel pump index. Regarding adjusting of $p_{\max}$, [see Vol. II 'Maintenance', Chapter 909](#).

If the blow-by does not stop, the fuel pump roller guide should be lifted, or the piston rings changed.

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 Chapter 704](#) under 'Fire in Scavenge Air Box'.

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 10 and 16

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 13 and 18

In the normal running condition, the reversible roller guide is in a self-locking position. (Reversible engine).

However, in the event of increased friction in the roller guide mechanism (seizure), there is a risk that the roller guide link might change position.



Points 12 and 17

If, to obtain full load, it proves necessary to increase an individual fuel pump index by more than 10% (from sea trial value), then this in most cases indicates that the pump is worn out. This can usually be confirmed by inspecting the plunger. If the cut-off edge shows a dark-coloured eroded area, the pump should be sent for repair. This can usually be done by reconditioning the bore, and fitting a new plunger.

Point 28

If the fault lies in the governor itself, the special governor instruction book should be consulted.

External influences can also cause erratic regulation. For instance:

- main chain drive wrongly tensioned (Woodward governor),
- falling oil pressure to the governor (Woodward governor),
- lack of control air pressure (Woodward governor),
- sluggishness in the regulating gear,
- firing failure,
- unbalance in the load distribution between the cylinders, see *Chapter 706 'Evaluation of Records', Item 2.1.*

See also *Item 2.2, 'Starting Difficulties', point 27.*

4.3 Check during Running

Check 11: Thrust Bearing

Check measuring equipment.

Check 11A: Chain Tighteners

Check the chain tighteners for the cam shaft drive and 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 12: Shut Down and Slow Down

Check measuring equipment.

Check 13: 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 14: Temperature Alarms (Thermostats)

See also Check 13, '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 15: 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 16: Observations

Make a full set of observations, including indicator cards, see [Plate 70603](#) 'Performance Observations' and [Chapter 706](#), [Appendix 1](#). Check that pressures and temperatures are in order.

Check the load distribution between the cylinders, see [Chapter 706](#) 'Evaluation of Records', [Item 2.1](#).

5. Preparations PRIOR to Arrival in Port

Note: See [Chapter 707](#), [item 3.1](#), 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 [Chapter 705](#), [Item 4.2](#).

Change-over should be carried out **one hour** before the first manoeuvres are expected. See [Chapter 705](#), [Item 4.2](#), 'Fuel Change-over'.

2. Start an additional auxiliary engine to ensure a power reserve for the manoeuvres.
3. Make a reversing test (FPP-plants)
This ensures that the starting valves and reversing mechanism are working.
4. Blow-off any condensed water from the starting air and control air systems just before the manoeuvres.

6. Stopping

Stop the engine as described under STOP-order in [Item 8](#) for fixed pitch propeller plants and in [Item 9](#) for controllable pitch propeller plants.

See also [Item 10](#), 'Crash Stop', regarding quick reduction of the ship's speed.

7. Operations AFTER Arrival in Port

When the 'FINISHED WITH ENGINE' order is received in the control room:

1. Switch over to control room control.
2. Switch-off the auxiliary blowers.
3. 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 valve to the starting air distributor.
 - Open the indicator valves.
 - Change-over to MANUAL control from engine side control console.

See [Item 8.4](#), 'Manual Control from



- 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.

- Replace or overhaul any defective starting valves.

4. 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 distributor is closed.

5. Stop the camshaft lube oil pump/booster pumps.

6. Close and vent the control air and safety air systems. Check that the action of the springs causes the slide valve spindles of the sealing air control units to move inwards, thus stopping the sealing air supply.

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.

7. 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.

8. Fuel oil pumps:

Did engine run on heavy fuel oil until STOP ?	
YES	● Stop the fuel oil supply pumps. ● Do <u>not</u> stop the circulating pumps. ● Keep the fuel oil preheated <i>The circulating oil temperature may be reduced during engine standstill, as described in Chapter 705, Item 3.2, 'Fuel Preheating when in Port'.</i> Note: Cold heavy fuel oil is difficult or even impossible to pump.
NO	● Stop the fuel oil supply and circulating pumps.

9. Freshwater preheating during standstill:

Will harbour stay exceed 4-5 days?	
YES	● Keep the engine preheated or unheated. However, see <i>Items 1.3 and 3.1.</i>
NO	● Keep the engine preheated to minimum 50°C. <i>This counteracts corrosive attack on the cylinder liners during starting-up.</i> ● Use a built-in preheater or the auxiliary engine cooling water for preheating of the engine. See also Chapter 709, Item 3, 'Jacket Water Cooling System.'

10. Switch-off other equipment which need not operate during engine standstill.

11. Re-engage the engine during standstill.



8. Engine Control System, FPP Plant, 50-70 MC Engines

8.1 General

For plants equipped with fixed pitch propeller, the following modes of control are available:

- Remote control from control room
- Remote control from bridge (option)
- Manual Control from engine side control console.

On [Plate 70306](#), the pneumatic STOP signal is indicated in red and control air is indicated in green.

Note: The safety air system, which is indicated in purple, is only pressurised after valve 127-C6 during engine shut-down.

See [Chapter 701](#), 'Alarm Limits'.

The manoeuvring system is shown with the following status:

- STOP
- Latest direction of rotation ordered:
AHEAD
- Remote control from control room
- Power on (pneumatic + electric)
- Main starting valve on SERVICE.

In this condition the engine is ready to start.

8.2 Remote Control from Control Room [Plates 70306, 70307](#)

The change-over valve (100-E2) must be in its 'Remote Control' position.

STOP, START, reversing (AHEAD or ASTERN) and speed-setting orders are given manually by moving the regulating handle, corresponding to the order from the bridge

STOP order	<i>The STOP signal is indicated in red on Plates 70306, 70307</i>
Move the regulating handle to STOP position	
The following items are actuated:	Function:
63-K1 (STOP switch)	Activates valve 84-K4 and subsequently valve 38-D4, which activates: 25-C4: Leads control air to the puncture valve on each fuel pump. <i>This prevents the injection of high-pressure fuel oil into the cylinders.</i> 117-B8: Activates the starting air distributor so that it is ready when the starting signal is given.
40-B2 (Via 151-A4)	Adjusts the fuel pumps to maximum VIT-index by means of reducing valve 59-C1. The consequent early fuel oil injection facilitates starting and running in ASTERN direction.
<i>The STOP signal is kept as long as the regulating handle is in STOP position, in START position and in the range in between.</i>	



START order	The START signal is indicated in dotted red on Plate 70307 . The AHEAD signal is indicated in blue, and the ASTERN signal is indicated in dotted blue on Plate 70307 .
Note: Regarding slow-turning, see 'Slow-Turning (Optional)', page 703.22 Acknowledge the telegraph. Move the regulating handle into START position, in the required direction of rotation. The following describes the sequence for START AHEAD.	
The following items remain actuated:	Function:
63-K1	Maintains the STOP-signal, see 'STOP-order', above.
The following items are actuated:	Function:
176-K1 (AHEAD switch)	- Activates valve 86-K4, which: - Activates valve 10-G11 which supplies air to reversing cylinders 13-C11 and 57-E9. <i>This causes reversing of the starting air distributor and the roller guides for the fuel pumps, provided that they are not already in the required position.</i> Note: The roller guides are only able to reverse when the engine rotates. - Leads air to interlock valve 55-E8. <i>When the starting air distributor has reached the required position, air is supplied to valve 37-E5.</i> <i>This prevents the engine from starting if the starting air distributor is in an incorrect position.</i>
64-K1 (START switch)	- Activates valve 90-K5 and subsequently valve 37-E5. Provided interlock valve 55-E8 is released: - Leads pilot air to valve 33-D5. Provided the turning gear is disengaged (115-G7): - Activates valves: 14-E9: Blocks reversing of the starting air distributor to prevent damage. 15-E10: See 14-E9, above. 26-B8: Admits air supply to the starting air distributor. 27-D9: Opens the main starting valve and the (Optional) slow-turning valve which leads air to: - Starting air distributor - Starting valves Note: If slow-turning is installed, valve 28-C9 is inserted to prevent opening of the main starting valve until the crankshaft has rotated at least one revolution.
The engine will now rotate on starting air. When the RPM detector 117, detects the motion, valve 40-B2 is deactivated, enabling regulating pump VIT-index via valve 52-A2 during running AHEAD.	



START order (Cont.)	
When START-LEVEL RPM is reached:	8 - 12% of MCR speed, see Plate 70305
Move the regulating handle to the ordered position. (However, see Item 3, 'Loading').	
The following items are deactuated:	Function:
63-K1 (STOP switch)	Deactivates valve 84-K4 and subsequently valve 38-D4, which deactuates: 25-C4: Vents puncture valves (A3), causing high-pressure fuel oil to be injected into the cylinders. 117-B8: Cuts-off the pilot air supply to the starting air distributor. <i>The memory function causes those starting valves which are already activated to stay open during the remaining opening period.</i>
64-K1 (START switch)	Deactivates valve 90-K5 and subsequently valve 37-E5, causing deactivation of valve 33-D5, and with one second's delay (32-D5) deactivates: 14-E9: Vents the blocking of the starting air distributor. 15-E10: See 14-E9, above. 26-B8: Closes the air supply to the starting air distributor. 27-D9: Closes the main starting valve and the (optional) slow-turning valve, <i>This one second's delay causes the main starting valve to remain open, so as to supply air to those cylinders that are in START position.</i>
176-K1 (AHEAD switch)	With six seconds' delay, valve 86-K4 deactivates valve 10-G11 which vents reversing cylinders 13-C11 and 57-E9. <i>This six seconds' delay is to ensure that the fuel roller guides change their position.</i>
Set the speed with the regulating handle. See also Item 3, 'Loading'.	
In case of START-FAILURE , i.e. if the engine stops after the starting sequence is finished:	
● Cancel the limiters in the governor by activating switch 79-H2. <i>This allows the governor to give more fuel during the starting sequence.</i> ● Make a new start attempt as described under 'START order' above.	



Reversing and START in a new direction

Note: Regarding reversing and start in a new direction when the ship's speed is high, see *Item 11, 'Crash Stop'*.

- Stop the engine, as described under 'STOP order', above.
- Start the engine in the opposite direction, as described under 'START order', above.
- During starting and running in ASTERN direction, valve 40-B2 is activated, hereby leading the pre-set air signal for maximum VIT-index from valve 59-C1 to the VIT-actuators (52-A2). The consequent early fuel injection facilitates starting and running in ASTERN direction.

Slow-Turning (Optional)

If the manoeuvring system is equipped with a slow turning feature, we recommend using this in connection with starting the engine, if it has been stopped for more than 30 minutes.

- Activate the slow turning switch 78-H2 on the manoeuvring console manually.
The switch activates solenoid valve 28-C9, which deaerates the pneumatic opening line to the main starting valve.
- Give START order with the regulating handle. *The main starting valve is kept in the closed position, while only the smaller slow turning valve opens.*
- When the crankshaft has rotated at least one revolution, deactivate the slow-turning switch.

The main starting valve opens, and the normal START procedure can continue.

8.3 Remote Control from Bridge (Option) *Plates 70305-07*

The change from remote control from control room to remote control from bridge is made by moving the change-over switch 80-H2 on the manoeuvring console.

The control position is changed immediately when the switch is operated.

During remote control from bridge, the STOP, START, reversing (AHEAD or ASTERN) and speed-setting signals are given by an operating handle on the bridge, normally the bridge telegraph handle, not shown in the diagram.

The necessary functions such as changing to fuel at START level r/min, slow-turning (option), delay of reversing signals, and cancelling of limiters in the governor at repeated START are built-in electronically in the remote control system. The conversion into pneumatic signals is effected by means of solenoid valves (84-K4), (86-K4), (88-K5) and (90-K5) for STOP, AHEAD, ASTERN and START, respectively, as described under 'Remote Control from Control Room'.

The procedure outside the manoeuvring console takes place as described under 'Remote Control from Control Room', *Plate 70306*



If the engine r/min falls below starting level to "starting-error" level after "change to fuel", the remote control system automatically detects a starting error and carries out an automatically repeated START, cf. sequence diagram, [Plate 70305](#).

8.4 Manual Control from Engine Side Control Console

[Plates 70301, 70302, 70308](#)

In the event of breakdown of the normal pneumatic manoeuvring system, the governor or its electronics, or if - for other reasons - direct index-control is required, the engine can be operated from the engine side control console.

Change-over with stopped engine:

See detailed description on [Plate 70302](#).

Change-over with running engine:

- Reduce the engine load to max. 80% of MCR.
- Check that the position of reversing valve 105-E3 corresponds to the present running direction.
- Move the regulating handwheel to bring the tapered slots of the change-over mechanism in position opposite each other.
- Put the blocking arm in position for engine side control.

- Quickly, move the impact handwheel, P-C3, to the opposite position.
This disconnects the fuel pumps from the governor and connects them to the regulating handwheel on the engine side control console.

- Move the change-over valve 100-E2 to the position for engine side control.
This vents valves 84-K4, 86-K4, 88-K5 and 90-K5, and leads control air to the valves in the engine side control console.

If STOP valve 102-D2 is **not** deactivated, the engine now receives a STOP order.

- Activate START valve 101-E2 briefly.
This air impulse deactivates STOP valve 102-D2.
- Set the engine speed directly with the regulating handwheel. See also Item 3, 'Loading'.

Note: When the governor is disengaged, the engine is still protected against overspeed by the electric overspeed trip, i.e. the engine is stopped automatically if the revolutions increase to the overspeed setting.

The overspeed shut-down can only be reset by moving the regulating handwheel to STOP position. Manoeuvring must therefore be carried out very carefully, especially when navigating in rough weather.

STOP order	<i>The STOP signal is indicated in red on Plates 70308</i>
Activate STOP valve 102-D2	
The following items are actuated:	Function:
25-C4	Leads control air to the puncture valve on each fuel pump. <i>This prevents the injection of high-pressure fuel oil into the cylinder.</i>
117-B8	Activates the starting air distributor so that it is ready when the starting signal is given. Furthermore, air is supplied to the reversing valve 105-E3.
40-B2 (Via 151-A4)	Adjusts the fuel pumps to maximum VIT-index by means of reducing valve 59-C1. The cc en fu ec facilitates starting and running



START order	<i>The START signal is indicated in dotted red on Plate 70308. The AHEAD signal is indicated in blue, and the ASTERN signal is indicated in dotted blue on Plate 70308.</i>
Move reversing valve 105-E3 to the ordered position. The following describes the sequence for START AHEAD.	
The following items are actuated:	Function:
10-G11	Supplies air to reversing cylinders 13-C11 and 57-E9. <i>This causes reversing of the starting air distributor and the roller guides for the fuel pumps, provided they are not already in the required position.</i> Note: The roller guides are only able to reverse when the engine rotates.
When the starting air distributor is in the correct position: Note: This must be checked visually	
Move the regulating handwheel to a suitable position. Activate START valve 101-E2.	
The following items remain actuated:	Function:
25-C4	See `STOP order', above.
117-B8	See `STOP order', above.
10-G11	See 10-G11 above.
The following items are actuated:	Function:
33-D5	Provided the turning gear is disengaged: Activates valves: 14-E9: Blocks reversing of the starting air distributor to prevent damage. 15-E10: See 14-E9, above. 26-B8: Admits air supply to the starting air distributor. 27-D9: Opens the main starting valve and the (optional) slow-turning valve which leads air to: ● Starting air distributor ● Starting air valves
The engine will now rotate on starting air. When the RPM-detector, H7, detects the AHEAD motion, valve 40-B2 is deactivated, enabling regulating valve 53-C2 to control the fuel pump VIT-index via valve 52-A2 during running AHEAD	



START order (Cont.)	
When START-LEVEL RPM is reached:	8 - 12% of MCR speed, see Plate 70305
Deactivate START valve 101-E2.	
The following items are deactivated:	Function:
25-C4	Vents the puncture valves (A3), causing high-pressure fuel oil to be injected into the cylinders.
117-B8	Cuts-off the pilot air supply to the starting air distributor. <i>The memory function causes those starting valves which are already activated to stay open during the remaining opening period.</i>
33-D5	With one second's delay, deactivates valves: 26-B8: Closes the air supply to the starting air distributor. 27-D9: Closes the main starting valve and the (optional) slow-turning valve. <i>This one second's delay causes the main starting valve to remain open, so as to supply air to those cylinders that are in START position.</i>
105-E3 (Delayed six seconds)	Deactivates valve 10-G11, which vents reversing cylinders 13-C11 and 57-E9. <i>This six seconds' delay is to ensure that the fuel roller guides change their position.</i>
Set the engine speed directly with the regulating handwheel. See Item 3, 'Loading'. See also the Note regarding overspeed shut-down at the beginning of Item 8.4.	

Reversing and START in a new direction	
Note: Regarding reversing and start in a new direction when the ship's speed is high, see Item 11, 'Crash-Stop'. ● Activate STOP valve 102-D2. ● Change-over reversing valve 105-E3. <i>This reverses the fuel pump roller guides and the starting air distributor.</i> ● Check visually that the starting air distributor is in the correct position. ● Start the engine, as described in 'START' order, above. ● During starting and running in ASTERN direction, valve 40-B2 is activated, hereby leading the pre-set air signal for maximum VIT-index from valve 59-C1 to the VIT-actuators (52-A2). The consequent early fuel injection facilitates starting and running in ASTERN direction.	



8.5 Interlocks

The following interlocks are built into the manoeuvring system:

1. START-blocking with turning gear

When the turning gear is engaged, valve (115-G7) is activated, whereupon the air supply to valve (33-D5), which forms part of the starting system, is blocked, [Plate 70306](#). This means that when the turning gear is engaged, the engine is unable to start.

Active in all modes of control.

2. Position of starting air distributor

When the starting air distributor is changed to AHEAD position, valve (55-E8) is activated, allowing air to be supplied to valve (37-E5), which forms part of the starting system.

The procedure is the same in the case of an ASTERN order. Valve (56-E8) is activated before air is supplied to valve (37-E5).

This interlock ensures that the engine is unable to start until the starting air distributor (E8) is in a well-defined position, i.e. in AHEAD or ASTERN position.

The interlock is only active during control room control and bridge control.

3. Blocking of starting air distributor during START

When START signal is given, both valve (14-E9) and valve (15-E10) are activated.

Thereby, the reversing of the starting air distributor is blocked while starting air is supplied to the engine. (Reversing of the starting air distributor during START might cause damage to the distributor.)

Active at all modes of control.

4. Disablement of start when pitch is applied (CPP-Plants only) ([Plate 70310](#))

If pitch is applied, an interlock in the electrical part of the manoeuvring system (not shown in the manoeuvring diagram), will be activated and the starting possibility will be blocked until the propeller is in zero position.

If the CPP-system fails mechanically or electrically, it is possible to by-pass the interlock by means of switch 140-H3 on the manoeuvring console. When the fault has been corrected, reset the switch to the normal service position. Only active during control room control.

8.6 Safety System

[Plates 70306, 70310, 70313, 70318](#)

The safety system is a completely separate system for the protection of the engine.

The pneumatic part of the safety system is separate from the control system and supplied with air via valve (16-A10) and is controlled by the safety system (with separate power supply, not shown in diagram). In case of shut-down, the safety system activates valve (127-C6). Then an air signal is led to the puncture valves (A3) on each fuel pump whereupon the engine stops. The system is connected in all modes of engine control. The safety air system is indicated in purple.

Regarding fuel oil leakage shut-down, see *Vol III, Chapter 909*.

8.7 Sequence Diagram

[Plates 70305, 70309](#)

The diagrams show the most important signals in the manoeuvring system during start, stop, reversing, etc.

The diagrams may also be useful for troubleshooting purposes.



8.8 Function of the Individual Valves

Components applied for:

- : All plant types
- F1 : FPP, 50-70 MC
- F2 : FPP, 80-90 MC/MC-C
- CR : CPP-plants, reversible engine
- CNR : CPP-plants, non-reversible engine

1: Ball valve

For manual cutting-off of control air supply.

2: Pressure switch/sensor

For alarm if control air supply pressure is too low. Alarm point 5.5 bar.

3: Ball valve

For manual cutting-off of air to exhaust valve. See also [Chapter 702](#), *Check A8 and Check C4*.

4: Pressure switch/sensor

For alarm if control air pressure is not vented during FINISHED WITH ENGINE. Alarm point 0.5 bar

6: Pressure gauge

Indicates control air supply pressure.

7: Magnet switch F1, F2, CR

Activated when reversing cylinder (13) is in AHEAD position.

8: Magnet switch F1, F2, CR

Activated when reversing cylinder (13) is in ASTERN position.

9: Ball valve F1, F2, CR

For manual blocking of the air supply to air cylinder (13).

10: Two-position, three-way valve

F1, F2, CR

Leads air to reversing cylinders (13) and (57) for reversing to AHEAD position.

11: Two-position, three-way valve

F1, F2, CR

Leads air to reversing cylinders (13) and (57) for reversing to ASTERN position.

13: Air cylinder F1, F2, CR

Reverses the roller for the fuel pump to AHEAD and ASTERN, respectively.

14: Two-position, three-way valve

F1, F2, CR

Prevents reversing of starting air distributor when starting air is supplied. F2: Activates the starting air distributor in AHEAD direction.

15: Two-position, three-way valve

F1, F2, CR

Prevents reversing of starting air distributor when starting air is supplied. F2: Activates the starting air distributor in ASTERN direction.

16: Ball valve

For manual cutting-off of safety air supply.

17: Pressure switch/sensor

For alarm if safety pressure is too low. Alarm point 5.5 bar.

18: Pressure switch/sensor

For alarm if safety air pressure is not vented during FINISHED WITH ENGINE. Alarm point 0.5 bar.

19: Pressure gauge

Indicates safety air supply pressure.

20: Air receiver

Reduces time lags in the manoeuvring system.

21: Ball valve

For draining off water from the manoeuvring system.



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| <p>23: <u>Double non-return valve</u></p> <p>25: <u>Two-position, three-way valve</u>
Controls puncture valves on fuel pumps.</p> <p>26: <u>Two-position, three-way valve</u>
Prevents air inlet to starting air distributor in case of leaking main starting valve. Allows air during START.</p> <p>27: <u>Two-position, five-way valve</u>
Controls the main starting valve and slow turning valve (if installed). (Open or closed).</p> <p>28: <u>Two-position, three-way solenoid valve</u>
Controls slow-turning. Blocks opening of the main starting valve during slow-turning.</p> <p>29: <u>Double non-return valve</u> F1, F2 CR</p> <p>30: <u>Double non-return valve</u> F1, F2, CR</p> <p>31: <u>Double non-return valve</u></p> <p>32: <u>Throttle non-return valve</u>
Delays venting of the pilot signal to valves (26) and (27). The delay is adjustable. The purpose of this delay is to ensure that those cylinders which are supplied with starting air when changing to fuel oil, will fulfil the starting sequence. This ensures a good start of the engine. Delay about 1 second.</p> <p>33: <u>Two-position, three-way valve</u>
Leads pilot signal to valves (26) and (27) when turning gear is disengaged and pilot signal is given from valve (37).
CNR: When START signal is received.</p> <p>34: <u>Two-position, three-way valve</u> F2
Activates the starting air distributor in AHEAD direction.</p> <p>35: <u>Two-position, three-way valve</u> F2</p> | <p>Activates the starting air distributor in ASTERN direction.</p> <p>36: <u>Two-position, three-way valve</u> F2
Controls the air supply to valves (34), (35) when STOP signal is given.</p> <p>37: <u>Two-position, three-way valve</u> F1, CR
Leads pilot signal to valve (33) during START.</p> <p>38: <u>Two-position, three-way valve</u>
Leads pilot signal to valves (25),(36) and (117) when STOP signal is given.</p> <p>40: <u>Two-position, three-way solenoid valve</u> F1, F2, CR
Changes the pilot signal to activator (52) during STOP and ASTERN running.</p> <p>41: <u>Switch</u>
Gives signal to manoeuvring system when the change-over mechanism is in remote control mode.
CNR: Also disconnects el. instrument box at engine side control console.</p> <p>42: <u>Electrical governor activator</u>
Controls the fuel pumps.</p> <p>45: <u>Reducing valve</u> F2
Leads pre-set control pressure to VIT-actuators (52) during AHEAD running and MANUAL control mode.</p> <p>48: <u>Switch</u>
Resets shut-down function (in safety panel) when regulating handle is in STOP position during control from engine side control console.</p> <p>49: <u>Throttle non-return valve</u> F1, CNR, CR
Controls the time delay of the pilot signal to activator (52) during AHEAD running.</p> |
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| <p>50: <u>Double non-return valve</u> F1, CR</p> <p>51: <u>Pressure gauge</u>
Indicates the control pressure to activator (52).</p> <p>52: <u>VIT activator</u>
Adjusts the injection lead (timing) in accordance with the mean indicated pressure.</p> <p>53: <u>Regulating valve</u>
Supplies control pressure to activator (52) in accordance with the mep during AHEAD running.
F2: I/P converter. Controls the pilot pressure to VIT-activator (52) during remote control mode.</p> <p>54: <u>Two-position, three-way valve</u> F2
Changes the signal to VIT-actuators from remote control mode to manual control mode, respectively.</p> <p>55: <u>Two-position, three-way valve</u> F1, CR
Blocks the START AHEAD signal until starting air distributor is in AHEAD position.</p> <p>56: <u>Two-position, three-way valve</u> F1, CR
Blocks the START ASTERN signal until the starting air distributor is in ASTERN position.</p> <p>57: <u>Air cylinder</u> F1, CR
Reverses the starting air distributor from AHEAD to ASTERN and vice versa.</p> <p>59: <u>Reducing valve</u> F1, F2, CR
Controls the pre-set control pressure to activator (52) during STOP and ASTERN running.</p> <p>60: <u>Switch</u>
Gives shut-down signal to governor when regulating handle is in STOP position.</p> | <p>61: <u>Switch</u>
Resets shut-down function (in safety panel) when regulating handle is in STOP position.</p> <p>62: <u>Potentiometer</u>
Regulates the speed-setting signal to governor during control-room control.</p> <p>63: <u>Switch</u>
The switch is actuated when the control handle is in STOP position, in START position, and in the range in between, and provides STOP signal to valve (166)/(84).</p> <p>64: <u>Switch</u>
The switch is actuated when the control handle is in START position, and provides START signal to valve (172)/(90).</p> <p>70: <u>Telegraph</u> F2</p> <p>78: <u>Switch</u>
Activates the slow turning valve (28) during control-room control.</p> <p>79: <u>Switch</u>
Cancels limitation in governor during control-room control.</p> <p>80: <u>Switch/valve</u>
Change-over between bridge control and control-room control.</p> <p>83: <u>Pressure switch</u> F1, F2, CR
Gives signal to manoeuvring system when engine is on remote control.
Set point: 2 bar.</p> <p>84: <u>Two-position, three-way solenoid valve</u> F1, F2, CR
Gives pilot signal to valve (38) when STOP is ordered from bridge (or control room).</p> |
|---|---|



- 86: Two-position, three-way solenoid valve F1, F2, CR
Gives pilot signal to valve (10) and supply air to valve (55) when AHEAD is ordered from bridge.
F2: Signal to (10), (14), (34) when AHEAD is ordered from bridge or control room.
- 88: Two-position, three-way solenoid valve F1, F2, CR
Gives pilot signal to valve (11) and supply air to valve (56) when ASTERN is ordered from bridge.
F2: Signal to (11), (15), (35) when ASTERN is ordered from bridge or control room.
- 90: Two-position, three-way solenoid valve F1, F2, CR
Leads pilot signal to valves (33), (37) when START is ordered from bridge (or control room).
- 100: Two-position, five-way valve
Shifts control air from system for MANUAL control from the engine side to the remote control systems, and vice versa.
- 101: Two-position, three-way valve, hand operated
Leads START signal to valves (25), (33), (102) and (117) and supply air to valve (105) during MANUAL control from engine side. Gives combined START and STOP signal when activated during MANUAL control from engine side.
- 102: Two-position, three-way valve, hand operated
Leads STOP signal to valves (25), (36), (117) and supply air to valve (105) during MANUAL control from engine side.
- 103: Double non-return valve
- 104: Throttle non-return valve
F1, F2, CR
Keeps the AHEAD and ASTERN signals activated for 6 seconds after START during MANUAL control from engine side control console.
- 105: Two-position, five-way valve, hand-operated
F1, F2, CR
Leads reversing signal to valves (10) and (11), corresponding to order (AHEAD or ASTERN), during MANUAL control from engine side.
- 106: Pressure switch
Disconnects reset function and cancelling functions in remote control systems from safety system during MANUAL control from engine side. Set point: 2 bar.
- 107: Pressure switch
Gives signal to manoeuvring system when engine is on MANUAL control from engine side control console. Set point: 2 bar.
- 114: Switch
Gives signal to lamp in manoeuvring console when shut-off valve (118) is in SERVICE position.
- 115: Two-position, three-way valve
Blocks the START possibility when the turning gear is engaged.
- 116: Switch
Gives indication on bridge if turning gear is engaged.
- 117: Two-position, three-way valve
Activates the starting air distributor when STOP signal is received.
F2: Controls air supply to valves (14), (15) when STOP signal is given.
- 118: Shut-off valve
For manual cutting-off of control air to the starting air distributor



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| <p>119: <u>Switch</u>
Gives indication on bridge when starting air distributor is blocked.</p> <p>120: <u>Switch</u>
Gives SERVICE / BLOCKED signal to lamps in manoeuvring console.</p> <p>121: <u>Switch</u>
Gives signal to lamps on manoeuvring console and to telegraph system/communication system when main starting valve is blocked.</p> <p>122: <u>Sensor for starting air pressure</u>
Blocks START possibility from bridge if starting air pressure is too low. Set point: 15 bar.</p> <p>125: <u>Air receiver 20 l</u>
Reduces time lags in the safety system.</p> <p>126: <u>Ball valve</u>
For draining off water from the safety system.</p> <p>127: <u>Two-position, three-way solenoid valve</u>
Activates puncture valve on fuel pumps when shut-down signal is given (from safety system).</p> <p>128: <u>Double non-return valve</u></p> <p>129: <u>Pressure switch</u>
For alarm when lifting gear device for fuel pumps are activated.</p> <p>130: <u>Two-position, five-way valve</u>
Actuates the lifting gear device in case of leakage from high-pressure pipes.</p> <p>131: <u>Diaphragm</u>
Controls valve (130)</p> | <p>132: <u>Non-return valve</u>
Drains diaphragm (131) if pressure exceeds 1 bar.</p> <p>133: <u>Ball valve</u>
For manual blocking of drain pipe.</p> <p>137: <u>Non-return valve</u>
Prevents back-flow of air from exhaust valve.</p> <p>138: <u>Pressure switch/sensor</u>
For alarm if pressure is too low. Set point 5.5 bar.</p> <p>140: <u>Switch</u> CNR, CR
By-pass of zero pitch interlock.</p> <p>141: <u>Pressure switch</u> CNR
Gives information to bridge control system and safety system when engine is on bridge control.</p> <p>146: <u>Switch</u> CR
Gives AHEAD or ASTERN signal to valves 86 or 88, respectively.</p> <p>147: <u>Double non-return valve</u></p> <p>148: <u>Three-position, four-way valve</u>
For manual actuation and resetting of the lifting gear device.</p> <p>149: <u>Air cylinder (lifting gear device)</u>
Lifts the fuel pump roller guide clear of the cam.</p> <p>150: <u>Reduction unit</u>
Reduces the starting air pressure to 7 bar.</p> <p>151: <u>Pressure switch</u>
Cancels tacho failure alarm from safety system when STOP signal is given. Set point: 4 bar.</p> |
|---|--|



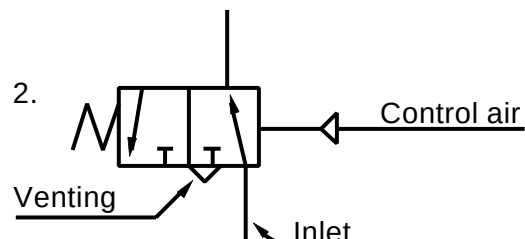
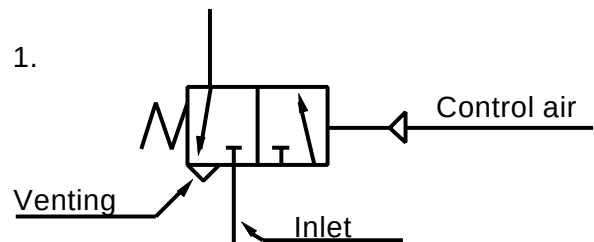
- 166: Two-position, three-way solenoid valve _____ CNR
Gives pilot signal to valve (38) when STOP is ordered during manual control.
- 172: Two-position, three-way solenoid valve _____ CNR
Leads pilot signal to valve (33) when START is ordered during manual control.
- 176: Switch F1, F2
The switch is activated when the control handle is in AHEAD position and provides AHEAD signal to valve (168)/(86).
- 177: Switch F1, F2
The switch is activated when the control handle is in ASTERN position and provides ASTERN signal to valve (170)/(88).
- 180: Safety valve F2
Opens at 12 bar.
- 181: Throttle non-return valve (non-adjustable) _____ F2
Delays venting of the air cylinder (13) when reversing ASTERN.
- 182: Safety valve F2
Opens at 12 bar.
- 183: Throttle non-return valve (non-adjustable) _____ F2
Delays venting of the air cylinder (13) when reversing AHEAD.
- 184: Double non-return valve F1

8.9 Symbol Description

The Symbols consist of one or more square fields. The number of fields corresponds to the number of valve positions. The connecting lines are connected to the field which represents the valve position at a given moment of the process.

The change of position is conceived to take place by the fields being displaced at right angles to the connecting lines, which are assumed to have a stationary position on the paper. A short crossline on a broken line indicates a closed path.

Example of pressure controlled 2-position valve with spring return:



1. = Initial Position
2. = Changed Position



9. Engine Control System, CPP-Plant, 50-70 MC Engines

9.1 General (Reversible Engines)

For plants of the reversible type, equipped with controllable pitch propeller, the following modes of control are available:

- Remote Control from Control Room.
- Bridge Control: Restart of Engine
- Manual Control from Engine Side Control Console.

Note: This description only includes the pneumatic manoeuvring system. The control of the propeller pitch, including loading, is indicated in the sequence diagram. [Plate 70309](#). See also Item 3, 'Loading'.

Regarding description of the pitch control

equipment, see the supplier's special instructions.

On [Plates 70310, 70311](#) the pneumatic STOP signal is indicated in red, the START signal is indicated in dotted red, control air is indicated in green and safety air is indicated in purple.

Note: The safety air system, which is indicated in purple, is only pressurised after valve 127-C6 during engine shut-down, see [Chapter 701](#) 'Alarm Limits'.

The manoeuvring system is shown with the following status:

- STOP
- Control room control
- Power on (pneumatic + electric)
- Main starting valve on SERVICE
- Latest direction of rotation ordered: AHEAD.

9.2 Remote Control from Control Room [Plate 70312](#)

The change-over valve 100-E2 must be in its 'Remote Control' position.

STOP, START and speed-setting orders are given manually by moving the regulating

handle, corresponding to the order from the bridge.

The reversing valve 146-H3 is maintained in AHEAD position by a detachable blocking device in order to prevent unintentional reversing.

STOP order	<i>The STOP signal is indicated in red on Plate 70310.</i>
Move the regulating handle to STOP position.	
The following items are actuated:	Function:
63-K1 (STOP switch)	Activates valve 84-K4 and subsequently valve 38-D4, which activates: 25-C4: Leads control air to the puncture valve on each fuel pump. <i>This prevents the injection of high-pressure fuel oil into the cylinders.</i> 117-B8: Activates the starting air distributor so that it is ready when the starting signal is given.
40-B2 (Via valve 151-A4)	Adjusts the fuel pumps to maximum VIT-index by means of reducing valve 59-C2. The consequent early fuel oil injection facilitates starting and running in ASTERN direction.
The STOP signal is kept as long as the regulating handle is in STOP position, in START position and in the range in between.	



START order	<i>The START signal is indicated in dotted red on Plate 70310.</i>
Note: Regarding slow-turning, see ' <i>Slow-Turning (Optional)</i> ' in Item 8.2. Move the regulating handle into START position. The following describes the sequence for START AHEAD.	
The following items remain actuated:	Function:
63-K1	Maintains the STOP signal, see ' <i>STOP</i> ' order above.
The following items are actuated:	Function:
64-K1 (START valve)	● Activates valve 86-K4 via switch 146-K3, which: - Activates valve 10-G11, which supplies air to reversing cylinders 13-C11 and 57-E9. <i>This causes reversing of the starting air distributor and the roller guides for the fuel pumps, provided that they are not already in the required position.</i> Note: The roller guides are only able to reverse when the engine rotates. - Leads air to interlock valve 55-E8. <i>When the starting air distributor has reached the required position, air is supplied to valve 37-E5. This prevents the engine from starting if the starting air distributor is in an incorrect position.</i> ● Activates valve 90-K5 and provided the propeller is in zero pitch (interlock built into the electrical part of the manoeuvring system): - Leads pilot air to valve 37-E5. Provided interlock 55-E8 is released: - Leads pilot air to valve 33-D5. Provided the turning gear is disengaged (115-H6): - Activates valves: 14-E9: Blocks reversing of the starting air distributor to prevent damage. 15-E10: See 14-E9, above. 26-B8: Admits air supply to the starting air distributor. 27-D9: Opens the main starting valve and the (optional) slow-turning valve, which leads air to: ● Starting air distributor ● Starting valves Note: If slow-turning is installed, valve 28-C9 is inserted to prevent opening of the main starting valve until the crankshaft has rotated at least one revolution.
The engine will now rotate on starting air. When the RPM-detector, H7, detects the AHEAD motion, valve 40-B2 is deactivated, enabling the regulating valve 53-C2 to control the fuel pump VIT-index via valve 52-A2 during running AHEAD.	



START order (Cont.)	
When START-LEVEL RPM is reached:	8 - 12% of MCR speed, see Plate 70310
Move the regulating handle to the ordered position. However, see Item 3, 'Loading'	
The following items are deactuated:	Function:
63-K1 (STOP switch)	Deactivates valve 84-K4 and subsequently valve 38-D4, which deactuates: 25-C4: Vents puncture valves (A3), causing high-pressure fuel oil to be injected into the cylinders. 117-B8: Cuts-off the pilot air supply to the starting air distributor. <i>The memory function causes those starting valves which are already activated to stay open during the remaining opening period.</i>
64-K1 (START switch)	Deactivates valve 90-K5 and subsequently valve 37-E5, causing deactivation of valve 33-D5, and with one second's delay (32-D5), deactivates: 14-E9: Vents the blocking of the starting air distributor. 15-E10: See 14-E9, above. 26-B8: Closes the air supply to the starting air distributor. 27-D9: Closes the main starting valve and the (optional) slow-turning valve. <i>This one second's delay causes the main starting valve to remain open, so as to supply air to those cylinders that are in START position.</i>
86-K4 (AHEAD switch)	With six seconds' delay, valve 86-K4 deactivates valve 10-G11 which vents reversing cylinders 13-C11 and 57-E9. <i>This six seconds' delay is to ensure that the fuel roller guides change their position.</i>
Set the speed with the regulating handle.	
In case of START-FAILURE , i.e. if the engine stops after the starting sequence is finished:	
● Cancel the limiters in the governor by activating switch 79-H2. <i>This allows the governor to give more fuel during the starting sequence.</i> ● Make a new start attempt as described under 'START order', above.	
Note: The engine can only be started when the propeller is on zero pitch, due to an interlock built into the electrical part of the manoeuvring system. In case of breakdown, it is possible to by-pass this interlock by actuating switch 140-H2. See also Item 8.5 'Interlocks', point 4.	



Reversing and START in ASTERN direction

Note: Regarding reversing and start in ASTERN direction when the ship's speed is high, see *Item 11, 'Crash Stop'*.

- Stop the engine, as described under 'STOP order', above.
- Disable the blocking device of reversing valve 146-H3, and move the reversing handle to the opposite position.
- Start the engine, as described under 'START order', above.
- During starting and running in ASTERN direction, valve 40-B2 is activated, hereby leading the pre-set air signal for maximum VIT-index from valve 59-C2 to the VIT-actuators (52-A2). The consequent early fuel injection facilitates starting and running in ASTERN direction.

9.3 Bridge Control: Restart of Engine

Plate 70311

During remote control from bridge, adjustment of speed-setting (and pitch) is effected via an operating interface, normally a combinator handle or, for plants with constant speed, a telegraph handle. The operating interface is not shown in the diagrams.

- Start the engine from the control room, as described in Item 9.2.
- Transfer control to the bridge (80-H2).

If the engine stops during control from the bridge, it can be restarted from the bridge, but restart from bridge is not to be considered as a normal manoeuvre.

The restart switch on the bridge activates STOP valve 84-K4, START valve 90-K5 as well as the valve (86-K4 or 88-K5) which corresponds to the position of valve 146-H3.

Restart of engine from bridge:

- Set the propeller on zero.
- Set the speed setting pressure to the value corresponding to idling speed.
- Actuate the restart switch.

- When the START-LEVEL rpm is reached (8-12% of MCR speed, see *Plate 70309*), release the restart switch.

The engine will now run on fuel.

9.4 Manual Control from Engine Side Control Console

As described for plants with fixed-pitch propeller, Item 8.4.

9.5 Interlocks

As described for plants with fixed-pitch propeller, Item 8.5.

9.6 Safety System, Sequence Diagram, etc.

As described for fixed pitch propeller, Items 8.6, 8.7, 8.8 and 8.9.

9.7 General (Non-Reversible Engines)

For plants of the non-reversible type equipped with controllable pitch propeller, the following modes of control are available:

- Remote Control from Control Room.
- Bridge Control: Restart of Engine
- Control from Engine Side Control Console



Note: This description only includes the pneumatic manoeuvring system. The control of the propeller pitch is indicated in the sequence diagram. [Plate 70309](#).

Regarding description of the pitch control equipment, see *the supplier's special instructions*.

On [Plates 70312-13](#) the pneumatic STOP signal is indicated in red, the START signal is indicated in dotted red and control air is indicated in green.

Note: The safety air system, which is indicated in purple, is only pressurised after valve 127-C6 during engine shut-down. See [Chapter 701](#), 'Alarm Limits'.

The manoeuvring system is shown with the following status:

- STOP
- Control room control
- Power on (pneumatic + electric)
- Main starting valve on SERVICE.

9.8 Remote Control from Control Room

[Plate 70312](#)

The change-over valve 100-E2 must be in its 'Remote Control' position.

STOP, START and speed-setting orders are given manually by moving the regulating handle, corresponding to the order from the bridge.

STOP order	<i>The STOP signal is indicated in red on Plate 70312</i>
Move the regulating handle to STOP position	
The following items are actuated:	Function:
63-K1 (STOP switch)	Activates valve 166-K4 and subsequently valve 38-D4, which activates: 25-C4: Leads control air to the puncture valve on each fuel pump. <i>This prevents the injection of high-pressure fuel oil into the cylinders.</i> 117-C8: Activates the starting air distributor so that it is ready when the starting signal is given.
<i>The STOP signal is kept as long as the regulating handle is in STOP position, in START position and in the range in between.</i>	



START order	<i>The START signal is indicated in dotted red on Plate 70312.</i>
Note: Regarding slow-turning, see ' <i>Slow-Turning (Optional)</i> ' in Item 8.2. Move the regulating handle into START position.	
The following items remain actuated:	Function:
63-K1	Maintains the STOP signal, see ' <i>STOP order</i> ', above.
The following items are actuated:	Function:
64-K1 (START switch)	Provided the propeller is in zero pitch (interlock built into the electrical part of the manoeuvring system): - Activates valve 172-K5, which leads pilot air to valve 33-D5. Provided the turning gear is disengaged (115-H7): - Activates valves: 26-B8: Admits air supply to the starting air distributor. 27-D9: Opens the main starting valve and the (optional) slow-turning valve, which leads air to: ● Starting air distributor ● Starting valves Note: If slow-turning is installed, valve 28-C9 is inserted to prevent opening of the main starting valve until the crankshaft has rotated at least one revolution.
The engine will now rotate on starting air.	



START order (Cont.)	
When START-LEVEL RPM is reached:	8 - 12% of MCR speed, see Plate 70309
Move the regulating handle to the ordered position (See also Item 3, 'loading')	
The following items are deactuated:	Function:
63-K1 (STOP switch)	Deactivates valve 166-K4 and subsequently valve 38-D4, which deactuates: 25-C4: Vents puncture valves (A3), causing high-pressure fuel oil to be injected into the cylinders. 117-C8: Cuts-off the pilot air supply to the starting air distributor. <i>The memory function causes those starting valves which are already activated to stay open during the remaining opening period.</i>
64-K1 (START switch)	Deactivates valve 172-K5 and subsequently valve 33-D5, which, with one second's delay (32-D5) deactivates valves: 26-B8: Closes the air supply to the starting air distributor. 27-D9: Closes the main starting valve and the (optional) slow-turning valve. <i>This one second's delay causes the main starting valve to remain open, so as to supply air to those cylinders that are in START position.</i>
Set the speed with the regulating handle. (See also Item 3, 'Loading')	
In case of START-FAILURE, i.e. if the engine stops after the starting sequence is finished: ● Cancel the limiters in the governor by activating switch 79-H3. <i>This allows the governor to give more fuel during the starting sequence.</i> ● Make a new start attempt as described under 'START order', above. Note: The engine can only be started when the propeller is on zero pitch, due to an interlock built into the electrical part of the manoeuvring system. In case of breakdown, it is possible to by-pass this interlock by actuating switch 140-H3. See also Item 8.5, 'Interlocks', point 4.	



9.9 Bridge Control: Restart of Engine

[Plate 70313](#)

During remote control from bridge, adjustment of speed-setting (and pitch) is effected via an operating interface, normally a combinator handle or, for plants with constant speed, a telegraph handle. The operating interface is not shown in the diagrams.

- Start the engine from the control room, as described in Item 9.8.
- Transfer control to the bridge (80-H2).

If the engine stops during control from the bridge, it can be restarted from the bridge, but restart from bridge is not to be considered as a normal manoeuvre.

The restart switch on the bridge activates both STOP valve 166-K4 and START valve 172-K5.

Restart of engine from bridge:

- Set the propeller on zero.
- Set the speed setting pressure to the value corresponding to idling speed.

- Actuate the restart switch.

This causes actuation of those valves, which are mentioned under 'Control Room Control', 'START-order' section 'Move the regulating handle into START position'.

- When the START-LEVEL rpm is reached (8-12% of MCR speed, see [Plate 70309](#)), release the restart switch.

This cause deactuation of those valves, which are mentioned under 'Control Room Control', 'START-order' section 'When START-level RPM is reached'.

The engine will now run on fuel.

9.10 Manual Control from Engine Side Control Console

[Plate 70316](#)

In the event of breakdown of the normal pneumatic manoeuvring system, the governor or its electronics, or if - for other reasons - direct index control is required, the engine can be operated from engine side control console on the engine.

Change-over with **stopped engine**: as detailed on [Plate 70302](#).

Change-over with **running engine**: as described in Item 8.4, except that there is no reversing valve 105-E3.

STOP order	<i>The STOP signal is indicated in red on Plate 70313.</i>
Activate STOP valve 102-D3.	
The following items are actuated:	Function:
102-D3	Activates valves: 25-C4: Leads control air to the puncture valve on each fuel pump. <i>This prevents the injection of high-pressure fuel oil into the cylinders.</i> 117-C8: Activates the starting air distributor so that it is ready when the starting signal is given



START order	<i>The START signal is indicated in dotted red on Plate 70313.</i>
Move the regulating handle to START position. Activate START valve 101-E2.	
The following items are actuated:	Function:
101-E2	Deactivates valve 102-D3. Keeps the STOP signal via non-return valve 103-D3, see <i>102-D3, above</i> . Activates valve 33-D5. Provided the turning gear is disengaged (115-H8), activates valves: 26-B8: Admits air supply to the starting air distributor. 27-D9: Opens the main starting valve and the (optional) slow-turning valve which leads air to: ● Starting air distributor ● Starting valves
The engine will now rotate on starting air.	
When START-LEVEL RPM is reached:	<i>8 - 12% of MCR speed, see Plate 70309</i>
Deactivate START valve 101-E2.	
The following items are deactuated:	Function:
101-E2	Deactivates valves: 25-C4: Vents the puncture valves (A2) causing high-pressure fuel oil to be injected into the cylinders. 117-C8: Cuts off the pilot air to the starting air distributor. The memory function causes those starting valves which are already activated to stay open during the remaining opening period. 33-D5: With one second's delay, deactivates valves: 26-B8: Closes the air supply to the starting air distributor. 27-D9: Closes the main starting valve and the (optional) slow-turning valve. <i>This one second's delay causes the main starting valve to remain open, so as to supply air to those cylinders that are in START position.</i>
Set the engine speed directly with the regulating handle. See also the Note regarding overspeed shut-down in Chapter 1 .     	

9.11 Interlocks

As described for plants with fixed-pitch propeller, Item 8.5, pos. 1 and 4.

9.12 Safety System,
Sequence Diagram, etc.

As described for plants with fixed-pitch propeller, Items 8.6, 8.7, 8.8 and 8.9.



10. Engine Control System, FPP Plant, 80-90 MC/MC-C

10.1 General

For plants equipped with fixed pitch propeller, the following modes of control are available:

- Remote control from control room
- Remote control from bridge (option)
- Manual control from engine side control console.

On Plate 70314, the pneumatic STOP signal is indicated in red and control air is indicated in green.

Note: The safety air system, which is indicated in purple, is only pressurised after valve 127-A7 during engine shut-down. See [Chapter 701](#), 'Alarm Limits'.

The manoeuvring system is shown with the following status:

- STOP
- Latest direction of rotation ordered:
AHEAD
- Remote control from control room
- Power on (pneumatic + electric)
- Main starting valve on SERVICE.

In this condition the engine is ready to start.

10.2 Remote Control from Control Room

[Plates 70314, 70315](#)

The change-over valve (100-G1) must be in its 'Remote Control' position.

STOP, START, reversing (AHEAD or ASTERN) and speed-setting orders are given manually by moving the regulating handle, corresponding to the order from the bridge.

STOP order	<i>The STOP signal is indicated in red on Plate 70314</i>
Move the regulating handle to STOP position	
The following items are actuated:	Function:
63-K1 (STOP switch)	Activates valve 84-K4 and subsequently valve 38-C3, which activates: 25-B3: Leads control air to the puncture valve on each fuel pump. <i>This prevents the injection of high-pressure fuel oil into the cylinders.</i> 117-D8 and 36-D6 (9-12 cyl. engines): Provided the turning gear is disengaged (115-G9), supply air to valves 14-C8 + 34-C6 and 15-C8 + 35-C5, which control 'START AHEAD' and 'START ASTERN', respectively.
40-B1 (Via 151-A3)	Adjusts the fuel pumps to maximum VIT-index by means of reducing valve 59-B1. The consequent early fuel oil injection facilitates starting and running in ASTERN direction.
<i>The STOP signal is kept as long as the regulating handle is in STOP position. in START position and in the range in between.</i>	



START order	The <i>START</i> signal is indicated in dotted red on Plate 70315 . The <i>AHEAD</i> signal is indicated in blue, and the <i>ASTERN</i> signal is indicated in dotted blue on Plate 70315 .
Note: Regarding slow-turning, see '<i>Slow-Turning (Optional)</i>', page 703.46 Acknowledge the telegraph. Move the regulating handle into START position in the required direction of rotation The following describes the sequence for START AHEAD.	
The following items remain actuated:	Function:
63-K1	Maintains the STOP signal, see <i>STOP-order</i> above.
The following items are actuated:	Function:
176-K1 (AHEAD switch)	Activates valve 86-K4, which activates: 10-G11 Supplies air to reversing cylinder 13-D10. <i>This causes reversing of the roller guides for the fuel pumps, provided that they are not already in the required position. The last part of the reversing motion is dampened by means of valves 181-D11 and 183-D10.</i> Note: The roller guides are only able to reverse when the engine rotates. 14-C8 and 34-C6: Activates the starting air distributor in the AHEAD direction.
64-H1 (START switch)	Activates valve 90-K5 and subsequently valve 33-D4. Provided the turning gear is disengaged (115-G9): - Activates valves: 26-C8: Admits air supply to the starting air distributor. 27-D9: Opens the main starting valve and the (Optional) slow-turning valve which leads air to: ● Starting air distributor ● Starting valves Note: If slow-turning is installed, valve 28-C9 is inserted to prevent opening of the main starting valve until the crankshaft has rotated at least one revolution.
The engine will now rotate on starting air. When the RPM-detector, H8, detects the AHEAD motion, valve 40-B1 is deactivated, enabling regulating unit 53-C1 to control the fuel pump VIT-index via valve 52-A2 during running AHEAD.	



START order (Cont.)	
When START-LEVEL RPM is reached:	8 - 12% of MCR speed, see Plate 70305
Move the regulating handle to the ordered position. (However, see Item 3, 'Loading').	
The following items are deactuated:	Function:
63-K1 (STOP switch)	Deactivates valve 84-K4 and subsequently valve 38-C3, which deactuates: 25-B3: Vents puncture valves (A3), causing high-pressure fuel oil to be injected into the cylinders. 117-D8 and 36-D6: Cuts-off the pilot air supply to the starting air distributor. <i>The memory function causes those starting valves which are already activated to stay open during the remaining opening period.</i>
64-H1 (START switch)	Deactivates valve 90-K5 and subsequently valve 33-D4 and with one second's delay (32-D4) deactivates: 26-C8: Closes the air supply to the starting air distributor. 27-D9: Closes the main starting valve and the (optional) slow-turning valve, <i>This one second's delay causes the main starting valve to remain open, so as to supply air to those cylinders that are in START position.</i>
176-K1 (AHEAD switch)	With six seconds' delay, 86-K4 deactivates valve 10-G11 which vents reversing cylinder 13-D10. <i>This six seconds' delay is to ensure that the fuel roller guides change their position.</i>
Set the speed with the regulating handle. See also Item 3, 'Loading'.	
In case of START-FAILURE , i.e. if the engine stops after the starting sequence is finished:	
● Cancel the limiters in the governor by activating switch 79-H3. <i>This allows the governor to give more fuel during the starting sequence.</i> ● Make a new start attempt as described under 'START order', above.	



Reversing and START in a new direction

Note: Regarding reversing and start in a new direction when the ship's speed is high, see *Item 11, 'Crash Stop'*.

- Stop the engine, as described under 'STOP order', above.
- Start the engine in the opposite direction, as described under 'START order', above.
- During starting and running in ASTERN direction, valve 40-B1 is activated, hereby leading the pre-set air signal for maximum VIT-index from valve 59-B1 to the VIT-actuators (52-A2). The consequent early fuel injection facilitates starting and running in ASTERN direction.

Slow-Turning (Optional)

If the manoeuvring system is equipped with a slow turning feature, we recommend using this in connection with starting the engine, if it has been stopped for more than 30 minutes.

- Activate the slow turning switch 78-H3 on the manoeuvring console manually.

The switch activates solenoid valve 28-C9, which deaerates the pneumatic opening line to the main starting valve.

- Give START order with the regulating handle. *The main starting valve is kept in the closed position, while only the smaller slow turning valve opens.*
- When the crankshaft has rotated at least one revolution, deactivate the slow-turning switch.

The main starting valve opens, and the normal START procedure can continue.

10.3 Remote Control from Bridge (Option) *Plates 70305, 70314-15*

The change from remote control from control room to remote control from bridge is made by moving the change-over switch 80-H2 on the manoeuvring console.

The control position is changed immediately when the switch is operated.

During remote control from bridge, the STOP, START, reversing (AHEAD or ASTERN) and speed-setting signals are given by an operating handle on the bridge, normally the bridge telegraph handle, not shown in the diagram.

The necessary functions such as changing to fuel at START level r/min, slow-turning

(option), delay of reversing signals, and cancelling of limiters in the governor at repeated START are built-in electronically in the remote control system. The conversion into pneumatic signals is effected by means of solenoid valves (84-K4), (86-K4), (88-K4) and (90-K5) for STOP, AHEAD, ASTERN and START, respectively, as described under 'Remote Control from Control Room'.

The procedure outside the manoeuvring console takes place as described under 'Remote Control from Control Room', *Plate 70314-15*.



If the engine r/min falls below starting level to "starting-error" level after "change to fuel", the remote control system automatically detects a starting error and carries out an automatically repeated START, cf. sequence diagram, [Plate 70305](#).

10.4 Manual Control from Engine Side Control Console

[Plates 70301, 70302, 70316](#)

In the event of breakdown of the normal pneumatic manoeuvring system, the governor or its electronics, or if - for other reasons - direct index-control is required, the engine can be operated from the engine side control console on the engine side.

Change-over with stopped engine:

See detailed description on [Plate 70302](#).

Change-over with running engine:

- Reduce the engine load to max. 80% of MCR.
- Check that the position of reversing valve 105-G3 corresponds to the present running direction.
- Move the regulating handwheel to bring the tapered slots of the change-over mechanism in position opposite each other.
- Put the blocking arm in position for engine side control.

- Quickly, move the impact handwheel, P-C1, to the opposite position.
This disconnects the fuel pumps from the governor and connects them to the regulating handwheel on the engine side control console.

- Move the change-over valve 100-G1 to to the position for engine side control.
This vents valves 84-K4, 86-K4, 88-K4 and 90-K5, and leads control air to the valves in the engine side control console.

If STOP valve 102-E2 is **not** deactivated, the engine now receives a STOP order.

- Activate START valve 101-G2 briefly.
This air impulse deactivates STOP valve 102-E2.
- Set the engine speed directly with the regulating handwheel. See also Item 3, 'Loading'.

Note: When the governor is disengaged, the engine is still protected against overspeed by the electric overspeed trip, i.e. the engine is stopped automatically if the revolutions increase to the overspeed setting. The overspeed shut-down can only be reset by moving the regulating handwheel to STOP position. Manoeuvring must therefore be carried out very carefully, especially when navigating in rough weather.

STOP order	The STOP signal is indicated in red on Plates 70316
Activate STOP valve 102-E2	
The following items are actuated:	Function:
25-B3	Leads control air to the puncture valve on each fuel pump. <i>This prevents the injection of high-pressure fuel oil into the cylinder.</i>
117-D8, 36-D6	Provided the turning gear is disengaged (115-G9), supply air to valves 14-C8 + 34-C6 and 15-C8 + 35-C5, which control 'START AHEAD' and 'START ASTERN', respectively. Furthermore, air is supplied to the reversing valve 105-G3.
40-B1 (Via 151-A3)	Adjusts the fuel pumps to maximum VIT-index by means of reducing valve 59-B1. The c facilitates starting and runni



START order	<i>The START signal is indicated in dotted red on Plate 70316. The AHEAD signal is indicated in blue, and the ASTERN signal is indicated in dotted blue on Plate 70316.</i>
Move reversing valve 105-G3 to the ordered position. The following describes the sequence for START AHEAD.	
The following items are actuated:	Function:
10-G11	Supplies air to reversing cylinder 13-D10. <i>This causes reversing of the roller guides for the fuel pumps, provided they are not already in the required position. The last part of the reversing motion is dampened by means of valves 181-D11 and 183-D10.</i> Note: The roller guides are only able to reverse when the engine rotates.
Move the regulating handwheel to a suitable position. Activate START valve 101-G2.	
The following items are deactivated:	Function:
102-E2	Valve 102-E2 is reset to enable subsequent venting of the STOP signal.
The following items remain actuated: (Via 103-G2)	Function:
25-B3	See `STOP order', above.
117-D8, 36-D6	See `STOP order', above.
10-G11	See 10-G11, above.
The following items are actuated:	Function:
33-D4	Provided the turning gear is disengaged: Activates valves: 26-C8: Admits air supply to the starting air distributor. 27-D9: Opens the main starting valve and the (optional) slow-turning valve which leads air to: ● Starting air distributor ● Starting air valves
The engine will now rotate on starting air. When the RPM-detector, H8, detects the AHEAD motion, valve 40-B1 is deactivated, enabling regulating unit 53-C1 to control the fuel pump VIT-index via valve 52-A2 during running AHEAD.	



START order (Cont.)	
When START-LEVEL RPM is reached:	8 - 12% of MCR speed, see Plate 70305
Deactivate START valve 101-G2.	
The following items are deactivated:	Function:
25-B3	Vents the puncture valves (A3), causing high-pressure fuel oil to be injected into the cylinders.
117-D8, 36-D6	Cuts-off the pilot air supply to the starting air distributor. <i>The memory function causes those starting valves which are already activated to stay open during the remaining opening period.</i>
33-D4	With one second's delay, deactivates valves: 26-C8: Closes the air supply to the starting air distributor. 27-D9: Closes the main starting valve and the (optional) slow-turning valve. <i>This one second's delay causes the main starting valve to remain open, so as to supply air to those cylinders that are in START position.</i>
105-G3 (Delayed six seconds)	Deactivates valve 10-G11, which vents reversing cylinder 13-D10. <i>This six seconds' delay is to ensure that the fuel roller guides change their position.</i>
Set the engine speed directly with the regulating handwheel. See Item 3, 'Loading'. See also the Note regarding overspeed shut-down at the beginning of Item 10.4.	

Reversing and START in a new direction	
Note: Regarding reversing and start in a new direction when the ship's speed is high, see Item 11, 'Crash-Stop'. ● Activate STOP valve 102-E2. ● Change-over reversing valve 105-G3. <i>This reverses the fuel pump roller guides and supplies air to the starting air distributor, for 'START AHEAD' or 'START ASTERN'.</i> ● Start the engine, as described in 'START' order, above. ● During starting and running in ASTERN direction, valve 40-B1 is activated, hereby leading the pre-set air signal for maximum VIT-index from valve 59-B1 to the VIT-actuators (52-A2). The consequent early fuel injection facilitates starting and running in ASTERN direction.	



10.5 Interlocks

As described for plants with fixed-pitch propeller, 50-70MC engines, Item 8.5, pos. 1.

10.6 Safety system, Sequence diagram, etc.

As described for plants with fixed pitch propeller, 50-70MC engines, Items 8.6, 8.7, 8.8 and 8.9.

11. Crash-Stop (FPP-Plants and Reversible CPP-Plants)

When the ship's speed must be reduced quickly, the engine can be started in the opposite direction of rotation according to the procedure below:

The procedure is valid for:

- Remote Control from Control Room
See *Items 8.2, 9.2 and 10.2.*
- Manual Control from Engine Side Control Console. See *Items 8.4, 9.2 and 10.4.*

Regarding crash-stop during Bridge Control, see the special instruction book for the Bridge Control System.

1. Acknowledge the telegraph.
2. Give the engine a STOP order.

The engine will continue to rotate (at slowly decreasing speed), because the velocity of the ship through the water will drive the propeller, and thereby turn the engine.

3. Check that the limiters in the governor are not cancelled.
4. When the engine speed has fallen to the REVERSING-LEVEL (15-30% of MCR-speed, depending on engine size and type of ship, see [Plate 70305](#)):

- Give REVERSING order.
- Give START order.

5. When the START-LEVEL is reached in the opposite direction of rotation (8-12% of MCR-speed, see [Plate 70305](#)):

- Give order to run on fuel.

Note: If the ship's speed is too high, the START-LEVEL will not be reached quickly. This will cause a loss of starting air.

In this case:

- Give STOP order.
- Wait until the speed has fallen further.
- Return to point 4.

Does the engine run on fuel in the correct direction of rotation?

YES

Keep the engine speed low during the first few minutes.

This is in order to reduce the hull vibrations that may occur owing to "conflict" between the wake and the propeller.

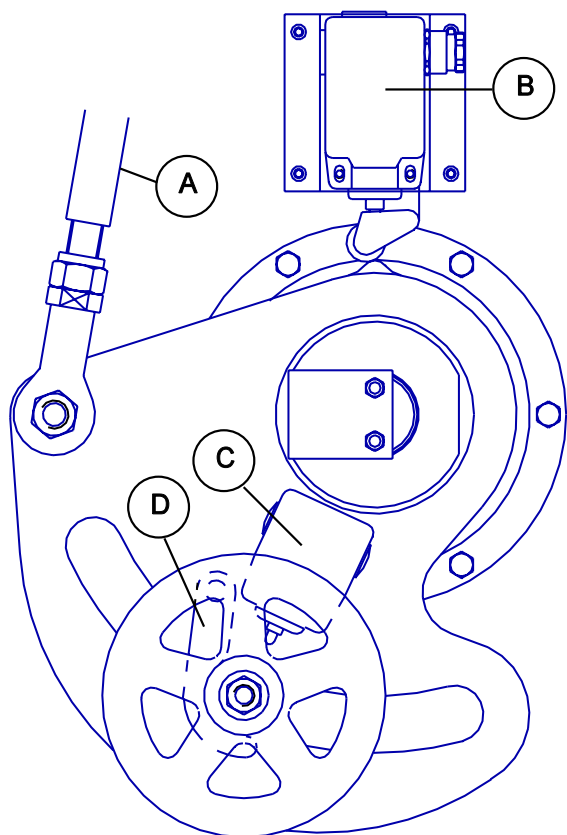
NO

Cancel the limiters in the governor.

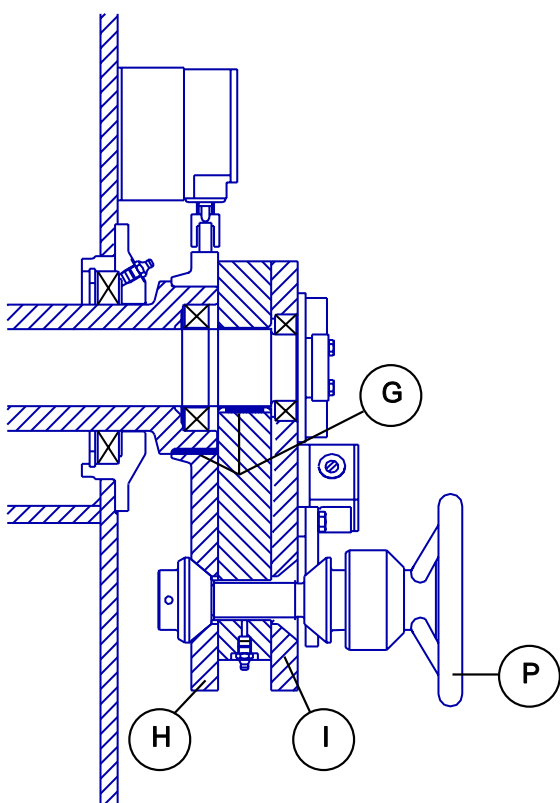
Return to point 4.



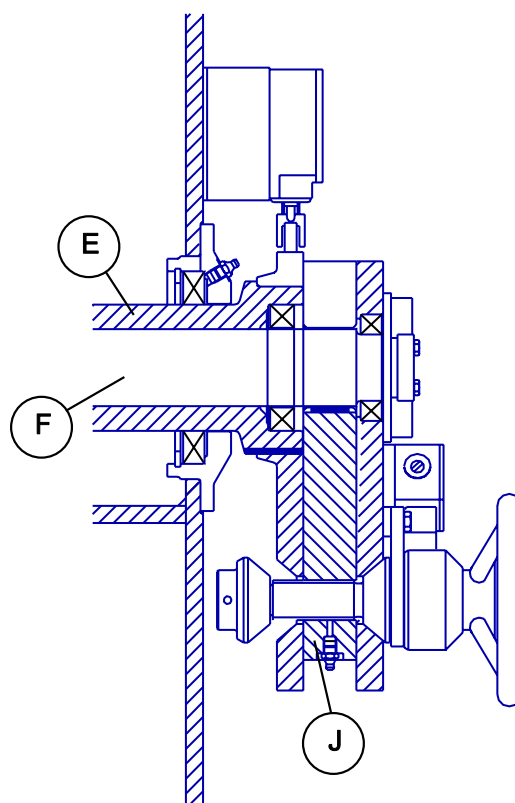
(See also Plate 70303, 'Manoeuvring Gear')



- A) Pull rod connection from governor.
- B) Stop indicator.
- C) Indicator from engine side control.
- D) Blocking arm ``Normal control''-position.
- E) Hollow shaft connected to regulating handwheel on engine side control console.
- F) Shaft connected to regulating arms on fuel pumps.
- G) Keys and keyways.
- H) Plate connected to regulating handwheel.
- I) Plate connected to governor.
- J) Plate connected to regulating shaft.
- P) Impact handwheel. Changing from Normal to Control from Engine Side Control Console, see Plate 70302.

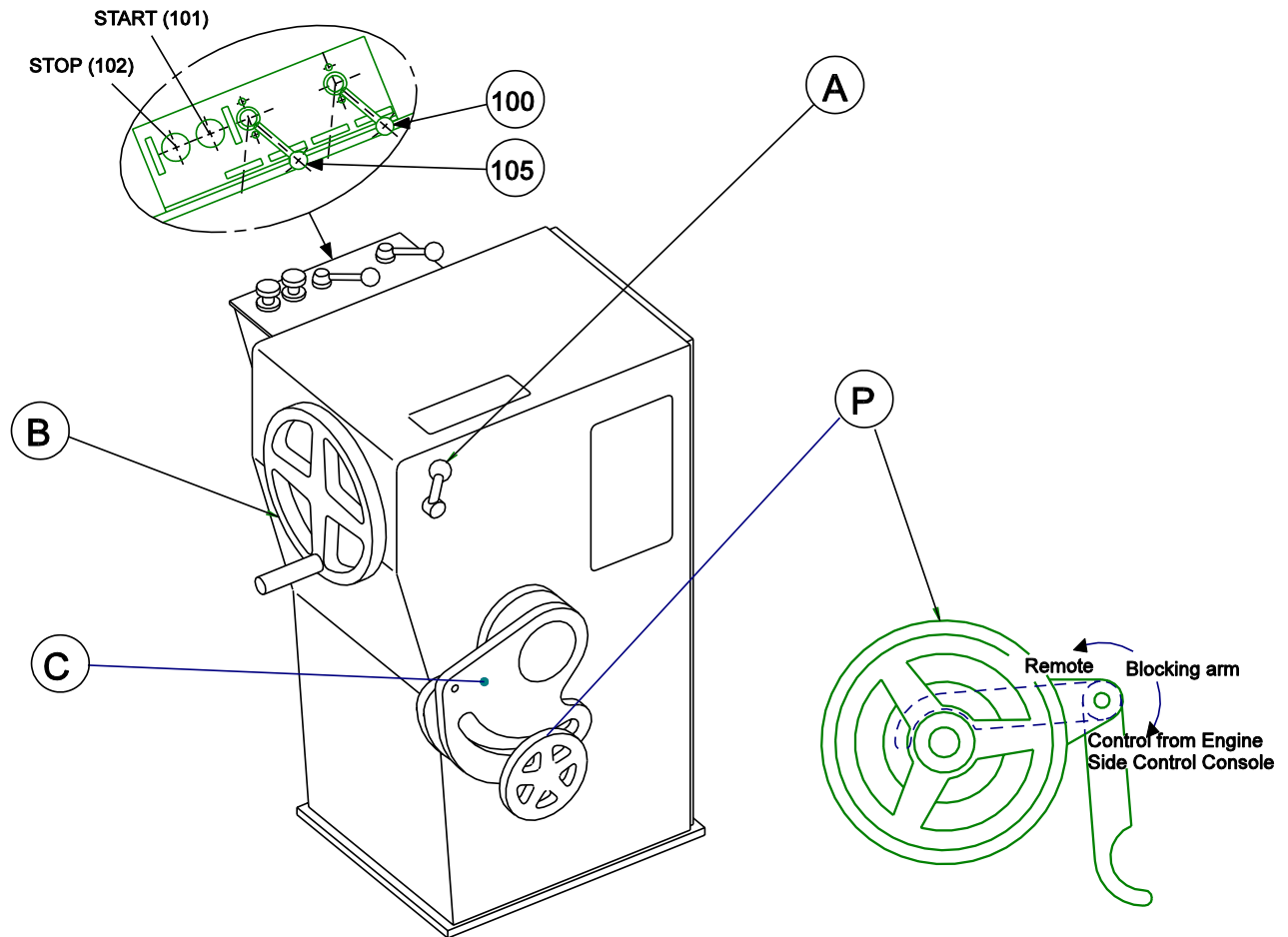


Control from Engine Side Control Console



Normal Control



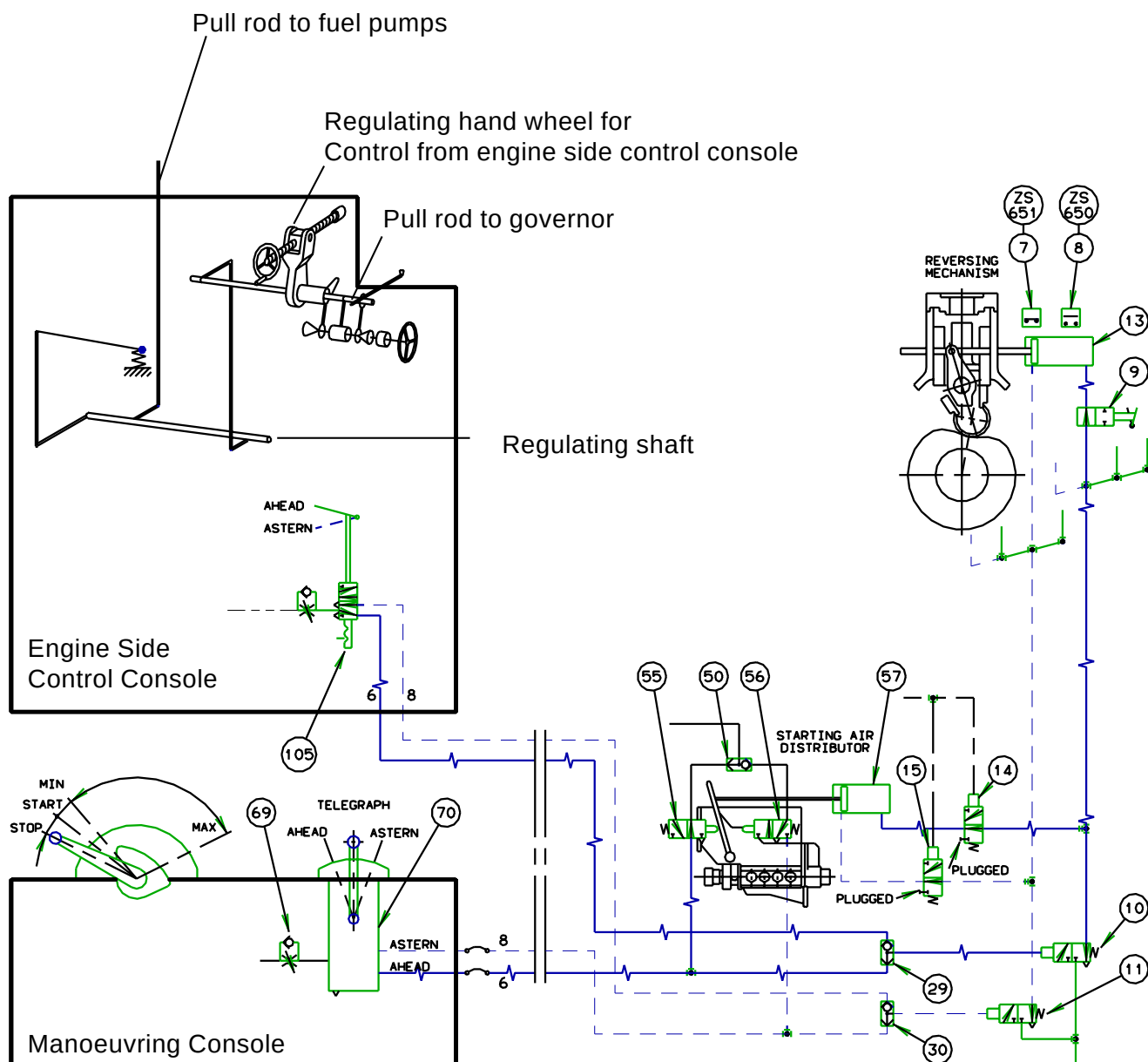


For changing-over to 'Control from Engine Side Control Console' with **running engine**, see Item 8.4 'Control from Engine Side Control Console'.

1. Check that valve (105), which is the "telegraph handle" of the engine side control system, is in the required position. Note that reversing to a new direction is only possible when STOP valve (102) is activated.
2. Turn the handle 'A' anti-clockwise to free the regulating handwheel 'B'.
3. Put the blocking arm in position for control from engine side control console.
4. Turn handwheel 'B' to move the innermost lever of the change-over mechanism 'C' to a position where the impact handwheel 'P' is able to enter the tapered slots in both levers. Quickly, turn the impact handwheel 'P' anti-clockwise. This causes disconnection of the governor and connection of the regulating handwheel 'B' to the fuel pumps.
5. Change position of valve (100) from Normal to Control from Engine Side Control Console. Now air supply is led to the valves of the manoeuvring system for control from engine side control console.
6. Ready for start. Start is described in Item 8.4 'Control from Engine Side Control Console'.

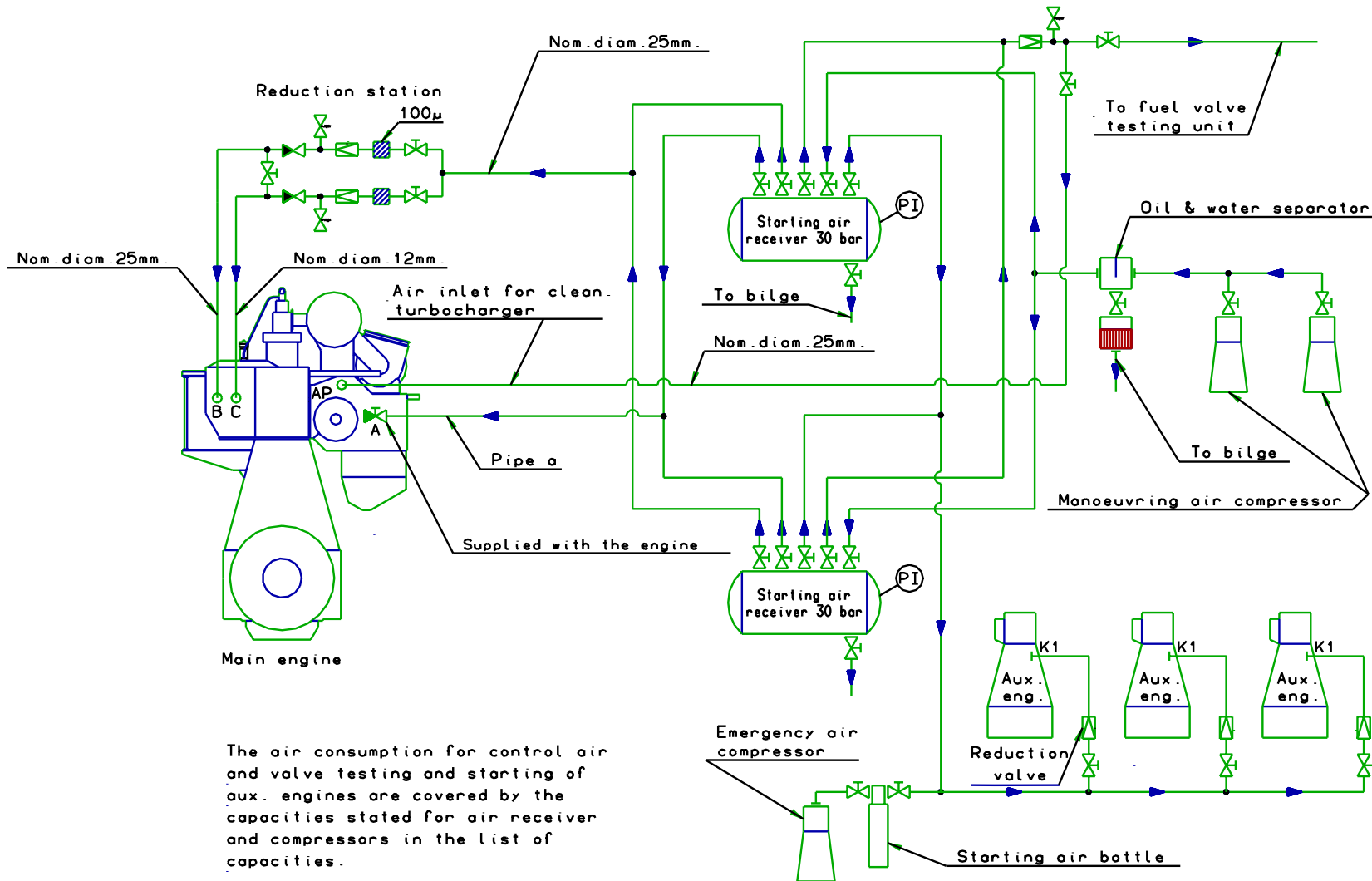
Note: Always keep the threads of the change-over mechanism well lubricated, to ensure a quick changing-over.

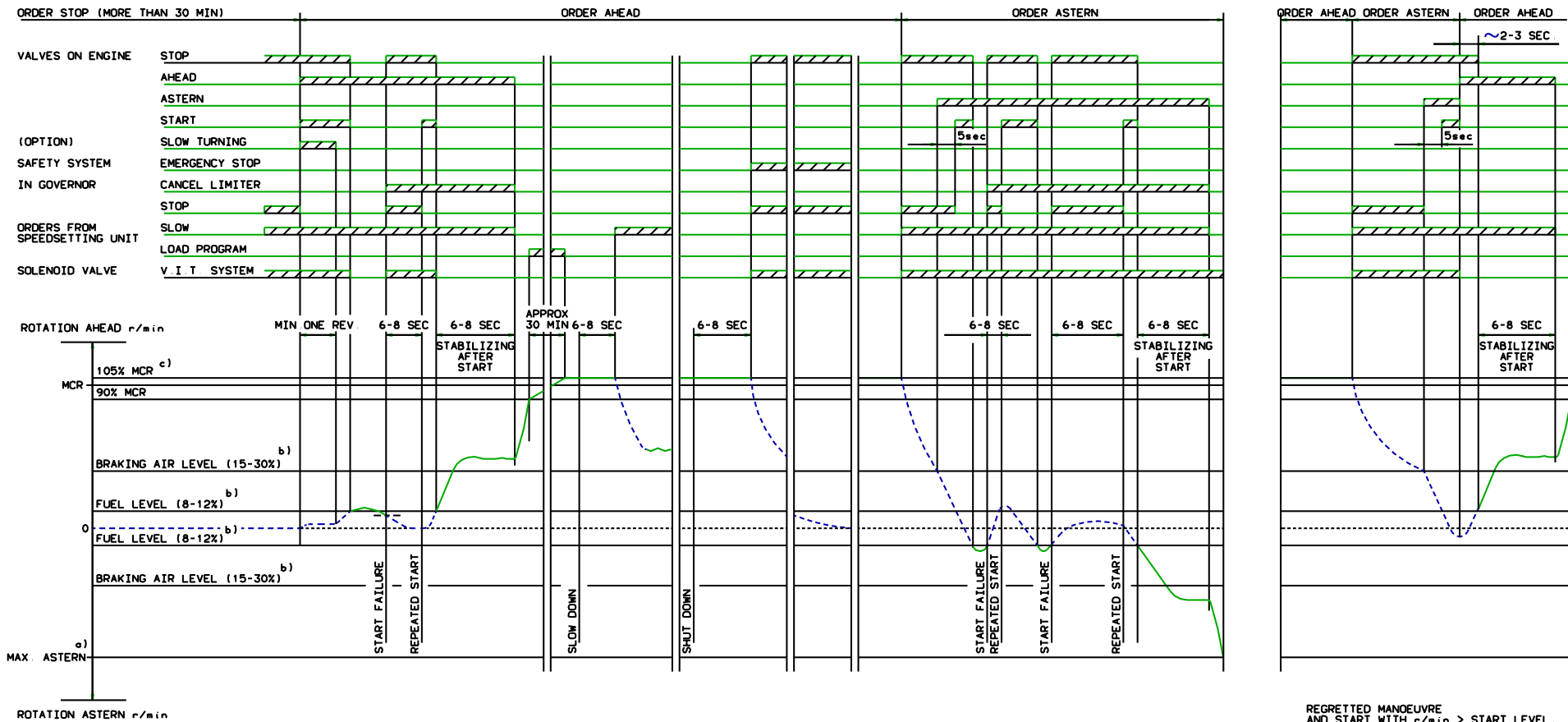




Pos.	Qty	Description
7	1	Magnet switch
8	1	Magnet switch
9	1	Ball valve
10	1	3/2-way valve
11	1	3/2-way valve
13	1	Air cylinder
14	1	3/2-way valve
15	1	3/2-way valve
29	1	Double non-return

Pos.	Qty	Description
30	1	Double non-return
50	1	Double non-return
55	1	3/2-way-valve
56	1	3/2-way valve
57	1	Air cylinder
69	1	Throttle non-return
70	1	Telegraph
105	1	5/2-way valve

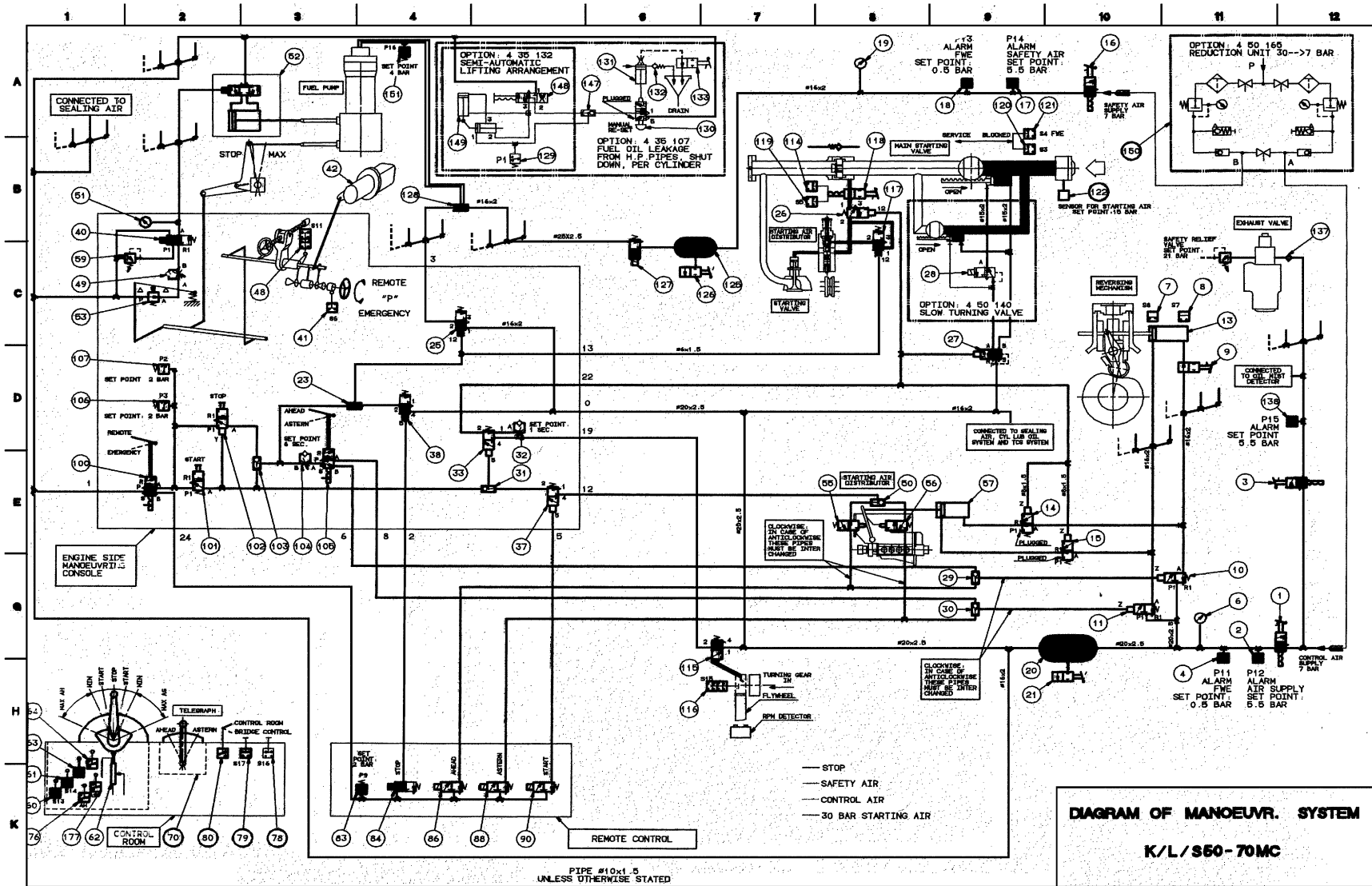


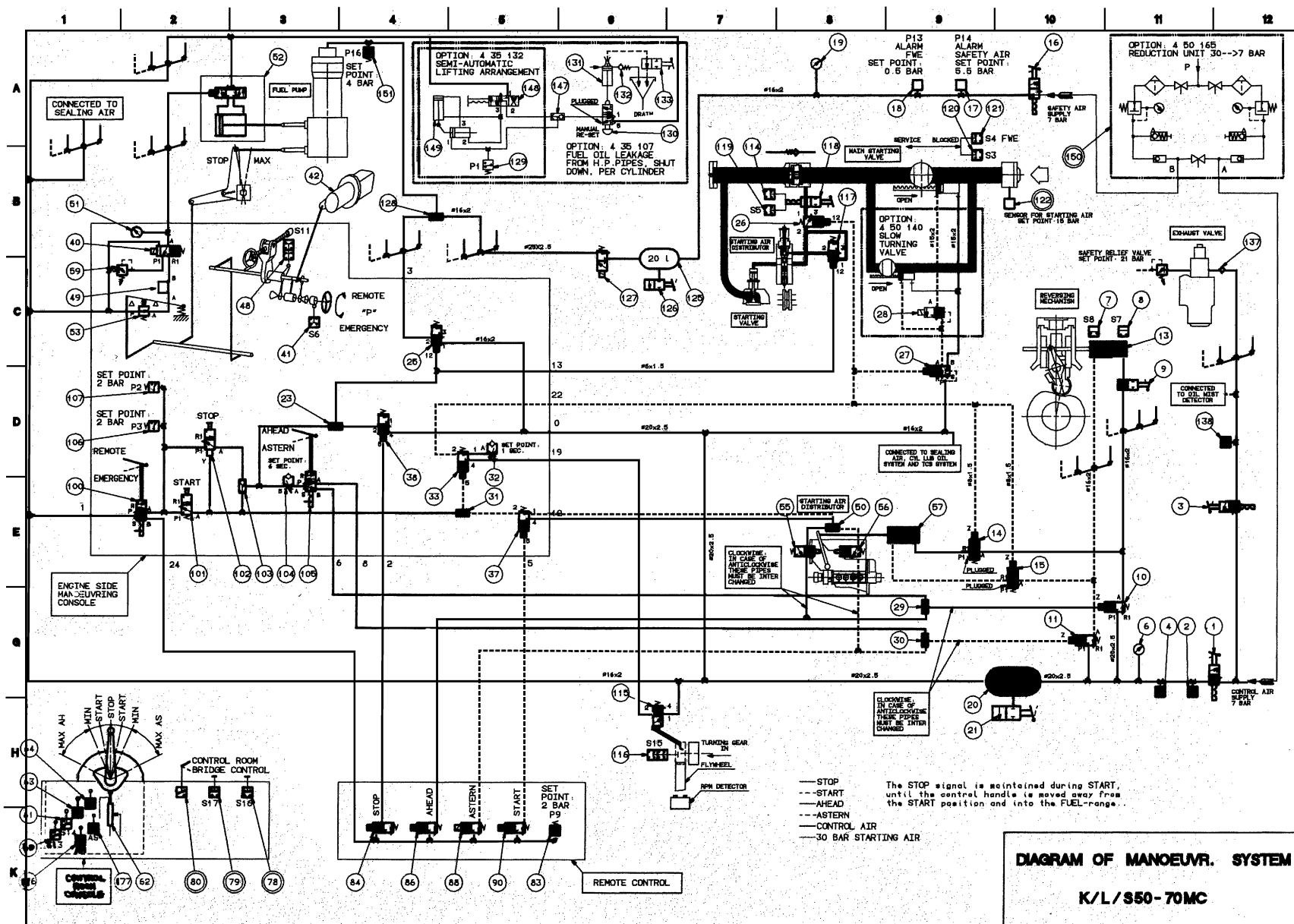


- a) MAX ASTERN: 90% SPECIFIED MCR r/min FOR PLANTS WITH STANDARD EXHAUST CAMS.
80% SPECIFIED MCR r/min FOR PLANTS WITH LONG EXHAUST CAMS.
- b) THESE VALUES GIVEN IN % REFER TO NOMINAL MCR r/min . (IF NOTHING ELSE STATED VALUES REFER TO SPECIFIED MCR r/min)
- c) ONLY PERMISSIBLE FOR LIGHT RUNNING PROPELLER. REF LOAD DIAGRAM FOR ACTUAL ENGINE

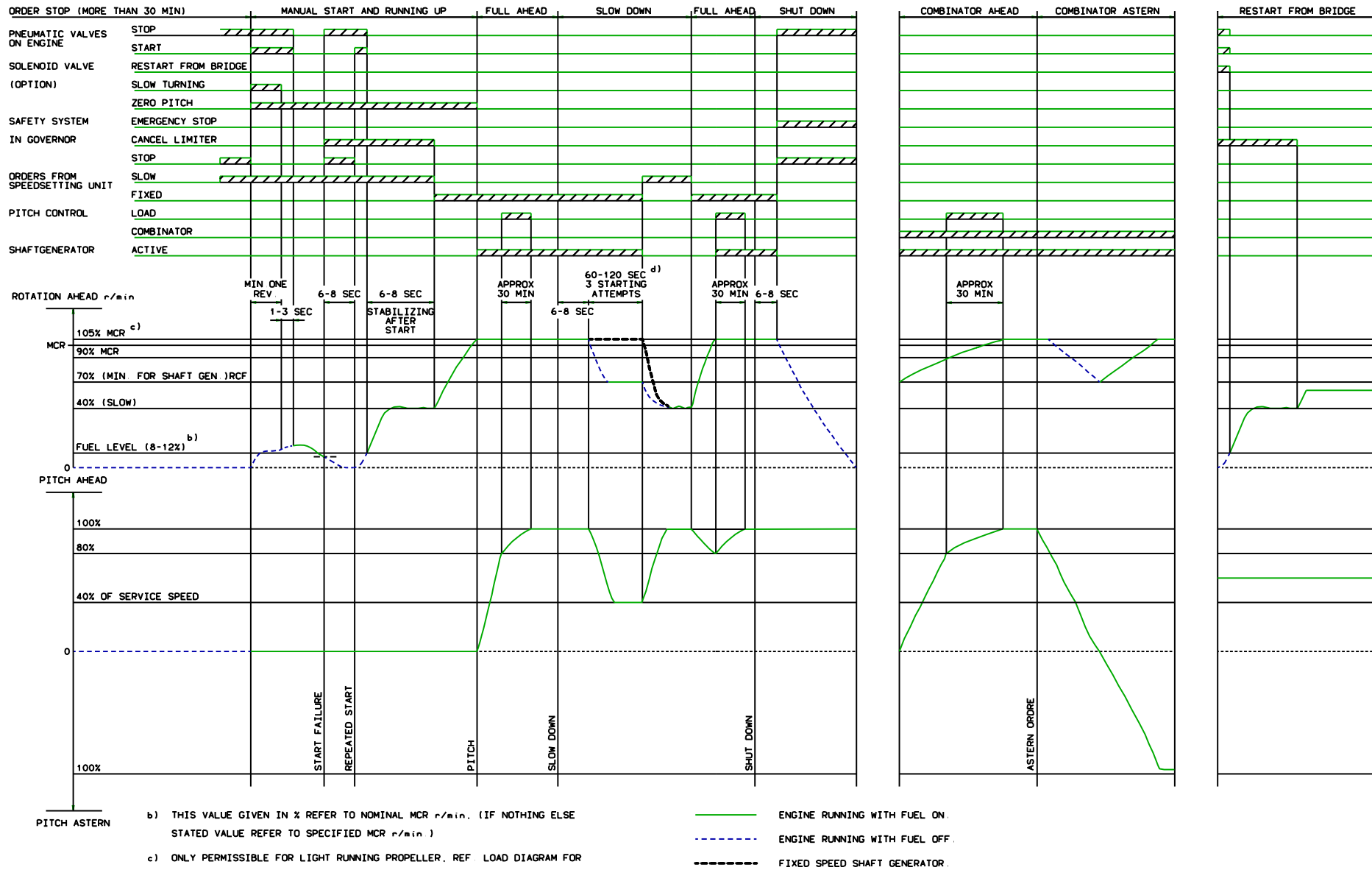
Sequence Diagram for Fixed Pitch Propeller Plant











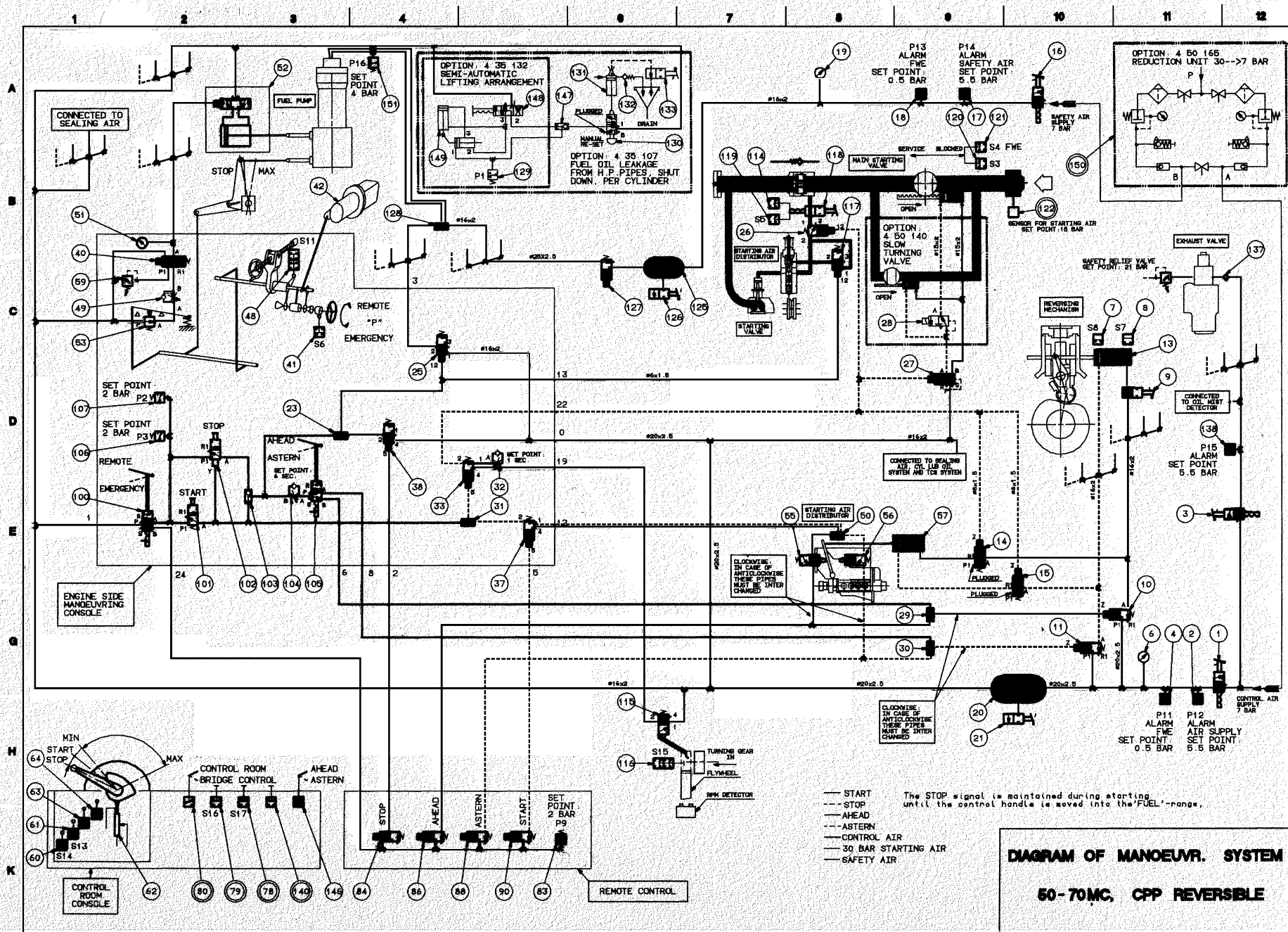
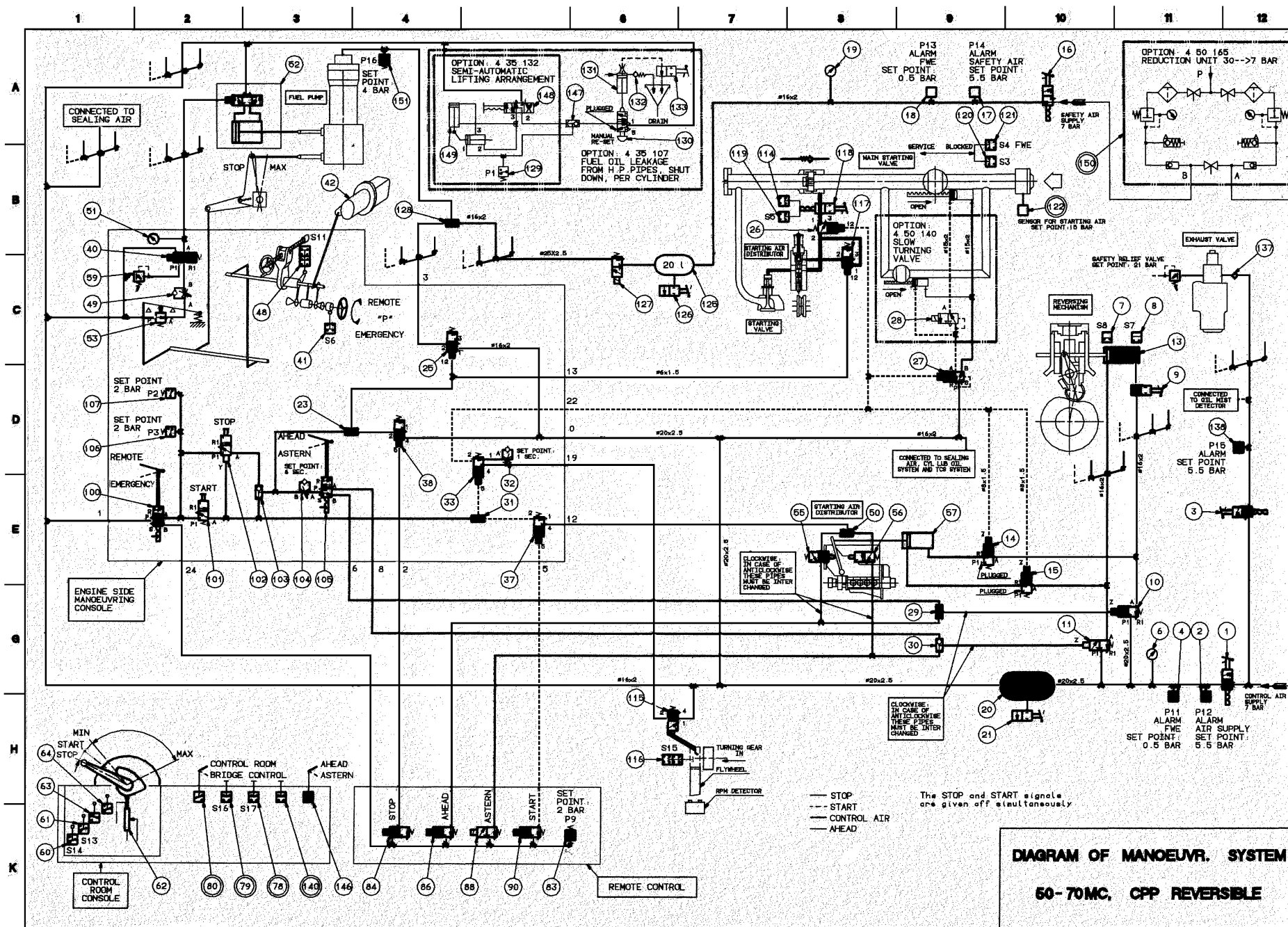
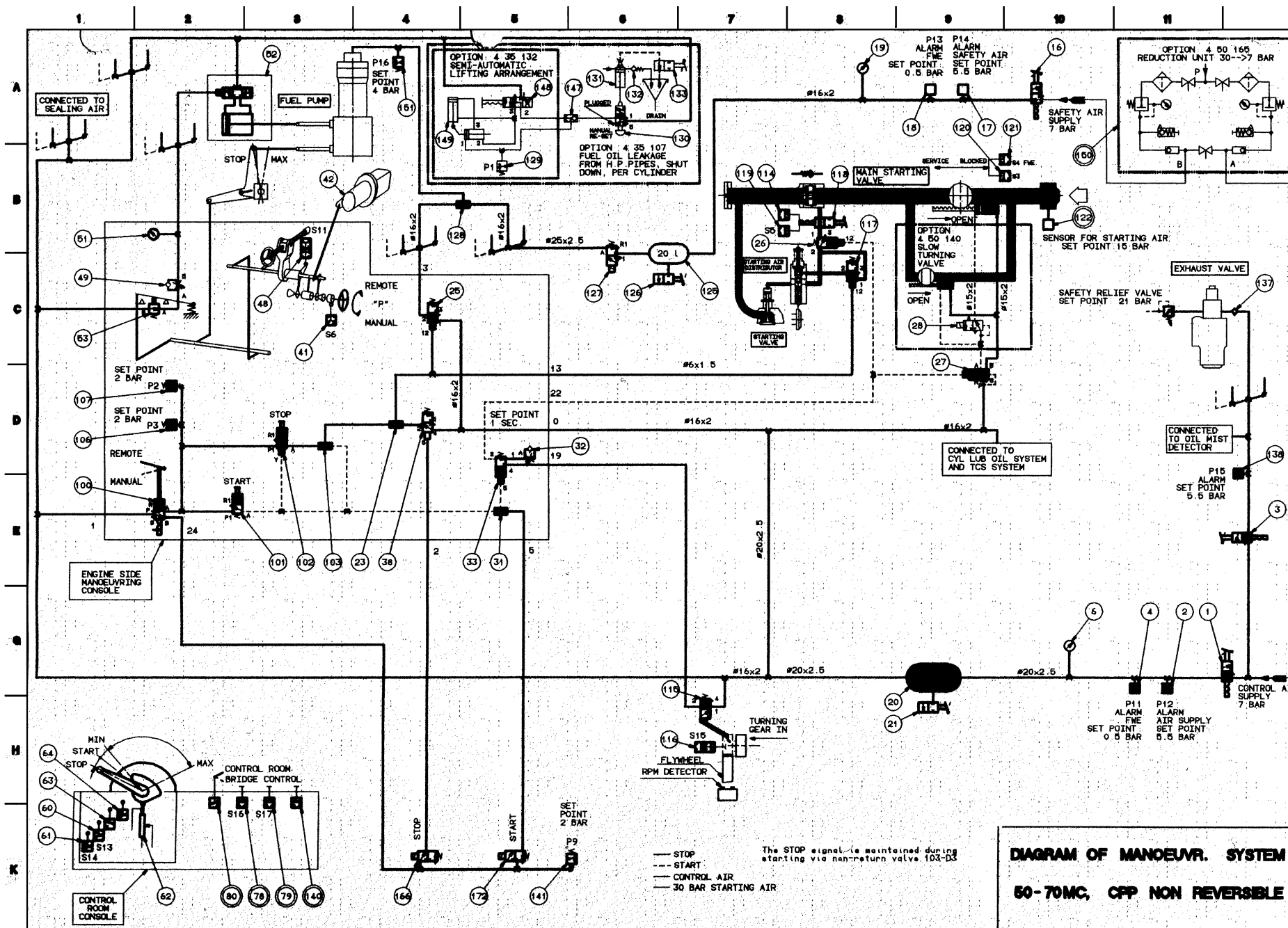
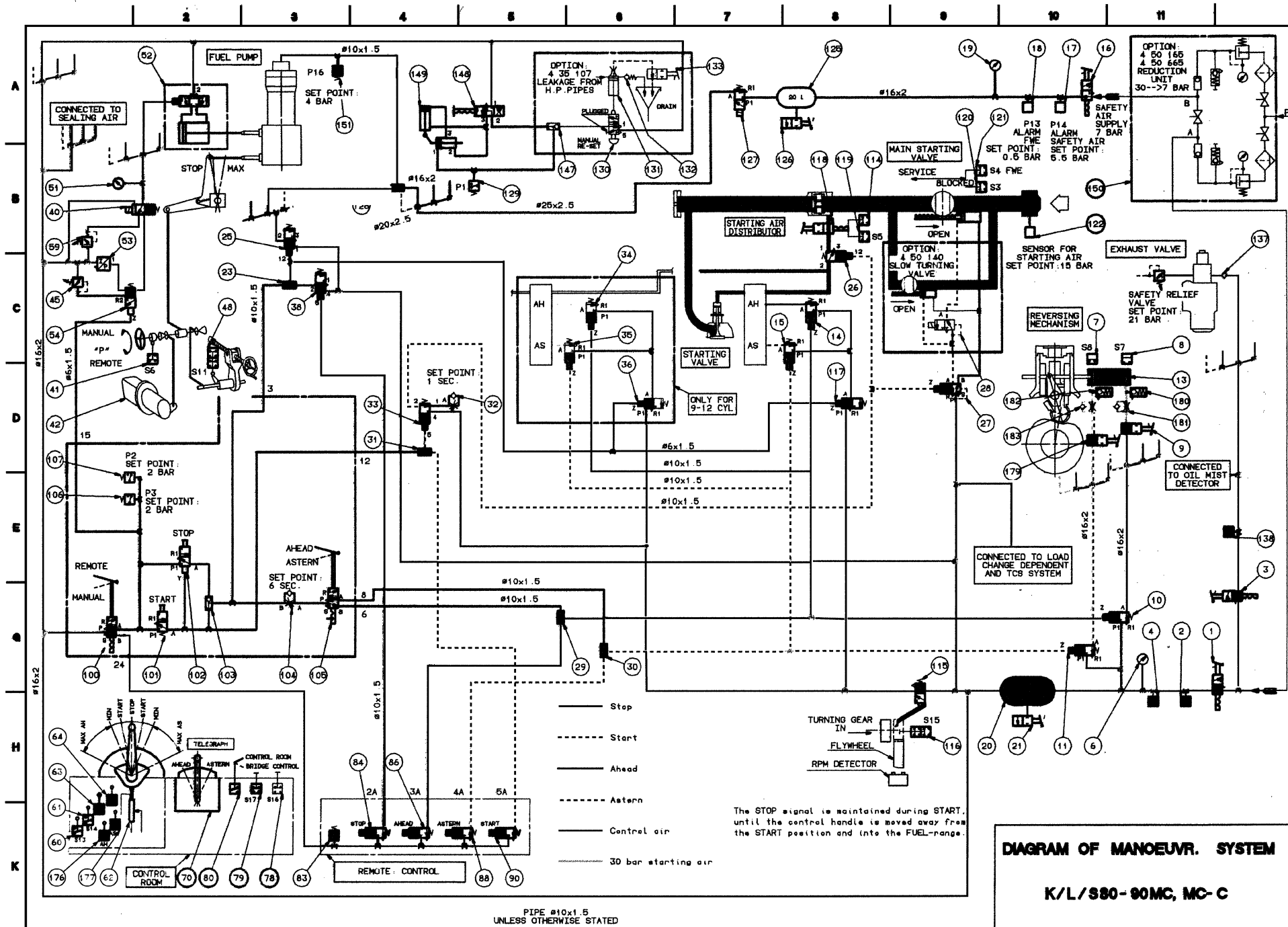


DIAGRAM OF MANOEVR. SYSTEM
50-70MC, CPP REVERSIBLE









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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 an incorrectly adjusted exhaust cam disc or large resistance in the exhaust system (back pressure).

To keep the exhaust resistance low, heavy deposits must not be allowed to collect on protective gratings, nozzle rings and turbine blades, and the back pressure after the turbocharger must not exceed 350 mm WC.

Warning !

If the auxiliary blowers do not start during low-load running (due to faults, or the switch for the blowers not being in “AUTO”-position), unburned fuel oil may accumulate on top of the pistons.

This will involve the risk of a **scavenge air box fire**.

In order to avoid such 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.

Note: 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.

2. Warnings of Fire

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, [Chapter 701](#), pos. 415, 416 (80°C), 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. [See Plate 70311 'Sequence Diagram'](#).



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.

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 Chapter 701 'Sealing Materials'.
- 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 *Chapter 703, Item 4.2, 'Supplementary comments', Point 7 (blow-by)*.

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. <i>This indicates free passage from the actual test-cock to flange AV.</i>
OIL	The scavenge air space is not being drained correctly. <i>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.</i> 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.

Note: 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.

Note !

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 chain casing 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 Chapter 701: Lub. Oil Pressure](#), pos. 331, 334, 335; [Thrust Segment Temperature](#), pos. 350, 351, 352).

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 Chapter 703, Item 3.2, 'Checks during Loading', Check 9 'Feel-over Sequence'](#)).

Check A1, [Chapter 702](#), 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 Chapter 701](#), pos. 436, 437, 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, see 'Sequence Diagram', [Plate 70311](#).

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:

- oil mist
- high lube oil temperature
- no piston cooling oil flow, or
- 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 Letter SL97-348/ERO.

- 1) Reduce speed/pitch to slow-down level, if not already carried out automatically, (Pos. 437), *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, chains, 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 Chapter 708, Item 7.1, point g*). *See also Chapter 701, 'Sealing Materials'.*



Ensure that the respective sliding surfaces are in good condition.

Take special care to check that the circulating oil supply is in order.

- 12) Start the circulating oil pump and turn the engine by means of the turning gear.

Check the oil flow from all bearings, spray pipes and spray nozzles in the crankcase, chaincase and thrust bearing (Check A1, [Chapter 702](#)).

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 [Chapter 703](#), 'Checks during Loading', Item 3.2, Check 9, 'Feel-over Sequence'.

- 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 (stalling) 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
- Defective puncture valve
- Sticking fuel pump plunger
- Sticking fuel valve spindle
- Damaged fuel valve nozzle
- Defect in overflow valve in fuel return pipe
- Camshaft timing, faulty load distribution.

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

- Hunting governor
- 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 fuel pump index 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, governor hunting may occur. When this happens, the fuel pump index must be limited by operating the electronic governor on “index control”.

For some electronic governors, it is not recommended to use the mechanical stop for max. index. These governors have a built-in electronic max. index control.

Regarding the mechanical/hydraulic governor (Woodward) the stop screw, mounted at the change-over mechanism, see [Plate 70301](#), is screwed slightly downwards, until the hunting just ceases.

Before this is carried out, measure or mark the position of the stop screw, so that it can be returned to the original position, when max. index is no longer needed.

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 vibra-



tion 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, chain and camshaft. 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 Volume II, 'Maintenance' for the respective procedures.

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](#).

A. Combustion cut out. Piston and exhaust valve gear 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 by lifting and securing the roller guide. (*See Vol. II, Procedure 909-5*).

Note: Piston cooling oil and cylinder cooling water must not be cut off.

See also Item 4, 704.11.

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, 704.11.

Procedure:

- 1) Cut out the fuel pump by lifting and securing the roller guide.
See Vol. II, Procedure 909-5.

- 2) Put the exhaust valve out of action and lock it in **open** position.
See Vol. II, Procedure 908-6.

Shut-off the air supply to the exhaust valve, and stop the lube oil pumps. Dismantle and block the actuator oil pipe. 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.

Note: 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 actuating gear is defective.

See also Item 4, 704.11.

Procedure:

- 1) Cut out the fuel pump by lifting and securing the roller guide. (See Volume II, Procedure 909-5).
- 2) Put the exhaust valve out of action (See Volume II, Chapter 908-5) so that the valve remains **closed** (lift the guide or stop the oil supply and remove the hydraulic pipe).

Note: 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, 704.11.

Procedure:

- 1) Cut out the fuel pump by lifting and fixing the roller guide.
See Vol. II, Procedure 909-5.
- 2) Put the exhaust valve out of action (Volume II, Chapter 908-5) 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.



Note: 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, 704.11.

Procedure:

- 1) Cut out the fuel pump by lifting and locking the roller guide.
See Vol. II, Procedure 909-5).
- 2) Put the exhaust valve out of action (See *Volume II, Chapter 908-5*) 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 Cylinder Misfiring (Cases A and C)

Misfiring is defined as:

- no injection and
- compression present.

If only **one** cylinder is misfiring, it will most likely be possible to run the engine, i.e. the remaining and working cylinders, with a mean indicated pressure, p_i , up to 90% of the specified MCR-value of p_i for the actual engine. In such cases, the following r/min and shaft powers may be obtained with a fixed-pitch propeller.



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

NB Only valid for misfiring, i.e. Item 2, points A and C, see Pages 704.09-10 and Plate 70401.

With a CP-propeller, the same values apply when running according to the design pitch.

If more than one cylinder is misfiring, the engine builder must be contacted.

Running Limitations in Cases B, D and E

In cases B, D and E, the engine builder must always be contacted for calculation of allowable output and possible barred speed range.

5. How to put Turbochargers out of Operation

(See 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:

Note: 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.

Engines with one turbocharger:

1. Stop the engine.
2. Lock the rotor of the defective turbocharger. *(See T/C manual).*
3. Remove the compensator between the compressor outlet and the scavenge air duct.
This reduces the suction resistance.
4. **Load restrictions:** See 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 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.

Note: 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

Engines with **one** turbocharger:

- Engines with exhaust by-pass (Option).
 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.

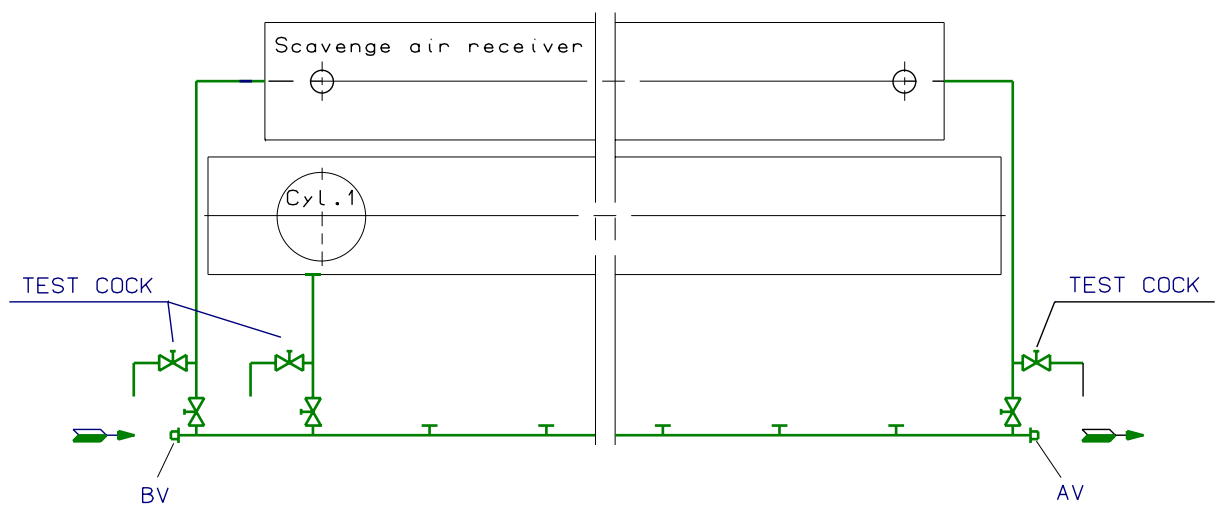
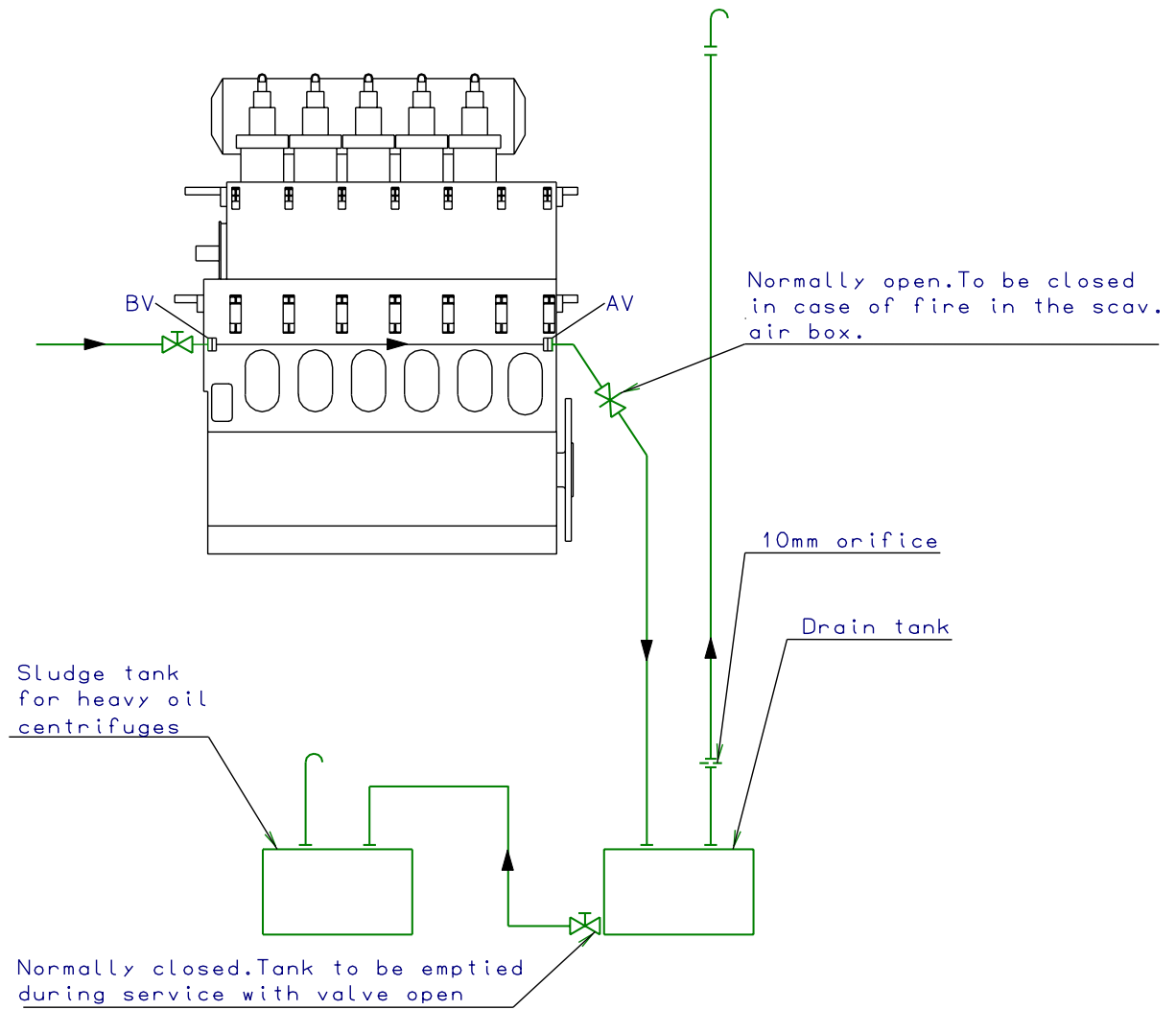


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	Case A	Case B	Case C	Case D	Case E
Nature of the action	Combustion to be stopped	Compression and combustion to be stopped	Combustion to be stopped (due to faulty exhaust valve)	All reciprocating parts suspended or out	All reciprocating parts out
Some 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 actuating gear, 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
Fuel pump with roller guide	Lifted	Lifted	Lifted	Lifted	Lifted
Exhaust valve	Working	Held open	Closed	Closed	Closed
Air for air spring	Open	Closed	Open	Open	Open
Exhaust valve actuator with roller guide	Working	Out or lifted	Out or lifted	Out or lifted	Out or lifted
Oil inlet for actuator	Open	Pipe dismantled and blocked	Open	Open	Open
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 lubricator	Working	Working	Working	``Zero" delivery	``Zero" delivery





Component	Case B		Case C ¹⁾			Case D (Engines with two or more T/C)
	Engines with one T/C	Engines with two or more T/C	Engines with one 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⁾	-	20-25/(58-63) 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	-	15/(53) ^{3) 5)}	-	-	66/(87) ^{3) 6)}	66/(87) ^{3) 6)}
1 Aux. bl. of 2 ₇₎	10/(46) ⁴⁾	10/(46) ⁴⁾	15/(53) ⁴⁾	10/(46) ⁴⁾	⁸⁾	⁸⁾
1 Aux. bl, of 3 ₇₎	-	12.5/(50) 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', page 704.08.

⁴⁾ The exhaust temperature must **not** exceed 400°C.

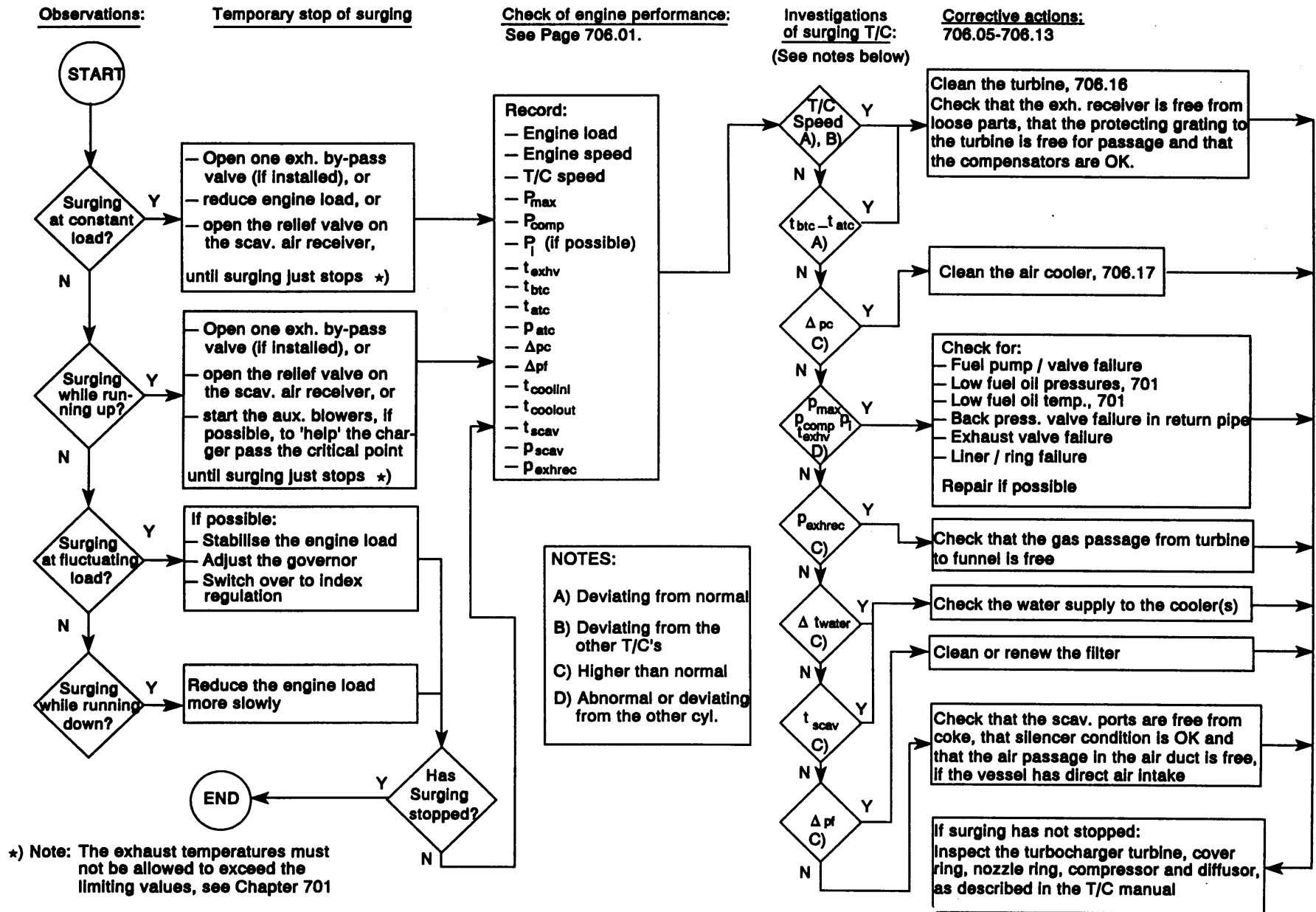
⁵⁾ This is due to the loss of exhaust gas through the damaged turbocharger.

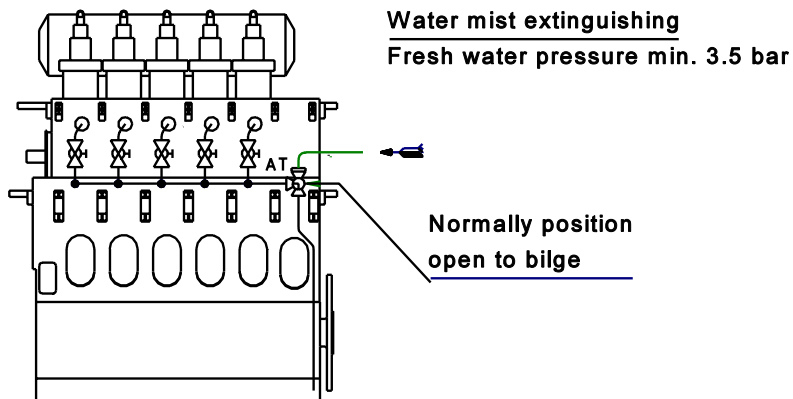
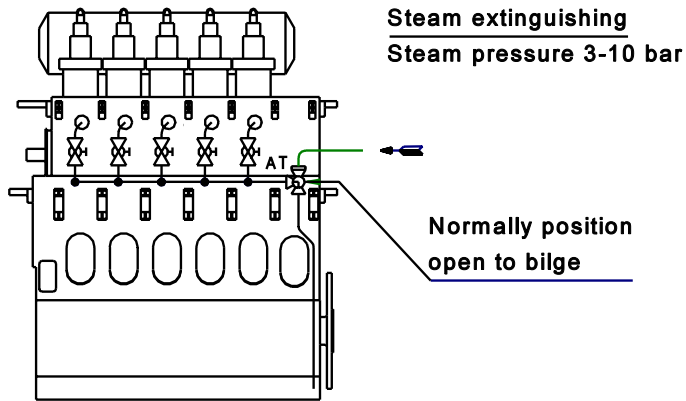
⁶⁾ The mentioned exhaust temperature limit is an average value for the whole load range.

⁷⁾ Simultaneous with T/C out of operation.

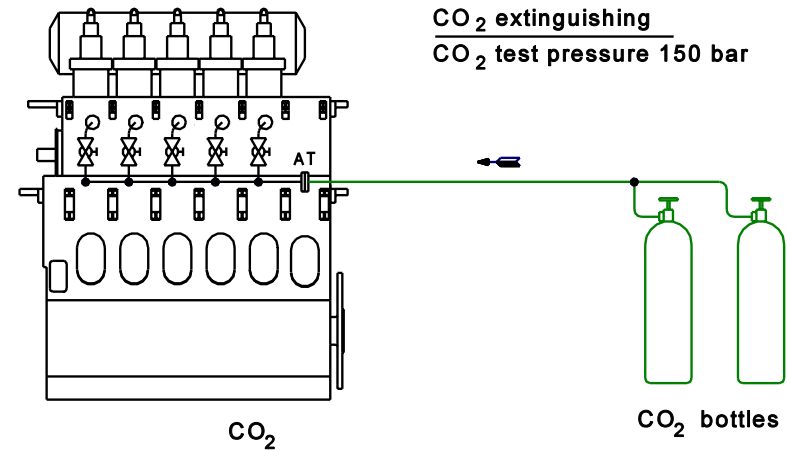
⁸⁾ See the limits given under '1 T/C of 2' and '1 T/C of 3', ε







To prevent the fire from spreading to the next cylinder(s), the ball-valve of the neighbouring cylinder(s) should be opened in the event of fire in one cylinder



At least two bottles ought to be installed. In most cases, one bottle should be sufficient to extinguish fire in three cylinders, while two or more bottles would be required to extinguish fire in all cylinders



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1. Diesel Oil

Diesel oil fulfilling:

British Standard MA 100, Class M2; ASTM Classification of Diesel fuel oil D 975, grade No. 4-D; CIMAC grade 1; or similar; may be used.

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 regarding requirements for heavy fuel for diesel engines, edition 1990. From these, the maximum accepted grades are RMH 55 and K55. 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 ship, i.e. before on-board 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 0.991.

Higher densities can be allowed if special treatment systems are installed. *See Item 3.1, 'High Density Fuels'.*

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 ship 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 main and auxiliary engines caused by long time settling is consequently considerably reduced.

For treatment of fuel oil, *see further on in this Chapter.*

3. Guiding Fuel Oil Specification

Based on our general service experience we have, as a supplement to the above-mentioned standards, drawn up the guiding fuel oil specification shown in the Table below.

Fuel oils limited by this specification have, to the extent of the commercial availability, been used with satisfactory results on MAN B&W two-stroke low speed diesel engines, as well as MAN B&W auxiliary engines.

Guiding specification (maximum values)		
Density at 15°C	kg/m ³	991 *
Kinematic viscosity at 100°C	cSt	55
at 50°C	cSt	700
Flash point	°C	≥ 60
Pour point	°C	30
Carbon residue	%(m/m)	22
Ash	%(m/m)	0.15
Total sediment after ageing	%(m/m)	0.10
Water	%(v/v)	1.0
Sulphur	%(m/m)	5.0
Vanadium	mg/kg	600
Aluminium + Silicon	mg/kg	80
Equal to ISO 8217/CIMAC - H55		

* 1010 provided automatic modern clarifiers are installed.

The data refers to the fuel as supplied, i.e. before any on-board 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 of the above-mentioned residuals, 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 ppm

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 main and auxiliary engines. It is possible to run the auxiliary engines on heavy fuel oil or diesel oil independent of the main engine.

From the bunker 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 about 95-98°C (regarding the cleaning, see 'Fuel Treatment' in this Chapter).

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 entering harbour, provided that the circulating pump is kept running and preheating of the circulated fuel oil is maintained, see *Section 3.2 in this Chapter.*

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 *Item 4.2.B*, 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 *Item 4.2.C.*



2. Fuel Oil Pressure

Carry out adjustment of the fuel oil pressure, during engine standstill, in the following way:

1. Adjust the valves in the system as for normal running, thus permitting fuel oil circulation.
2. Start the supply and circulating pumps, and check that the fuel oil is circulating.
3. Supply Pumps: Adjust the spring-loaded safety valve at supply pump No. 1 to open at the maximum working pressure of the pump.

The pressure must not be set below 4 bar, due to the required pressure level in the supply line, *see point 4*.

Make the adjustment gradually, while slowly closing and opening the valve in the discharge line, until the pressure, with closed valve, has the above-mentioned value.

Carry out the same adjustment with supply pump No. 2.

4. Regulate the fuel oil pressure, by means of the over-flow valve between the supply pump's discharge and suction lines. Adjust so that the pressure in the low pressure part of the fuel system is 4 bar.
5. Circulating Pumps: With the supply pumps running at 4 bar outlet pressure, adjust the spring-loaded by-pass valve at circulating pump No. 1 to open at the maximum working pressure of the circulating pump, about 10 bar.

Make the adjustment gradually, while slowly closing and opening a valve in the pressure line, until the pressure, with closed valve, has the above-mentioned value.

Carry out the same adjustment with circulating pump No. 2.

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 catalysts; 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.

We recommend the capacity of the installed centrifuges to be at least according to the maker's instructions.

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 - 95-98 °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 "through-put" 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.

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.

Plate 70504 Fig. 1



As regards centrifuge treatment of today's residual fuel qualities, experimental work has shown that, provided the capacity of each centrifuge is sufficient, the best cleaning effect, particularly as regards removal of catalyst fines, is achieved when the centrifuges are operated in *series* - in purifier/clarifier mode.

Series operation of centrifuges (ensuring a maximum of safety), is therefore a fully acceptable alternative to the previously recommended parallel operation. Each centrifuge must however be able to handle the total amount of fuel required by the engine, without exceeding the flow-rate recommended by the centrifuge maker.

This recommendation is valid for conventional centrifuges. For later types, suitable for treating fuels with densities higher than 991 kg/m^3 at 15°C , it is recommended to follow the maker's specific instructions, see *item 1.3 below*.

Plate 70504 Fig. 2

If the installed centrifuge capacity is on the low side (relative to the specific viscosity of the fuel oil in question), and if more than one centrifuge is available, *parallel operation* may be considered in order to obtain a lower flow rate. However, in view of the above recommendations, serious considerations should be given to the possible advantages of installing new equipment, in accordance with today's fuel qualities and flow recommendations.

As regards 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 clarifiers, with automatic desludging 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.

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 bottom 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.

However, experience from service has shown that the viscosity of the fuel, before the fuel 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 point 4.3*).

3.2 Fuel Preheating when in Port

During engine standstill, the circulation of preheated heavy fuel oil 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 Staying in Port

If the engine has been stopped on heavy fuel, and if the heavy fuel 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 Fuel change-over

(See also 'Pressurised fuel oil system' earlier in this Chapter).

The engine is equipped with uncooled, "all-symmetrical", light weight fuel valves - with built-in fuel circulation. This automatic circulation of the preheated fuel (through the high-pressure pipes and the fuel valves) during engine standstill, is the background for our recommending *constant operation on heavy fuel*.

However, change-over to diesel oil can become necessary if, for instance:

- the vessel is expected to have a prolonged inactive period with cold engine, e.g. due to:
 - a major repair of the fuel oil system etc.
 - a docking
 - more than 5 days' stop (incl. laying-up)
- environmental legislation requiring the use of low-sulphur fuels.

Change-over can be performed at any time:

- during engine running, *see Items 4.2.A and 4.2.B.*
- during engine standstill, *see Item 4.2.C.*

In order to prevent:

- fuel pump and injector sticking/scuffing,
- poor combustion,
- fouling of the gasways,

it is very important to carefully follow the temperature / load requirements of the

change-over procedures. *See Items 4.2.A, 4.2.B and 4.2.C.*

A. Change-over from Diesel oil to Heavy Fuel during Running

To protect the injection equipment against rapid temperature changes, which may cause sticking/scuffing of the fuel valves and of the fuel pump plungers and suction valves, the change-over is carried out as follows (manually):

First, ensure that the heavy oil in the service tank is at normal temperature level.

Reduce the engine load to 3/4 of normal. Then, by means of the thermostatic valve in the steam system, or by manual control of the viscosity regulator, the diesel oil is heated to *maximum* 60-80°C. Regulate the preheating so as to give a temperature rise of about 2°C per minute.

The diesel oil viscosity should not drop below 2 cSt, as this might cause fuel pump and fuel valve scuffing, with the risk of sticking, due to failing lubrication ability of the diesel oil.

For some light diesel oils (gas oil), this will limit the upper temperature to somewhat below 80°C.

Due to the above-mentioned risk of sticking/scuffing of the fuel injection equipment, the temperature of the heavy fuel oil in the service tank must not be more than 25°C higher than the heated diesel oil in the system (60-80°C) at the time of change-over.

When the temperature requirements have been fulfilled, the change to heavy oil is performed by turning the change-over cock. The temperature rise is then continued at a rate of about 2°C per minute, until reaching the required viscosity, *see Item 3, 'Pre-heating before Injection'.*



B. Change-over from Heavy Fuel to Diesel Oil during Running

See also Item 3.1, 'Precautions'.

To protect the fuel oil injection equipment against rapid temperature changes, which may cause scuffing with the risk of sticking of the fuel valves and of the fuel pump plungers and suction valves, the change-over to diesel oil is performed as follows (manually):

- Preheat the diesel oil in the service tank to about 50°C, if possible.
- Cut off the steam supply to the fuel oil preheater and heat tracing.
- Reduce the engine load to 3/4 of MCR-load
- Change to diesel oil when the temperature of the heavy oil in the preheater has dropped to about 25°C above the temperature in the diesel oil service tank, however, not below 75°C.

Note: If, after the change-over, the temperature (at the preheater) suddenly drops considerably, the transition must be moderated by supplying a little steam to the preheater, which now contains diesel oil.

C. Change-over from Heavy Fuel to Diesel Oil during Standstill

- Stop the preheating. Regarding temperature levels before change-over, see *Item B, 'Change-over from Heavy Fuel to Diesel Oil during Running'*.
- Change position of the change-over valve at the fuel tanks, so that diesel oil is led to the supply pumps.
- Start the supply pumps 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-tank.
- When the heavy fuel oil is replaced by diesel oil, turn the change-over valve at the venting pipe back to its normal position, so that the heavy oil in the venting pipe is now mixed with diesel oil.
- Stop the supply pumps.
- Stop the circulating pumps.



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Designation			CIMAC A 10	CIMAC B 10	CIMAC C 10	CIMAC D 15	CIMAC E 25	CIMAC F 25	CIMAC G 35	CIMAC H 35	CIMAC K 35	CIMAC H 45	CIMAC K 45	CIMAC H 55	CIMAC K 55
Related to ISO 8217 (87): F -			RMA 10	RMB 10	RMC 10	RMD 15	RME 25	RMF 25	RMG 35	RMH 35	RMK 35	RMH 45	RMK 45	RMH 55	-
Characteristic	Dim.	Limit													
Density at 15 °C	Kg/m³	max.	950	975		980	991		991		1010	991	1010	991	1010
Kinematic viscosity at 100 °C	cSt ²⁾	max.	10			15	25		35			45		55	
		min. ⁴⁾	6				15								
Flash point	°C	min.	60			60	60		60			60		60	
Pour point	°C	max.	0 6 ³⁾		24	30	30		30			30		30	
Carbon residue	%(m/m)	max.	12		14	14	15	20	18	22		22		22	
Ash	%(m/m)	max.	0.10			0.10	0.10	0.15	0.15			0.15		0.15	
Total sediment after ageing	%(m/m)	max.	0.10			0.10	0.10		0.10			0.10		0.10	
Water	%(V/V)	max.	0.50			0.80	1.0		1.0			1.0		1.0	
Sulphur	%(m/m)	max.	3.5			4.0	5.0		5.0			5.0		5.0	
Vanadium	mg/kg	max.	150		300	350	200	500	300	600		600		600	
Aluminium and silicon	mg/kg	max.	80			80	80		80			80		80	
Ignition properties ⁵⁾															

¹⁾ Approximate equivalent viscosities (for information only)

Kinematic viscosity (cSt) at	100 °C	6	10	15	25	35	45	55
Kinematic viscosity (cSt) at	50 °C	22	40	80	180	380	500	700
Sec. Redwood I at	100 °F	165	300	600	1500	3500	5000	7000

²⁾ 1 cSt = 1 mm²/sec

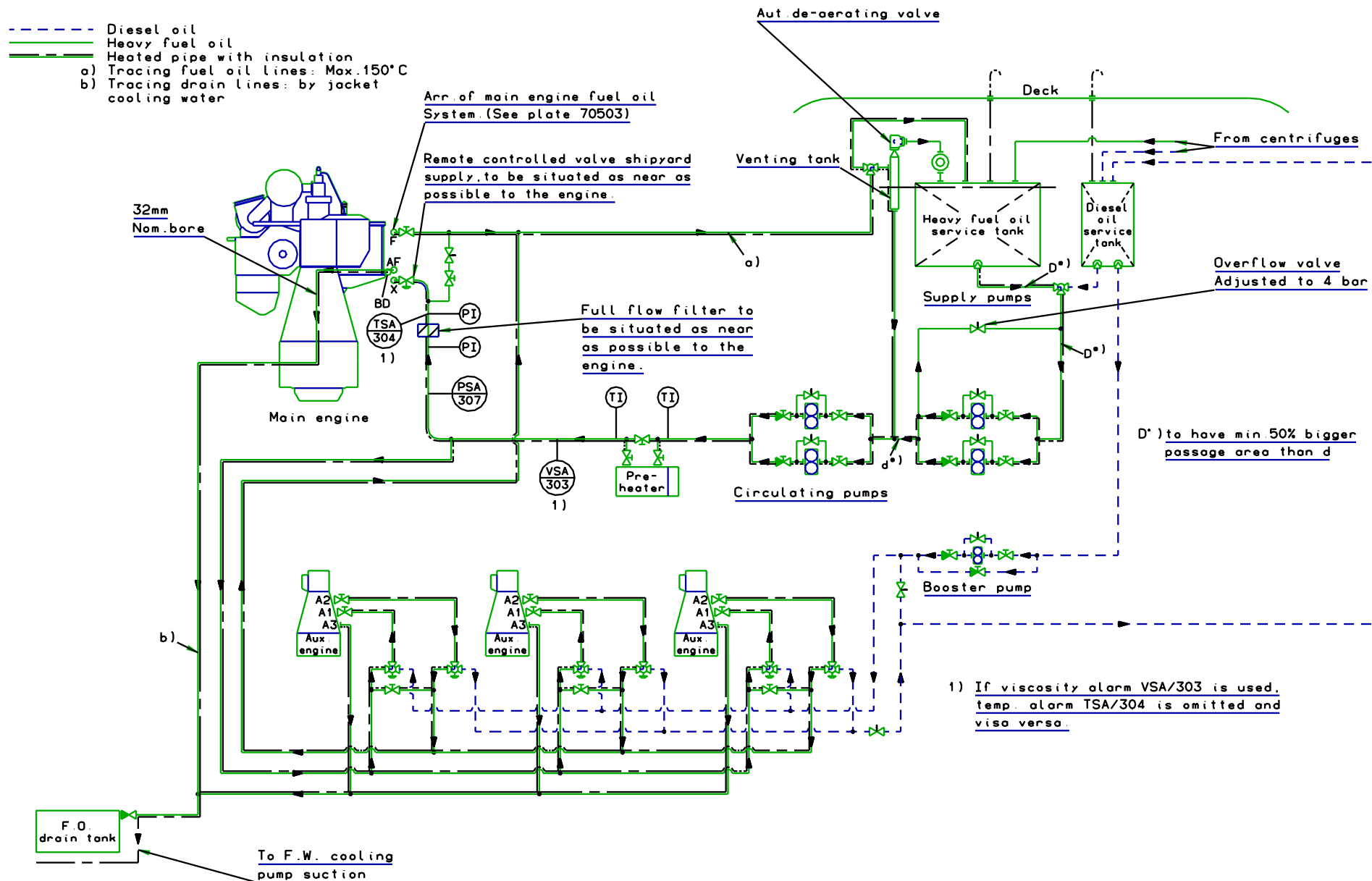
³⁾ Applies to region and season in which fuel is stored and used,
(upper value winter quality, bottom value summer quality)

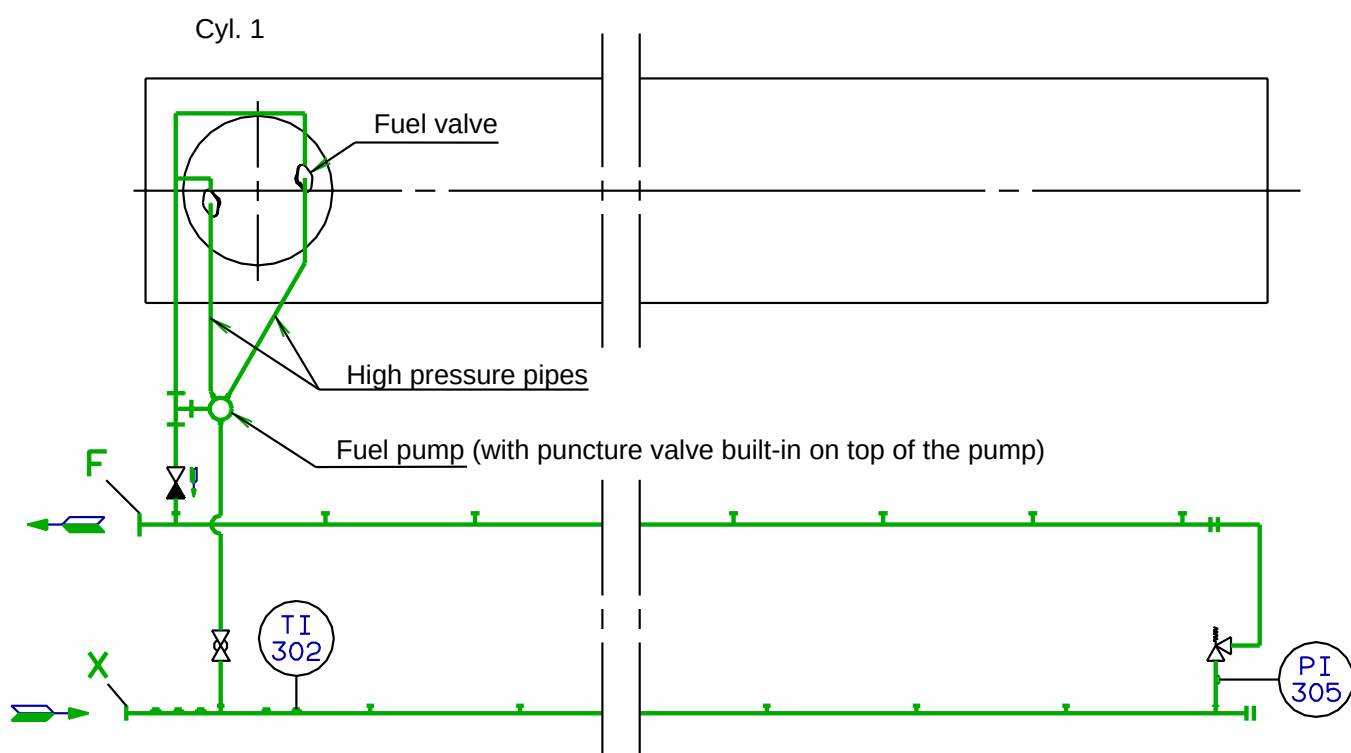
⁴⁾ Recommended value only. May be lower if density is also lower

⁵⁾ **Ignition Properties**

Normally applied analytical data for fuel oil contain no direct indication of ignition quality, neither do current specifications and standards. Although not an important parameter for low and medium speed engines with high compression ratios, the ignition quality can to some extent be predicted by calculations based on viscosity and density, using formulas issued by the oil industry (CCAI by Shell or CII by BP). High density in combination with low viscosity may be an indication of poor ignition quality.







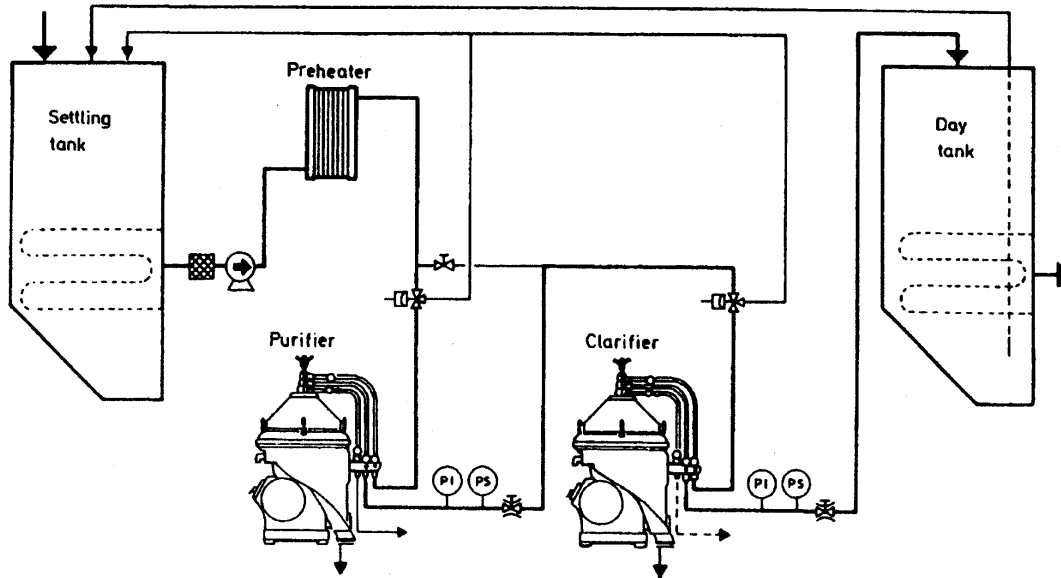


Fig. 1

In Series

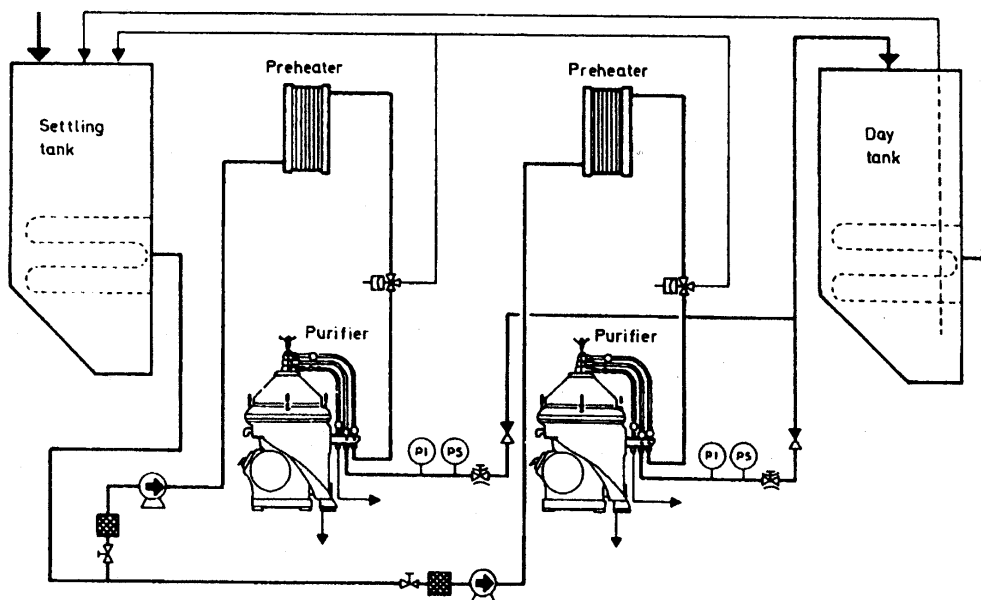


Fig.2

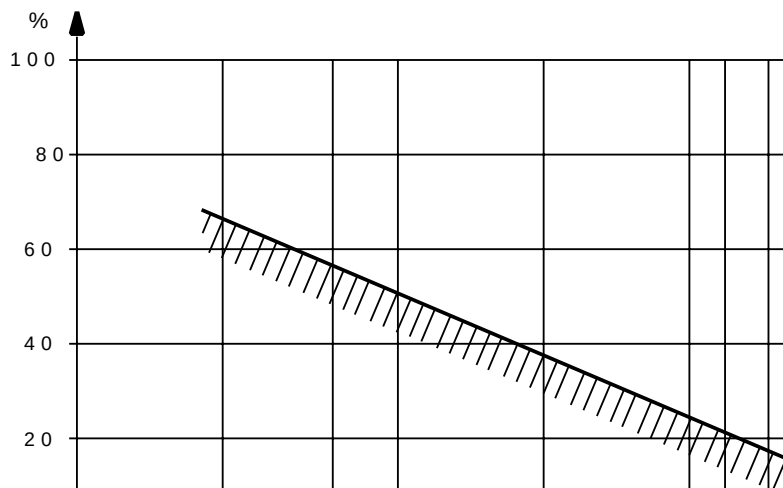
In Parallel

By courtesy of Alfa-Laval

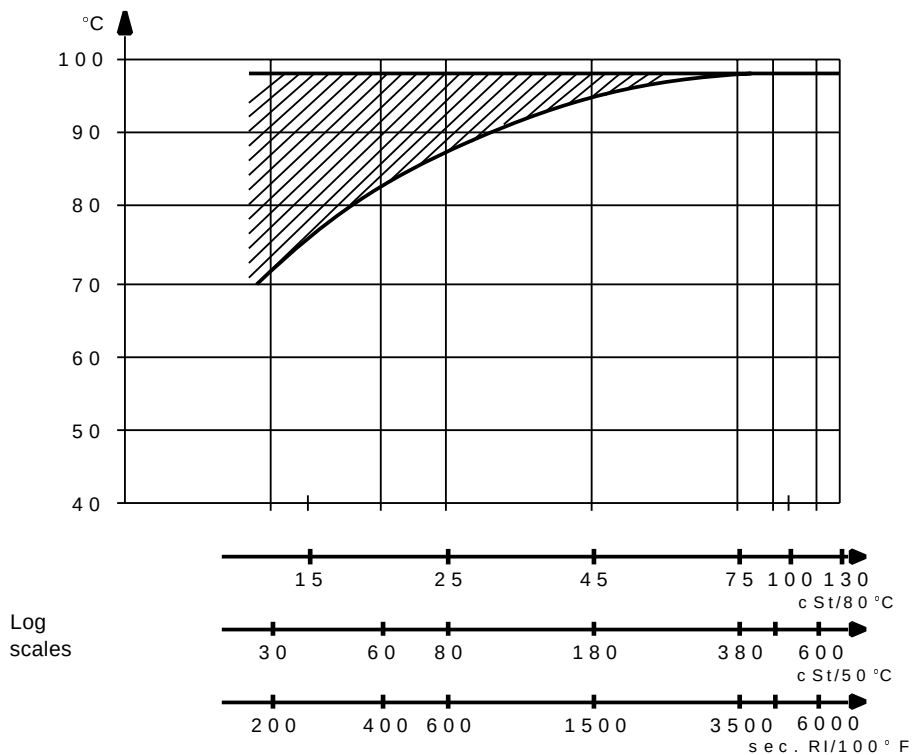


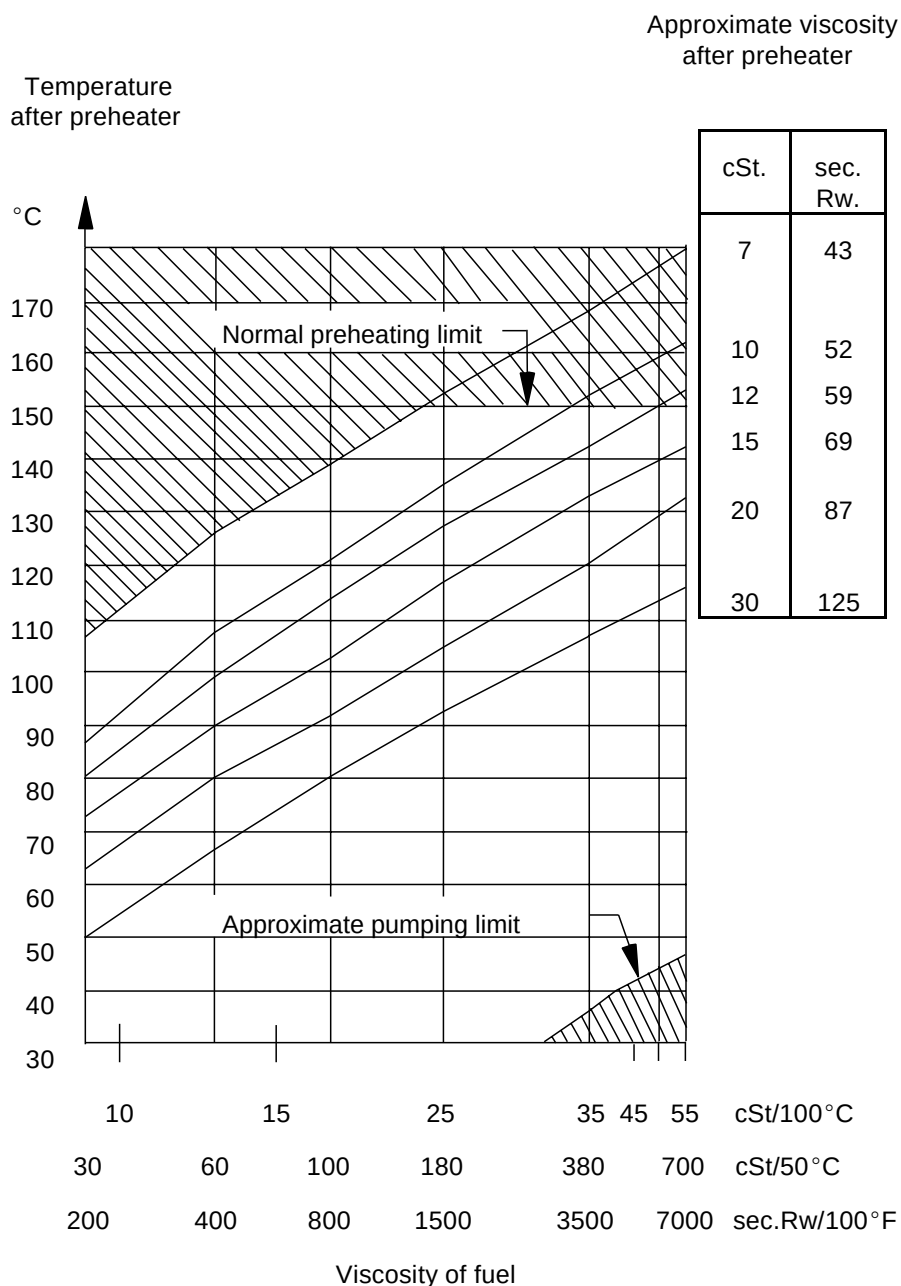
Rate of flow

Related to rated capacity of centrifuge



Separation temperature





This chart is based on information from oil suppliers regarding typical marine fuels with viscosity index 70-80.

Since the viscosity after the preheater is the controlled parameter, the preheating temperature may vary, dependent on the viscosity and viscosity index of the fuel.

Recommended viscosity meter setting is 10-15 cSt.



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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.	(mm)
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:

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

$$1 \text{ kg/cm}^2 = 0.9807 \text{ bar}$$

$$1 \text{ kW} = 1.3596 \text{ hp}$$

$$1 \text{ mbar} = 10.2 \text{ mmWC} = 0.75 \text{ mmHg}$$

$$\pi = 3.14159$$

★) **Note:** 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](#).

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 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.

Note: 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
- Δp air filter (if pressure gauge installed)
- Δp air cooler
- Air and cooling water temperatures before and after scavenge air cooler.

3.3 Measuring Instruments

The measuring instruments for performance observations comprise:

- thermometers,
- pressure gauges,
- tachometers,
- indicator and planimeter,

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

Regarding check of thermometers and pressure gauges as well as check and functioning of the indicator, see Appendix 1 in this Chapter.

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 *Chapter 701, 'Alarm Limits'*.

Daily: Fill-in the Performance Observation record, *Plate 70603*, except for the values which require the taking of indicator cards.

Every two weeks: Take indicator cards, and fill-in the complete Performance Observation record, *Plate 70603*. See also Appendix 1 in this Chapter.

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 the next Section, 'Evaluation of Records',

1. General

Record the performance observations as described in the previous Section 3 'Performance Observations'.

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)

NB: *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 Appendix 2 in this chapter.*

For engines without indicator drive or PMI-system, the estimated mean indicated pressure is read from *Plate 70606* 'Average Fuel Pump Index'.

Mean Draught

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

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.

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

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



It is recommended to apply PMI-system, for easy access to P-V-diagrams (work diagrams), if the indicator drive is not installed.

Engine Speed

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 Item 2.1 'Load Diagram'*, 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 Item 2.1 'Load Diagram'*, and from that judge the necessity of making alterations on the engine, or to the propeller.

Maximum Combustion Pressure (p_{max})

The model curve shows the relationship between the average p_{max} (corrected to ISO reference ambient conditions) and the average p_i .

NB For correction to reference conditions, *see Appendix 3 in this Chapter*.

Deviations from the model curve are to be compared with deviations in the compression pressure and the fuel pump index (*see further on*).

At loads lower than 85-90% of specified MCR-power, the p_{max} will increase in proportion to the fuel pump index.

At loads higher than 85-90%, the p_{max} is kept constant.

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. 35 bar.

Fuel Pump Index

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 pump index in relation to the mean pressure. Note, however, that the fuel pump 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 Appendix 2 in this Chapter*.

For engines without indicator drive, the estimated effective engine power is found by using the fuel pump index and T/C revolutions as parameters, *see Appendix 5 in this Chapter*.

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

Exhaust Temperature (t_{exhv})

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).

NB For correction to ISO reference ambient conditions, *see Appendix 3 in this Chapter*.

Regarding maximum exhaust temperatures, *see also Appendix 3 in this Chapter*.

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 pump indexes - Indicator and draw diagrams <i>See Appendix 2 in this Chapter</i> Check the fuel valves: - visually - by pressure testing.
b. Cylinder condition: - Blow-by, piston rings <i>See also Chapter 703, 'Running Difficulties', point 7.</i> - Leaking exhaust valves <i>See also Chapter 703, 'Running Difficulties' point 6.</i>	These faults occur in individual cylinders. - Compare the compression pressures from the indicator and draw diagrams. <i>See Appendix 2 in this Chapter.</i> - During engine standstill: Carry out scavenge port inspection. <i>See Chapter 707, 'Scavenge Port Inspection'.</i> Check the exhaust valves.
c. Air coolers: - Fouled air side - Fouled water side	Check the cooling capability. <i>See Section 'Evaluation of Records', Item 'Air Cooler Synopsis' in this Chapter.</i>
d. Climatic conditions: - Extreme conditions	Check cooling water and engine room temperatures. Correct T_{exhv} to reference conditions. <i>See Appendix 3, Items 3 and 4 in this Chapter.</i>
e. Turbocharger: - Fouling of turbine side - Fouling of compressor side	Use the turbocharger synopsis methods for diagnosing. <i>See Section 'Evaluation of Records, Item 'Turbocharger Synopsis', in this Chapter.</i>
f. Fuel oil: - Type - Quality	Using heavy fuel oil will normally increase T_{exhv} by approx. 15°C, compared to the use of gas oil. Further increase of T_{exhv} will occur when using fuel oils with particularly poor combustion properties. In this case, a reduction of p_{max} can also occur.



Compression Pressure (p_{comp})

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 .

NB For correction to reference conditions, see *Appendix 3 in this Chapter*.

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).

The ratio is first calculated for the "new" engine, either from the testbed results, or from the model curve.

See the example below regarding:

- Calculating the ratio
- Determining the influence of mechanical defects.

It should be noted that, the measured compression pressure, for the individual cylinders, can deviate from the average, owing to the natural consequence of air/gas vibrations in the receivers. The deviations will, to some degree, be dependent on the load.

However, such deviations will be "typical" for the particular engine, and should not change during the normal operation.

When evaluating service data for individual cylinders, comparison must be made with the original compression pressure of the cylinder concerned, at the corresponding load.

Example:

The following four values can be assumed read from the *model curves*:

The barometric pressure was : 1.00 bar

The scavenge pressure was : 2.25 bar

This gave an absolute scavenge pressure of : 3.25 bar

The average (or individual) compression pressure was : 115 bar

which gave an absolute compression pressure of $115 + 1.00 = 116$ bar

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

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:

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

$$\text{i.e. } p_{comp} = 107.8 - 1.02 = 106.8 \text{ bar}$$

The difference between the expected 106.8 bar and the measured 101 bar could be owing to *mechanical defects or grinding of exhaust valve spindle and bottom piece*.

Concerning the pressure rise $p_{comp} - p_{max}$, see *Item 2.1, 'Maximum Combustion Pressure'*.



Mechanical Defects which can influence the Compression Pressure

Possible cause	Diagnosis / Remedy
a. Piston rings: - Leaking	Diagnosis: See table 'Increased Exhaust Temperature Level - Fault Diagnosis', point b, 'Cylinder Condition'. Remedy: See Chapter 703, 'Running Difficulties', point 7.
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 Chapter 703, 'Running Difficulties', point 6. Check: - Cam lead - 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, Procedure 902.



3. Turbocharger Synopsis

Plates 70608 and 70609

(Turbocharger synopsis diagrams)

NB: 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 'Cleaning of Turbochargers and Air Coolers', further on in this Chapter.

Scavenge Air Pressure (p_{scav})

The model curve shows the scavenge air pressure (corrected to reference conditions) as a function of the effective engine power (P_e).

See Appendices 2 and 5 regarding the effective engine power.

NB For correction to ISO reference ambient conditions, see Appendix 3 in this Chapter.

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 cam timing.

Reference is therefore made to the various sections covering these topics.

Turbocharger Speed (T/C speed)

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.

Pressure Drop across Turbocharger Air Filter (Δp_f)

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.

Turbocharger Efficiency (η T/C)

The model curves show the compressor and turbine efficiencies as a function of the scavenge air pressure (p_{scav}).



In order to determine the condition of the turbocharger, the calculated efficiency values are compared with the model curves, and the deviations plotted.

Calculation of the efficiency is explained in *Appendix 4 to this Chapter*.

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 ‘Cleaning of Turbochargers and Air Coolers’, further on in this Chapter*.

Temperature Difference between Air Outlet and Water Inlet ($\Delta t_{(air-water)}$)

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.

Cooling Water Temperature Difference (Δt_{water})

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.

Pressure Drop across Air Cooler (Δp_{air})

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.

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:

- Fouling of the air side
- 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 ‘Cleaning of Turbochargers and Air Coolers’, Item 3, ‘Drain System’ further on in this Chapter.*

- b) Fouling of the water side: Normally involves a *reduction of the cooling water temperature difference*, because the heat transmission (cooling ability) is reduced.

Note however that, if the deposits reduce the cross sectional area of the tubes, so that the water quantity is reduced, the cooling water temperature difference may not be affected, whereby diagnosis is difficult (i.e. lower heat transmission, but also lower flow volume).

Furthermore, a similar situation will arise if such tube deposits are present simultaneously with a fault in the salt water system, (corroded water pump, erroneous operation of valves, etc.). Here again the reduced water quantity will result in the temperature difference remaining approximately unaltered.

In cases where it is suspected that the air cooler water side is obstructed, the resistance across the cooler can be checked by means of a differential pressure gauge.

NB: 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.

NB: 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 Appendix 2. For engines without indicator drive, *see Appendix 5 in this Chapter.*

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/cm³) 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:

LCV₁ LCV₁ = the specific lower calorific value, in kJ/kg, of the bunker oil concerned)

or

LCV₂ 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 m³ over 3 hours

Measuring point temperature : 119°C

Fuel data : Specific gravity: 0.9364 g/cm³ at 15°C, 3% sulphur

Density at 119°C ([see Plate 70611](#)),
ρ₁₁₉: 0.9364 - 0.068 = 0.8684 g/cm³.

Specific consumption:

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

where:

Co = Fuel oil consumption over the period, m³

ρ₁₁₉ = Corrected gravity, g/cm³

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:

LCV₁ = 40,700 kJ/kg, derived for [Plate 70611](#).

Consumption corrected for calorific value:

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

or



LCV₂ = 9723 kcal/kg derived from
[Plate 70611](#).

Consumption corrected for calorific value:

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

Note: 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.

Note: If the cleaning is not carried out at regular intervals, the deposits may not be removed uniformly. This will cause the rotor to be unbalanced, and excite vibrations.

IF	THEN
Vibrations occur after cleaning	Clean again.
Vibrations occur after repeated cleaning	See Chapter 704 <i>Running with Cylinders or Turbochargers out of Operation</i> , Item 5 'How to put Turbochargers out of Operation'. 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

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.

Water Cleaning (Not MET-Turbochargers)

(Plate 90613)

Intervals between cleaning:
Approx. 6 days of operation.

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.

Note: 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.

Note: 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 Chapter 701, pos. 420 and 421 regarding the basis for intervals between cleaning.

Note: 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 from a Humid Atmosphere.

A combination of high air humidity and cold air cooler pipes will cause an amount of condensed water to be separated from the scavenge air in the water mist catcher.

A typical example is high air temperature and low cooling water temperature.

To give an impression of the amount of condensed water, two examples are shown in *Plate 70713*.



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 (*Chapter 701, Item 434*) 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

Note: A sight glass which is completely filled with clean water, and with no air flow, visually looks like an empty air-filled sight glass.



Measuring Instruments

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. The Indicator

The indicator is employed for taking indicator diagrams, whereby the combustion chamber pressures can be measured while the engine is running.

2.1 Indicator and Draw Diagrams

The draw diagram is used for measuring the compression pressure and maximum pressure, and for evaluating the ignition characteristics of the fuel oil.

For engines fitted with indicator drive or PMI-system:

The indicator diagram (pv diagram: work diagram), illustrates the pressure variations in the engine cylinder as a function of the main piston position. The diagram area can be integrated by means of a planimeter, and the mean indicated pressure calculated.

The power developed in the particular cylinder can then be found by multiplication by the engine speed and the cylinder constant, *see Appendix 2, item 3.*

In order to ensure true indicator/draw diagrams, and correct evaluation of data, the following instructions should be followed in detail.

2.2 Maintenance of the Indicator

Friction in the indicator piston movement, as well as slackness in the stylus (writing) mechanism, will distort both the shape and the area of the diagram.



Test and maintain the indicator in the following way:

Friction and tightness of piston:

Remove the indicator spring.

Dismantle the upper part of the indicator, and remove the piston from the cylinder.

Wipe the piston and cylinder with a clean cloth.

Mount the upper part again.

Note: During mounting, check that the piston sinks slowly down the liner, by its own weight, when the cylinder is held vertically.

Hold the indicator upright.

Pull the piston to the upper position.

Block the bottom of the cylinder with a finger.

Check that the piston fits so tightly that it remains in the upper position.

Push the piston downwards and release.

Check that the piston springs back to the upper position.

Tighten the top screw, which retains the spring, firmly against the ball-head of the spring.

Check that the ball is not loose on the spring (older spring types).

Check that the coils of the spring have not worked loose at the soldered joint in the base.

Stylus (writing) mechanism:

Check that the stylus is sharp.

Check for slackness in the writing mechanism.

Replace any worn parts.

Adjust the stylus so that, with a light writing pressure, a single passage over the paper can just be seen.

To obtain sufficiently distinct work diagrams, trace the diagram two or three times.

Lubricate the mechanism with thin oil.

2.3 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.

2.4 Fitting the Indicator

Dismantle the upper part.

Give the piston a little cylinder oil.

Check that the various recesses are clean.

Otherwise the parts could be positioned askew, and this would cause the piston to move sluggishly in the cylinder.

Mount the upper part.

Fit the indicator and the cord.

Engage the indicator drive.

Check the cord alignment.

Adjust the length of the indicator cord so that:

- the diagram is traced in the centre of the paper,
- the cord is tight in all positions.

2.5 Taking the Diagrams

For diagram descriptions and nomenclature - [see Plate 70615](#).

1. Atmospheric line:

Keep the indicator valve closed.

Press the stylus against the paper.

Release the stylus when the indicator drive has turned the drum one or two times.



2. For engines fitted with indicator drive/ PMI-system.

Indicator diagram:

Open the indicator valve.

Press the stylus against the paper.

Release the stylus, when the drum has turned two or three times.

Close the indicator valve.

3. Draw diagram:

Release the cord from the indicator drive.

Open the indicator valve.

Watch the movement of the stylus.

At the moment it moves upwards, *simultaneously*

- Press it against the paper.
- Pull the cord just quickly enough for the stylus to trace the compression and ignition sequence.

This operation requires some practice to ensure that both compression and maximum pressures are clearly recorded.

Close the indicator valve.

If the indicator quickly becomes very hot, and the piston is black after use, then this means that there is a leakage.

In such a case, exchange the piston and liner.

See also item 2.2 in this Appendix.

4. Check that the diagrams have been correctly taken and are distinct.

Normal indicator and draw diagrams are shown in the illustration, [Plate 70615](#).

Examples of incorrect diagrams and possible causes are shown on [Plate 70617](#). See also Item 2.6 in this Chapter.

Regarding pressure evaluation and engine power calculation, see Appendix 2 in this Chapter.

5. Repeat Items 2.3, 2.4 and 2.5 for the remaining cylinders.

Lubricate the piston with a drop of cylinder oil after about six diagrams have been taken.

When diagram taking is finished, unscrew the indicator head.

Clean and lubricate both the cylinder and the piston with cylinder oil.

2.6 Diagram Faults

The most common faults are shown on [Plate 70617](#), in Figs. 1 to 6.

Fig. 1 For engines fitted with indicator drive: Vibrations in the cord, or drive, give a wavy indicator diagram, but a smooth draw diagram.

Fig 2 For engines fitted with indicator drive: The drum hits the stop at one of the end points, before the diagram is completed:
The cord is too long or too short.

Fig. 4 The indicator piston works sluggishly in the cylinder, and moves in jerks: If only the expansion curve is wrong (wavy), the cause may be gas pulsations in the combustion chamber or indicator bore.

Fig. 5 The indicator spring is too weak. The piston strikes against the top of the indicator cylinder. Change to a more rigid spring.

Fig. 6 The indicator valve leaks:
Gives an untrue atmospheric line.



2.7 Adjustment of Indicator Drive

Plate 70616

The paper drum of the indicator is driven by the indicator drive, which is activated by the indicator cam on the camshaft, in line with the corresponding cylinder.

The indicator drive must be adjusted so that the position of the paper drum at any moment corresponds to the position of the main piston, when taking the diagrams.

This ensures correct indicator diagrams.

Check the adjustment of the individual indicator drives regularly, and after disassembling in the following way:

1. Prepare the indicator valve and indicator for taking diagrams.

See previous Items 2.3 and 2.4

2. Cut-off fuel injection in one cylinder:

- Reduce the load to 35-50% of MCR (70-80% of MCR speed).
- Pull the fuel rack for the cylinder concerned to 'O' index.

Alternatively, lift the roller guide as described in Vol. II, Procedure 909-5. Start the engine and load to 35-50% of MCR power (70-80% of MCR speed).

3. Trace the compression and expansion lines.

Follow the procedure in Item 2.5, point 2, 'Indicator Diagram'.

The compression line is traced when the engine piston moves upwards, and the expansion line is traced when the engine piston moves downwards.

4. Evaluate the diagram:

Do the compression line and the expansion line coincide?	
YES	The indicator drive is correctly adjusted. <i>See also Plate 70616, Fig. 1.</i>
NO	The indicator drive is incorrectly adjusted. <i>See also Plate 70616, Fig. 2.</i> Adjust the indicator drive. <i>See Plate 70616, Case A and Case B.</i>



Indicator Diagram, Pressure Measurements and Engine Power Calculations

Regarding taking the diagrams, see Appendix 1 in this Chapter.

1. Compression Pressure, Maximum Pressure, and Faults

Plate 70618 (See also Plate 70615)

Measure the compression pressure and maximum pressure on the cards.

Use a scale rule which corresponds to the stiffness of the indicator spring used.

Compare the measurement results to the normal values for the actual engine.

Figs. 1-3 show some typical examples of engine maladjustment and faults which can be derived from the indicator and draw diagrams.

Fig. 1

Maximum pressure too low, but compression pressure correct.

Fuel injection delayed, check:

- the fuel pressure at engine (after the filter), *see Chapter 701 'Alarm Limits'.*
- the fuel valves function
- the fuel pump suction valve, puncture valve and shock absorber.
- VIT-index.

If the above are in order, the fuel oil is injected too late in relation to its ignition characteristics.

Note: Exceptionally bad fuels can have very poor ignition qualities.

Increase the fuel pump lead.

See Vol. II, Chapter 909.

Fig. 2

Maximum pressure too high, but compression pressure normal.

Too early injection, check VIT-index.

If this is in order, reduce the fuel pump lead. *See Vol. II, Chapter 909.*

Fig. 3

Compression and maximum pressures both too low. Possible causes:

- piston ring blow-by ★
- leaking exhaust valve ★
- increased combustion space volume (piston crown burnt) ★
- low scavenge air pressure, for instance due to fouling of exhaust and/or air system.
- defective or maladjusted damping arrangement in the exhaust valve ★
- Cooling water inlet and air inlet temperatures deviate from reference ambient conditions.

See also Appendix 3 in this Chapter.

★ *See also section 'Evaluation of Records', Item 2.2 'Compression Pressure', page 706.09.*



2. Area of Indicator Diagram

(For engines fitted with indicator drive or PMI-system)

Plate 70619

If the planimeter is adjustable, check the setting before use.

For checking, use the reference template, or the area of an accurately drawn rectangle or circle.

Place the planimeter and indicator card on a piece of plane cardboard (not too smooth), as shown in the illustration.

Trace the diagram as described in *Plate 70619*.

Note: Only consider the result satisfactory, when two readings are obtained which do not differ more than '1' on the planimeter vernier scale.

3. Calculation of the Indicated and Effective Engine Power

(For engines without indicator drive or PMI-system, see *Appendix 5 in this Chapter*)

Calculation of the indicated and effective engine power consists of the following steps:

Calculate:

- The mean indicated pressure, p_i
- The mean effective pressure, p_e
- The cylinder constant, k_2
- The indicated engine power, P_i
- The effective engine power, P_e

The mean indicated pressure, p_i

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

where:

$A \text{ (mm}^2\text{)}$ = area of the indicator diagram, as found by planimetry.

$L \text{ (mm)}$ = length of the indicator diagram (= atmospheric line).

$C_s \text{ (mm/bar)}$ = spring constant (= vertical movement of the indicator stylus (mm) for a 1 bar pressure rise in the cylinder).

p_i corresponds to the height of a rectangle with the same area and length as the indicator diagram.

I.e., if p_i was acting on the piston during the complete downwards stroke, the cylinder would produce the same total work as actually produced in one complete revolution.

The mean effective pressure, p_e

$$p_e = p_i - k_1 \text{ (bar)}$$

where

k_1 = the mean friction loss

The mean friction loss has proved to be practically independent of the engine load. By experience, k_1 has been found to be approx. 1 bar.

The cylinder constant, k_2

k_2 is determined by the dimensions of the engine, and the units in which the power is wanted.

For power in kW : $k_2 = 1,30900 \times D^2 \times S$

For power in BHP : $k_2 = 1,77974 \times D^2 \times S$

where:

$D \text{ (m)}$ = cylinder diameter

$S \text{ (m)}$ = piston stroke



Engine type	For power in kW k_2	For power in BHP k_2
S46MC-C	0.5351	0.7276
L50MC	0.5301	0.7208
S50MC	0.6250	0.8498
S50MC-C	0.6545	0.8899
L60MC	0.9161	1.2455
S60MC	1.0801	1.4685
S60MC-C	1.1310	1.5377
L70MC	1.4547	1.9779
S70MC	1.7151	2.3319
S70MC-C	1.7959	2.4418
L80MC	2.1715	2.9524
S80MC	2.5602	3.4809
K80MC-C	1.9268	2.6198
L90MC	3.0918	4.2037
K90MC	2.7037	3.6761
K90MC-C	2.4387	3.3157
S90MC-T	3.3802	4.5958
K98MC-C	3.0172	4.1022
S90MC-T	3.3802	4.5958
K98MC-C	3.0172	4.1022

The indicated engine power, P_i

$$P_i = k_2 \times n \times p_i \text{ (i kW or ihp)}$$

where

n (rpm) = engine speed.

The effective engine power, P_e

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

where

n (rpm) = engine speed.

Due to the friction in the thrust bearing, the shaft power is approx. 1% less than the effective engine power.



Correction of Performance Parameters

1. General

Some measured performance parameters need to be corrected to ISO ambient conditions to facilitate reliable evaluation.

These parameters are: $p_{\max}$, t_{exh} , p_{comp} and p_{scav} . See also 'Performance Observations', page 706.03.

Making such corrections enables comparison to earlier (corrected) readings or model curves, regardless of deviations of the actual t_{inl} and t_{coolinl} from reference conditions.

i.e. the correction provides the values which would have been measured if t_{inl} and t_{coolinl} had been 25°C.

In extreme cases, the divergencies can be large.

Record the corrected value as described in Section, 'Evaluation of Records' in this Chapter. See page 706.05.

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 ($t_{\text{scav}} - t_{\text{coolinl}}$).

See also Item 1 'Symbols and Limits', earlier in this Chapter.

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:

$$A_{\text{corr}} = (t_{\text{meas}} - t_{\text{ref}}) \times F \times (K + A_{\text{meas}})$$

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}	$- 2.446 \times 10^{-3}$	$- 0.59 \times 10^{-3}$	273
p_{scav}	$+ 2.856 \times 10^{-3}$	$- 2.220 \times 10^{-3}$	p_{baro} 1 bar or 750 mm H _g
p_{comp}	$+ 2.954 \times 10^{-3}$	$- 1.530 \times 10^{-3}$	p_{baro} 1 bar or 750 mm H _g
p_{max}	$+ 2.198 \times 10^{-3}$	$- 0.810 \times 10^{-3}$	p_{baro} 1 bar or 750 mm H _g

3. Examples of calculations:

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

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

Measured:

Exh. temp. after valve = 425 °C

Air inlet temp. = 42 °C

Cool. w. inlet temp.(air cooler) = 40 °C

Correction for air inlet temp.:

$$(42-25) \times (-2.466 \times 10^{-3}) \times (273+425) = -29.3^\circ\text{C}$$

Correction for cooling water inlet temp.:

$$(40-25) \times (-0.59 \times 10^{-3}) \times (273+425) = -6.2^\circ\text{C}$$

Corrected t_{exhv} value = $425 - 29.3 - 6.2 =$

$$\underline{389.5^\circ\text{C}}$$

2) Correction of p_{scav} (Plate 70623):

Measured:

Scav. air pressure = 2.0 bar

Air inlet temp. = 42 °C

Cool. w. inlet temp.(air cooler) = 40 °C

Correction for air inlet temp.:

$$(42-25) \times (2.856 \times 10^{-3}) \times (1+2.0) = 0.146 \text{ bar}$$

Correction for cooling water inlet temp.:

$$(40-25) \times (-2.220 \times 10^{-3}) \times (1+2.0) = -0.10 \text{ bar}$$

Corrected p_{scav} value

$$= 2.0 + 0.146 - 0.10 = \underline{2.046 \text{ bar}}$$

Alternatively, if p_{scav} is measured in mmH_g:

Scavenge air pressure = 1500 mmH_g

Correction for t_{inl} :

$$(42-25) \times (2.856 \times 10^{-3}) \times (750+1500) = 109.2 \text{ mmH}_g$$

Correction for $t_{coolinl}$:

$$(40-25) \times (-2.220 \times 10^{-3}) \times (750+1500) = -74.9 \text{ mmH}_g$$

Corrected p_{scav} value

$$= 1500 + 109.2 - 74.9 = \underline{1534.3 \text{ mmHg}}$$

Corrections of p_{comp} (Plate 70622) and p_{ax} (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 433A	+ 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 - 'Evaluation of Records', point 2.2, page 706.07.

For new engines it is not unusual to observe a temperature increase of 50-60 °C from the shop test to the sea trial.

This is due to the operation on heavy fuel oil and altered climatic conditions.

If the temperature increases further during service:

- Find the cause of the temperature increase.
- Clean, repair or overhaul the components in question at the first opportunity, to improve the engine performance.

Note: The exhaust temperature must not exceed the alarm limit, see [Chapter 701, Item 427](#).

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 (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 temperature 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.



Turbocharger Efficiency

1. General

To record the turbocharger efficiencies, see 'Evaluation of Records' point 3 'Turbocharger synopsis' earlier in this Chapter.

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.

Use the following conversion factors:

750 mm Hg = 1.000 bar = 0.1 MPa
 1 mm H₂O = 0.0001 bar
 1 kp/cm² = 735 mm Hg = 0.98 bar
 1 bar = 0.1 MPa
 Π = 3.14159

		Unit	Examples of Measurements
Barometric pressure	p_{baro}	mm Hg or bar	766.5/750 = 1.022 bar
Pressure drop, air filter	Δp_f	mm H ₂ O or bar	21 × 0.0001 = 0.002 bar
Pressure drop, air cooler	Δp_c	mm H ₂ O or bar	168 × 0.0001 = 0.017 bar
Temperature before compr.	t_{inl}	°C	= 21 °C
Turbocharger speed	n	rpm	= 13350 rpm
Scavenge air pressure	p_{scav}	mm Hg or bar	1900/750 = 2.533 bar *)
Exhaust receiver pressure	p_{exh}	mm Hg or bar	1795/750 = 2.393 bar *)
Pressure after turbine	p_{atc}	mm H ₂ O or bar	265 × 0.0001 = 0.026 bar *)
Temperature before turbine	t_{btc}	°C	= 400 °C

*) ``Gauge" Pressure

Table 1: Measurements for calculation of efficiencies

Note that the official designation of bar is ``absolute pressure".



Total Efficiency:

The total efficiency η_{tot} is given by the equation

$$\eta_{\text{tot}} = 0.9055 \frac{T_1 (R_1^{0.286} - 1)}{T_2 (1 - R_2^{0.265})}$$

	Example of Calculation, η_{tot} See measurements in Table 1		
$T_1 = t_{\text{inl}} + 273$	$21 + 273$	=	294 °K
$R_1 = \frac{p_{\text{baro}} + p_{\text{scav}} + \Delta p_c}{p_{\text{baro}} - \Delta p_f}$	$\frac{1.022 + 2.533 + 0.017}{1.022 - 0.002}$	=	3.502
$T_2 = t_{\text{btc}} + 273$	$400 + 273$	=	673 °K
$R_2 = \frac{p_{\text{baro}} + p_{\text{atc}}}{p_{\text{baro}} + p_{\text{exh}}}$	$\frac{1.022 + 0.026}{1.022 + 2.393}$	=	0.307
$(R_1^{0.286} - 1) \star$		=	0.4311
$(1 - R_2^{0.265}) \star$		=	0.2688
$\eta_{\text{tot}} = \frac{0.9055 \times T_1 (R_1^{0.286} - 1)}{T_2 (1 - R_2^{0.265})}$	$\frac{0.9055 \times 294 \times 0.4311}{673 \times 0.2688}$	=	<u>0.634</u>

Compressor efficiency:

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

$$\eta_{\text{compr}} = \frac{3614400 \times T_1 (R_1^{0.286} - 1)}{\mu \times U^2}$$

μ = slip factor, [see Plate 70628](#)

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

D = Diameter of compressor wheel,
[see Plate 70628](#)

$U = \pi \times D \times n$ is the peripheral speed of the compressor wheel.

The turbocharger used in this example is an MAN B&W, type NA57/TO7.

From [Plate 70628](#) is taken:

$$D = 0.656 \text{ m}$$

$$\mu = 0.77$$

	Example of Calculation, η_{compr} See measurements in Table 1		
$T_1 = t_{\text{inl}} + 273 \text{ °K}$	$21 + 273$	=	294 °K
$R_1 = \frac{p_{\text{baro}} + p_{\text{scav}} + \Delta p_c}{p_{\text{baro}} - \Delta p_f}$	$\frac{1.022 + 2.533 + 0.017}{1.022 - 0.002}$	=	3.502
$(R_1^{0.286} - 1) \star$		=	0.4311
$U^2 = (\pi \times D \times n)^2$	$(\pi \times 0.656 \times 13350)^2$	=	757000000
$\eta_{\text{compr}} = \frac{3614400 \times T_1 (R_1^{0.286} - 1)}{\mu \times U^2}$	$\frac{3614400 \times 294 \times 0.4311}{0.77 \times 757000000}$	=	<u>0.786</u>

★ 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

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

$$\text{i.e. } \eta_{\text{turb}} = \frac{\eta_{\text{total}}}{\eta_{\text{compr}}} = \frac{0.634}{0.786} = 0.807$$

2.2 Plants with TCS and/or Exhaust By-Pass

The equation $\eta_{\text{tot}} = 0.9055 \frac{T_1 (R_1^{0.286} - 1)}{T_2 (1 - R_2^{0.265})}$ stated in item 2.1 is based on a situation where the mass flow through the turbine is equal to the mass flow through the compressor plus the fuel oil amount.

If a TCS or an exhaust by-pass is fitted, the mass flow through the turbine is reduced by the mass flow through the TCS or the exhaust by-pass.

The mass flows through the turbine and the TCS or through the turbine and the exhaust by-pass are proportional to the effective areas in the turbines or the orifice in the exhaust by-pass.

Calculate the turbocharger efficiency as described in Item 2.1 'Plants without TCS and exhaust by-pass'.

Then correct the results in accordance with the following:

Total efficiency:

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

where

A_{eff} = Effective area in turbocharger turbine

a_{eff} = Effective area in TCS or exhaust by-pass.

See also 'Remarks', below

Turbine Efficiency:

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

See also 'Remarks', below

Compressor Efficiency:

η_{compr} is unchanged, as it is not affected by whether the plant operates with TCS/by-pass or not.

Remarks

The relation $\frac{A_{\text{eff}} + a_{\text{eff}}}{A_{\text{eff}}}$ can vary from plant to plant, but is most often about 1.07. This value can be used when evaluating the trend of the efficiency in service.

When using a computer program in which the relation $\frac{A_{\text{eff}} + a_{\text{eff}}}{A_{\text{eff}}}$ is not introduced, the value for η_{tot} and η_{turb} will have to be multiplied by the above-mentioned factor of about 1.07.

Estimation of the Effective Engine Power without Indicator Diagrams

1. General

The estimation is based on nomograms involving engine parameter measurements taken on testbed.

The nomograms are shown in [Plate 70627](#). The following relationships are illustrated:

Chart I - fuel pump index and mean effective pressure.

Chart II - mean effective pressure and effective engine power (BHP), with the engine speed as a parameter.

Chart III - turbocharger speed and effective engine power (BHP), 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 [Plate 70627](#))

2.1 Fuel Pump Index

(an approximate method)

Chart I: draw a horizontal line from the observed fuel pump 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. 16,400 BHP.

This method should only be used as a quick (rough) estimation, because the fuel oil, as well as the condition of the fuel pump, may have great effect on the index. In particular, worn fuel pumps or suction valves tend to increase the index, and will thus result in a too high power estimation.

2.2 Turbocharger Speed

(A more accurate method)

Chart III: draw a horizontal line from the observed t_{scav} value and an inclined line from the observed turbocharger speed.

From the intersection point, draw a vertical line down to the nomogram curve and then a horizontal line to the vertical line from the observed ambient pressure (point x in the ambient pressure scale).

Finally, a line is drawn parallel with the inclined 'ambient pressure correction' lines. The effective engine power can then be read on the scale at the right hand side, i.e. 15,700 BHP.

This method is more reliable, and an accuracy to within $\pm 3\%$ can be expected. However, the accuracy obtained will depend on the condition of the engine and turbocharger. A fouled or eroded turbocharger will in most cases tend to decrease the turbocharger speed, and thus result in a too low power estimation.

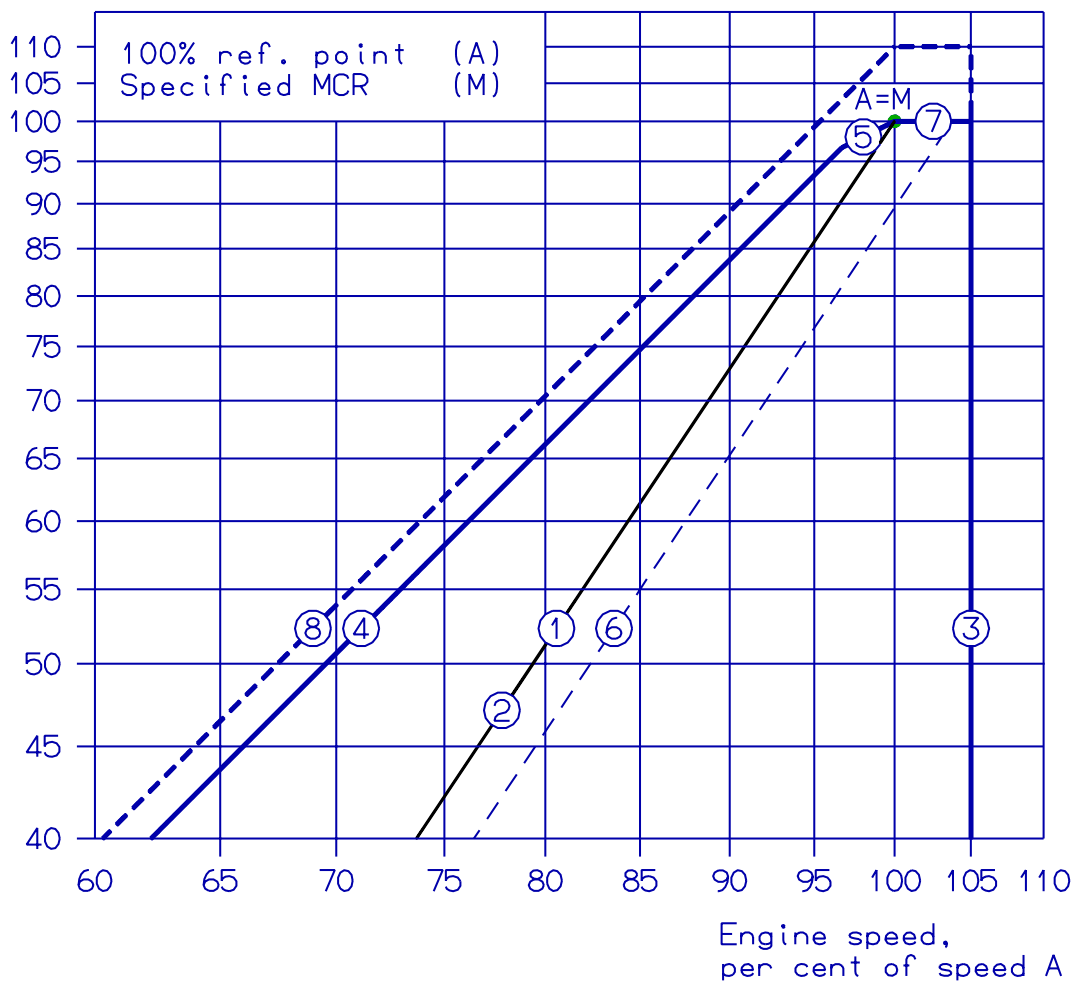
This situation is characterized by increased exhaust gas temperatures and a decreased scavenge air pressure.

It is recommended to apply PMI-system, for easy access to P-V-diagrams (work diagrams) for power calculation.

See also [Appendix 2](#) in this Chapter.



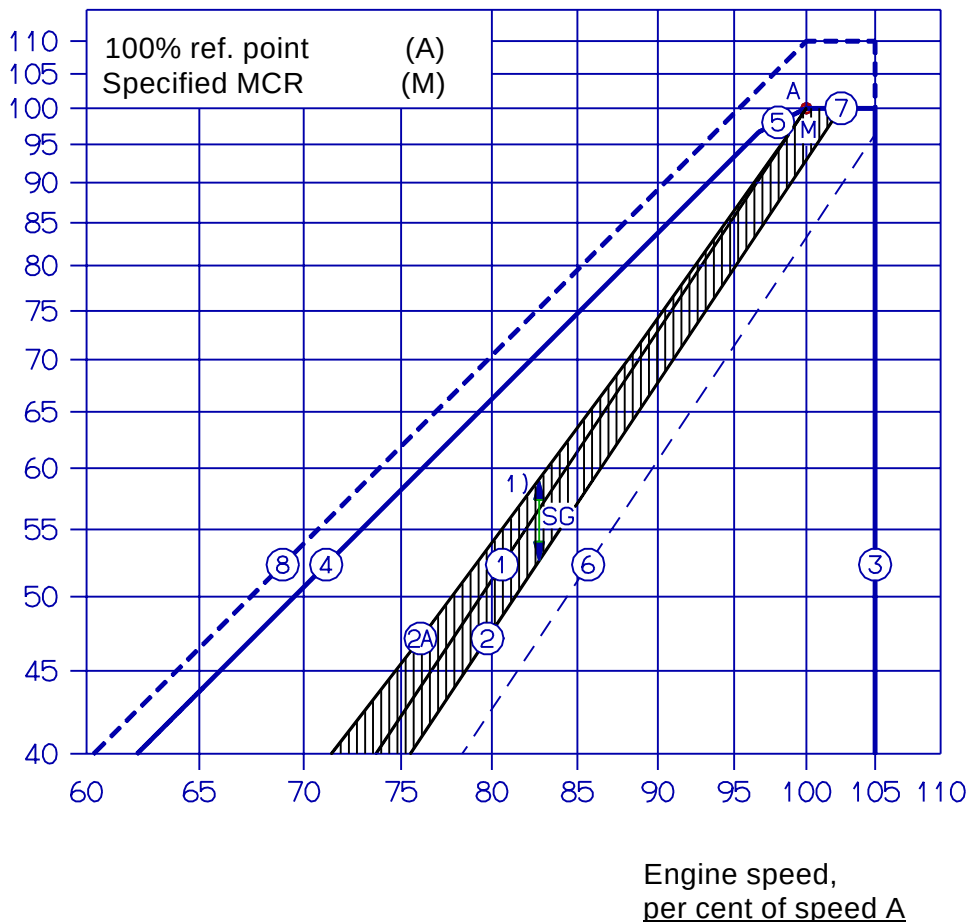
Engine shaft power,
per cent of power A



- Line 1: Propeller curve through point A.
- 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: 2.5-5.0%), for clean hull and calm weather conditions.
- Line 7: Power limit for continuous running.
- Line 8: Overload limit.



Engine shaft power,
per cent of power A



- Line 1 : Propeller curve through point A.
- Line 2 : Propeller curve for propulsion alone - heavy running, recommended limit for fouled hull at calm weather conditions.
- Line 2A : Engine service curve for 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: 2.5-5.0%), for clean hull and calm weather conditions.
- Line 7 : Power limit for continuous running.
- Line 8 : Overload limit.

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.



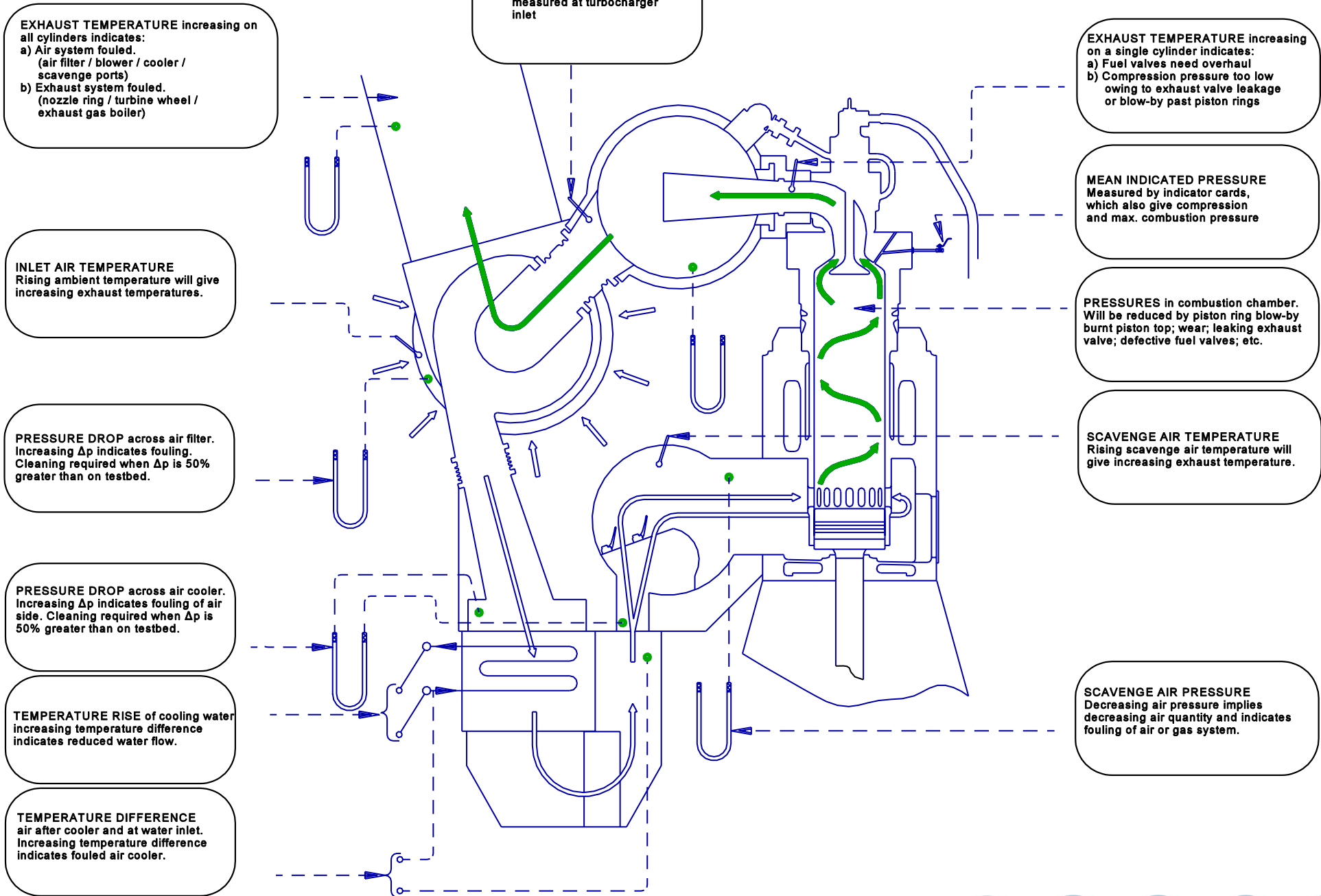
M/V		Engine Type:				Engine Layout:				Checked by:							
Yard:		Builder:		Engine		BHP:				Date:							
No.:		Built year:		No.:		r/min:											
Turbocharger(s)				Serial No.													
Make:		1		Cylinder constant (HP, bar)													
Type:		2		Governor:				Type:									
Max. RPM:		3		TC specification:													
Max. temp. °C:		4															
Lub. oil system: Internal system ☐ External from M. E. system ☐ External from gravity tank ☐																	
Fuel oil viscosity						at °C		Brand				Type					
Bunker station						Cylinder oil											
Oil brand						Heat value Kjoule/kg:		Circulating oil									
Density at 15°C:						Sulphur %:		Turbo oil									
Date	Draught fore m	Total running hours	RPM	Wind m/s	Direct	P_i bar			P_{max} bar			P_{comp} bar			Fuel pump index		
																	
Hour	Draught aft m	Speed setting bar	kW indicated	Wave height m	Direct	1	2	3	1	2	3	1	2	3	1	2	3
						4	5	6	4	5	6	4	5	6	4	5	6
Load %	Log Knots	Governor index	kW effective	g/kWh effective		7	8	9	7	8	9	7	8	9	7	8	9
						10	11	12	10	11	12	10	11	12	10	11	12
Barom. millibar	Obs. Knots	Pmax contr. pressure bar	BHP	g/BHP		10	11	12	10	11	12	10	11	12	10	11	12
						Average			Average			Average			Average		

P_{max} adjustment index			Exhaust gas temp. °C						Exh. press.		Turbo-charger RPM		Scav. air pressure				Scav. air temp. °C			Auxiliary blower	
			Exhaust valve			Turbine			Receiver	Turbine outlet			Δp Filter mmWC		Δp Cooler mmWC		Receiver	Inlet blower	Before cooler		After cooler
						Inlet	Outlet	mmHg					mmWC	mmWC	mmWC						
1	2	3	1	2	3	1	1		1	1	1	1	bar	1	1	1	On				
4	5	6	4	5	6	2	2		2	2	2	2		2	2	2					
7	8	9	7	8	9	3	3		3	3	3	3	mmHg	3	3	3	Off				
10	11	12	10	11	12	4	4		4	4	4	4	°C	4	4	4					
Average			Average																		
Remarks:																					

Special points		Cooling water temperature °C						Lubricating oil										Fuel oil pressure bar	
MAN TC p at spiral housing outer dia. mm Hg	MAN TC/ BBC TC Δp inner and outer dia. mm WC	Air cooler		Main engine			Turbine	Press. bar	Temperature °C										Before filter
		Inlet	Outlet	Inlet	Outlet cylinders			Outlet	System oil	Inlet engine			Outlet pistons			Turbochargers		After filter	
					1	2	3			1	2	3	1	2	3	MAN TC inlet/ BBC TC blower end	MAN TC outlet/ BBC TC turbine end		
		1	1		4	5	6	2		Cooling oil	Inlet camshaft	4	5	6	1	1			
		2	2		7	8	9	3		Camshaft oil	Outlet camshaft	7	8	9	2	2			
3	3		10	11	12	4				10	11	12	3	3					
4	4		Average					Turbine oil	Thrust segments	Average				4	4				
																		Turn	



[illegible]

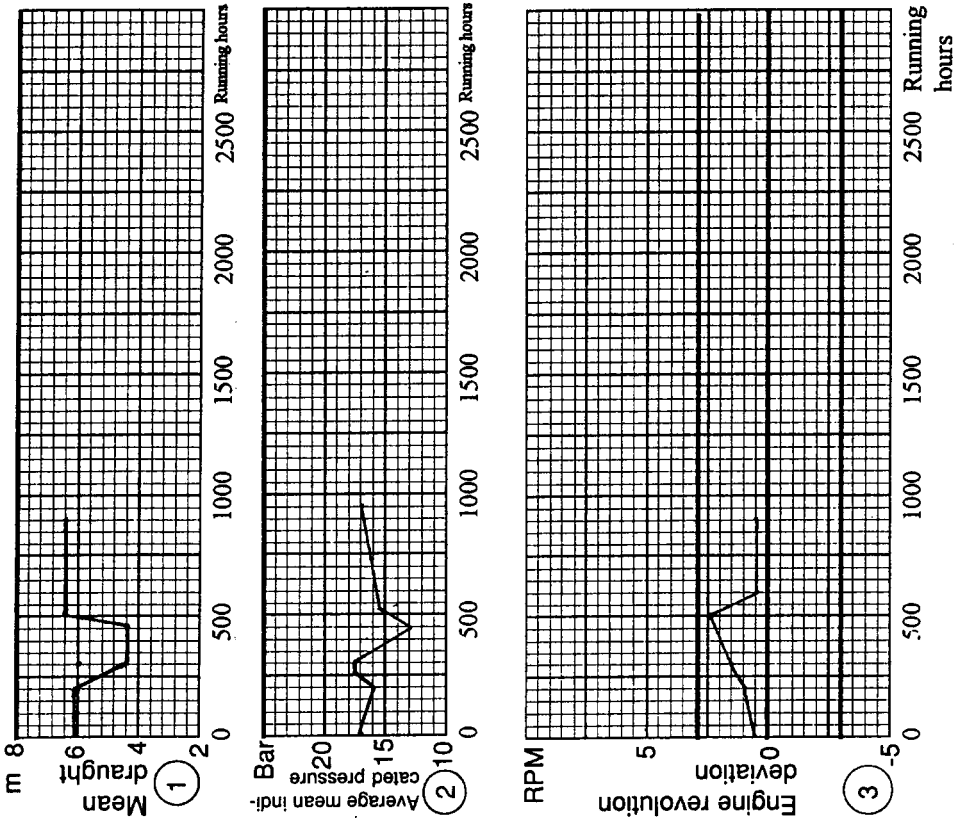


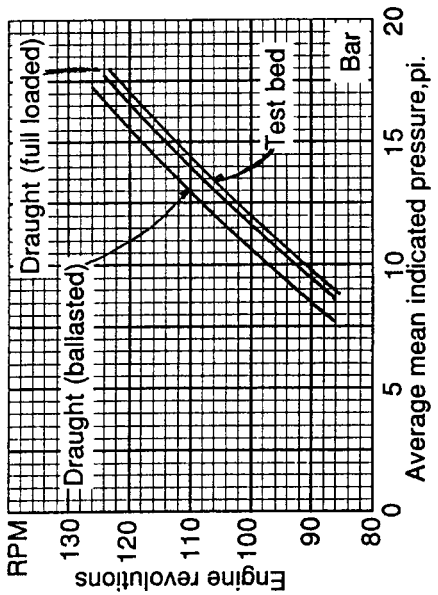
Time based deviation charts for: **mean draught**
and **average mean indicated pressure (p_i)**
Model curves + time based deviation chart for:
 r/min as a function of p_i

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

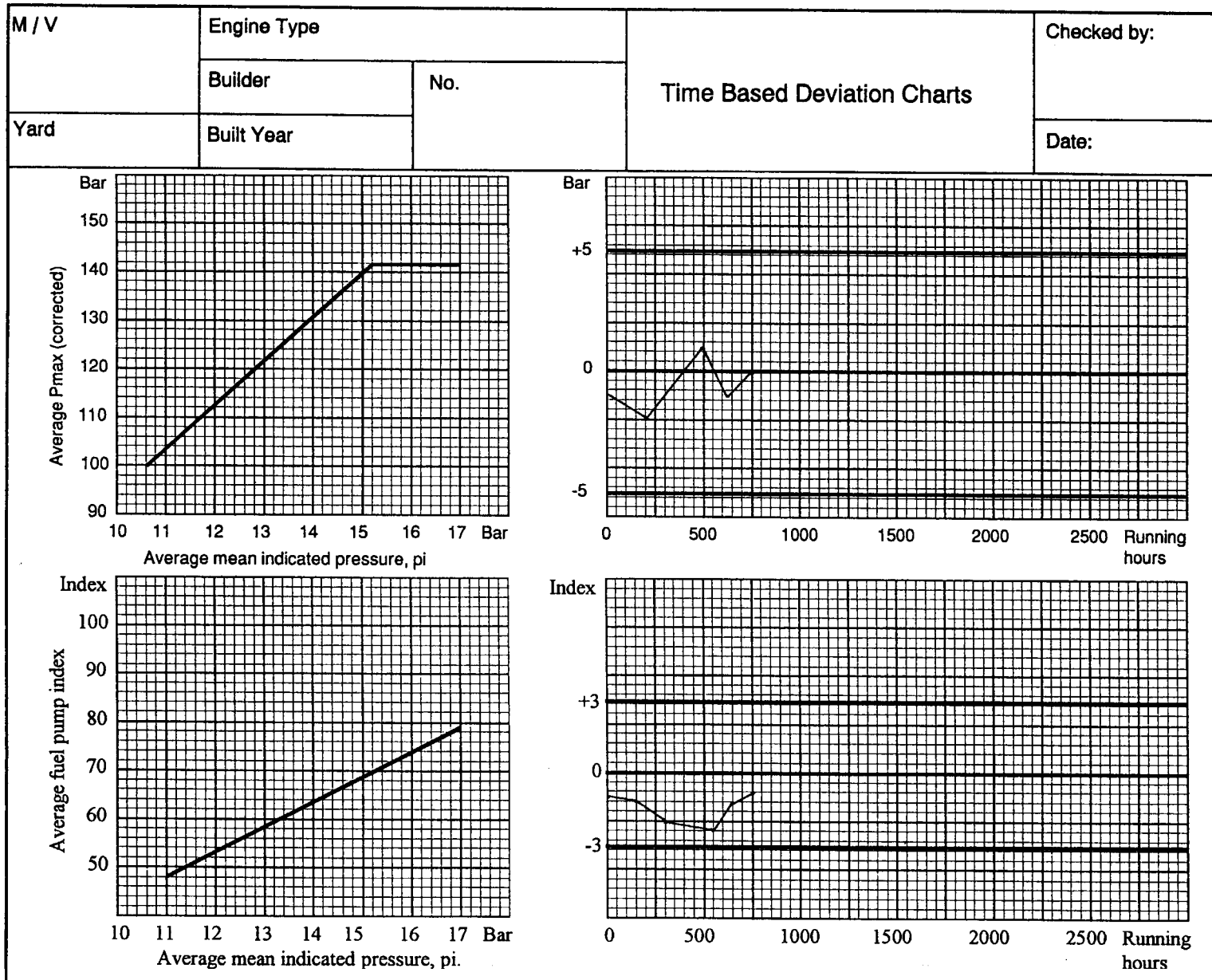
All the model Curves are based on Test results from Shop-trial or trial trip.

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).





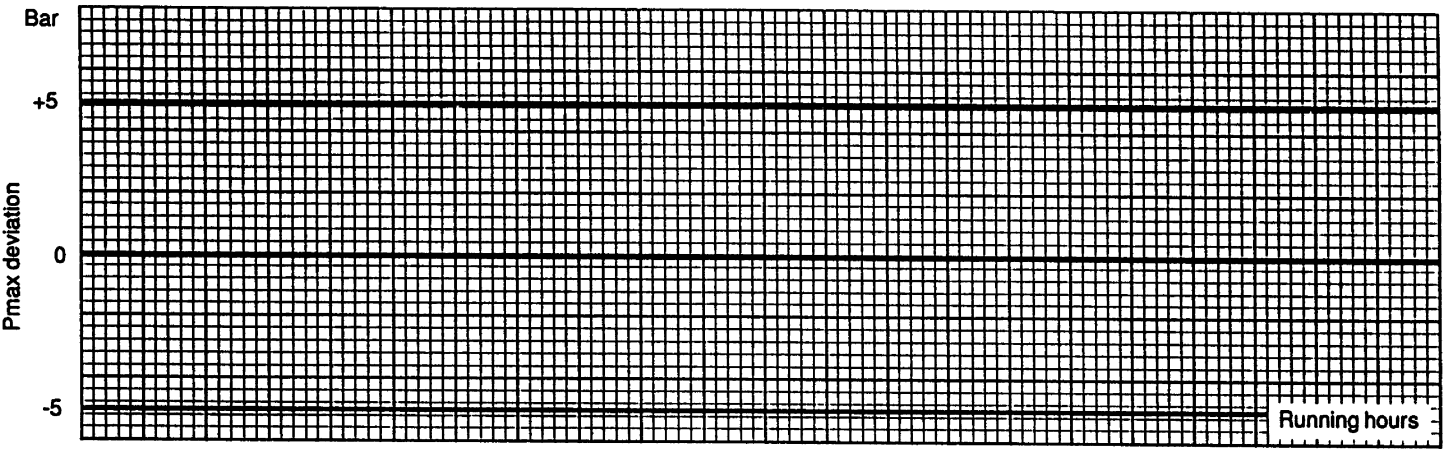
Model curves and time based deviation charts for:
 P_{max} and fuel pump index as a function of P_i



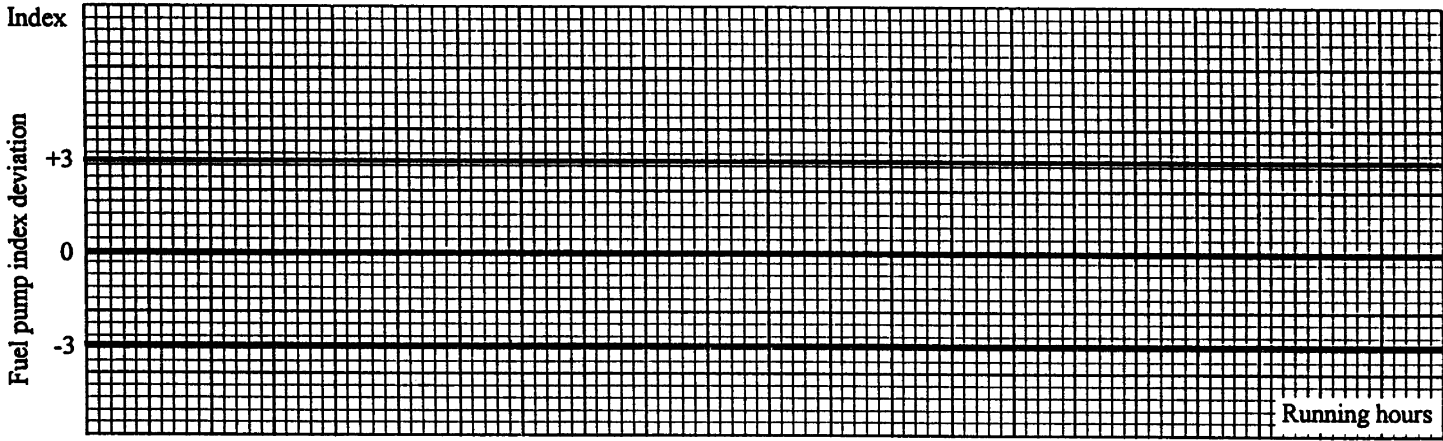
Time based deviation charts for:
p_{max} and **fuel pump index**

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

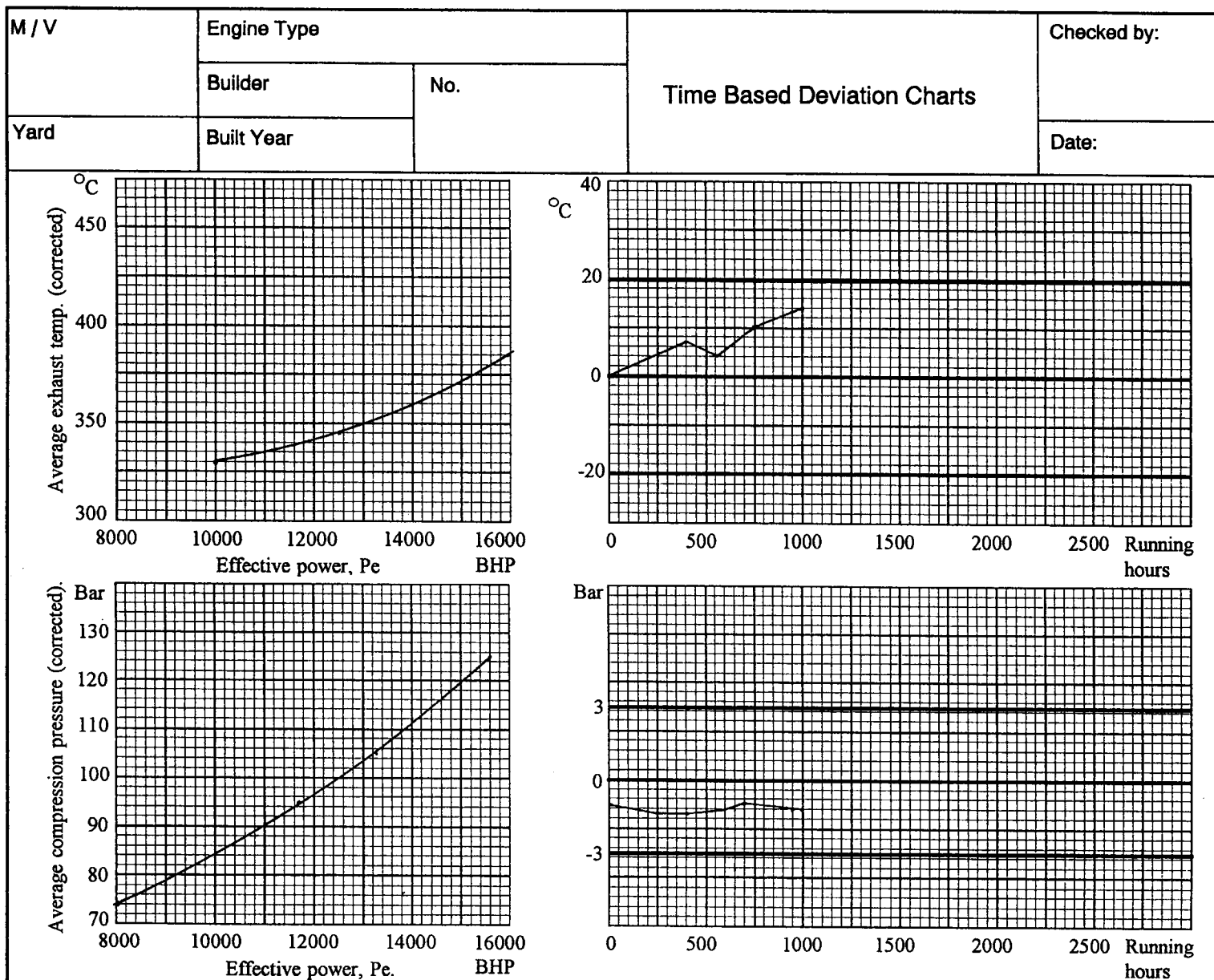
Bar



Index



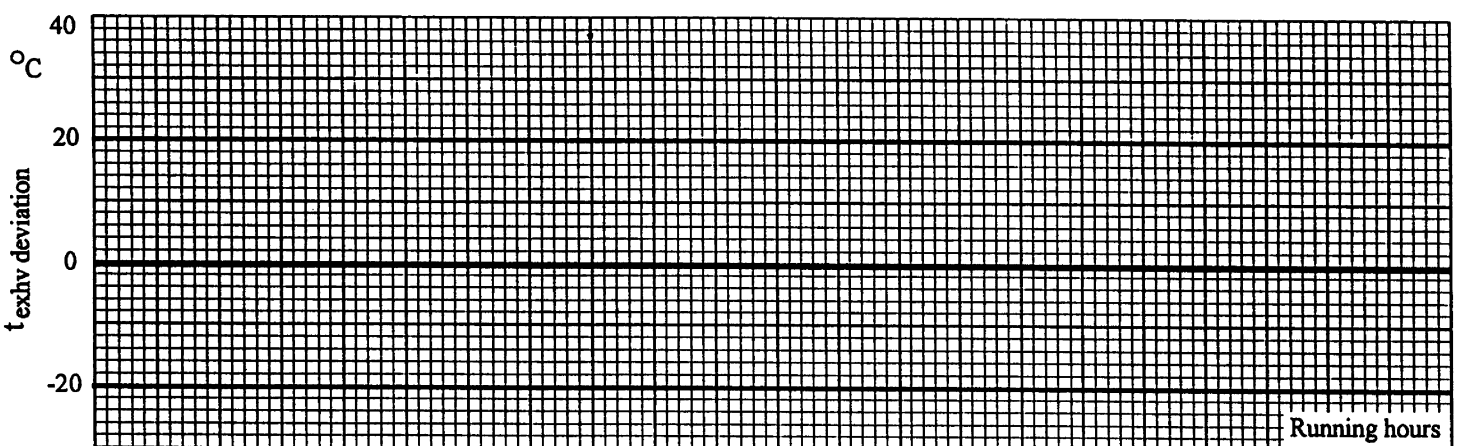
Model curves and time based deviation charts for:
 t_{exh} and P_{comp} as a function of P_e



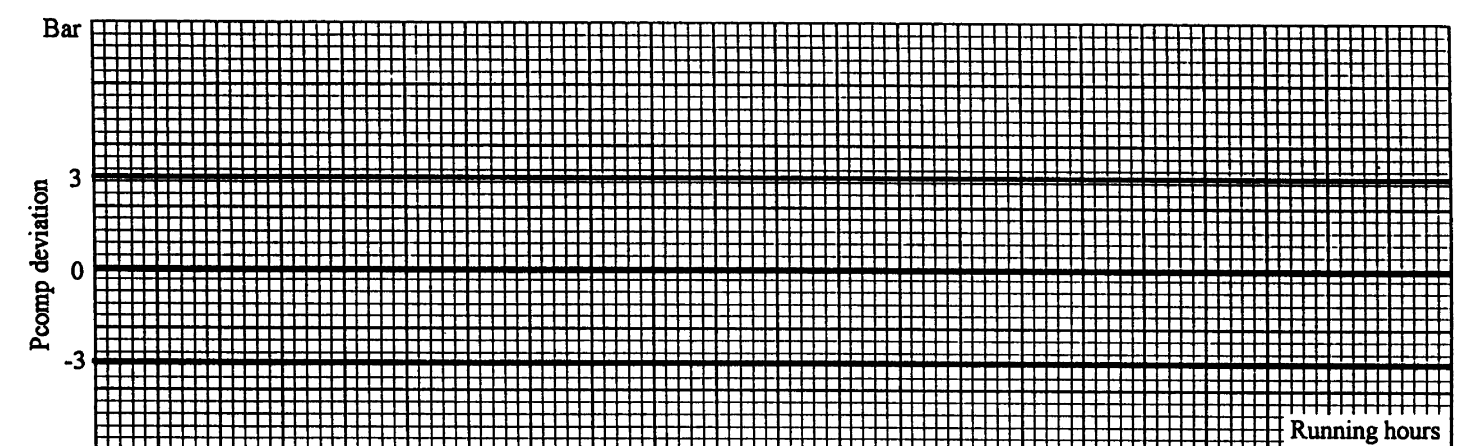
Time based deviation charts for: t_{exh} and p_{comp}

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

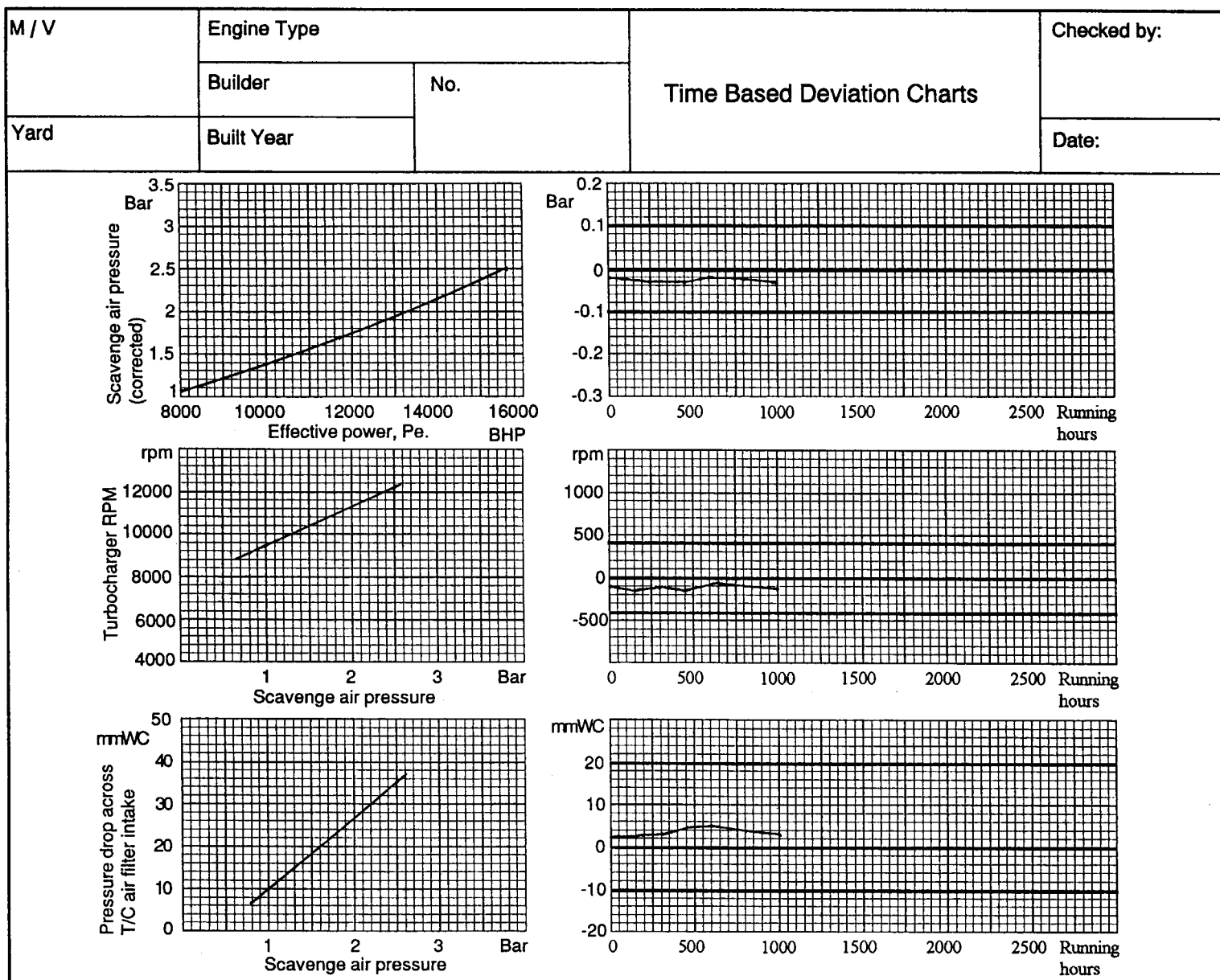
t_{exh} deviation $^{\circ}\text{C}$



Bar



Model curves and time based deviation charts for:
 p_{scav} as a function of p_e
 T/C r/min and Δp_f as a function of p_{scav}



Time based deviation charts for: P_{scav} , T/C r/min Δp_t

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

Bar
0.2
0.1
0
-0.1
-0.2
-0.3

Pscav deviation
Running hours

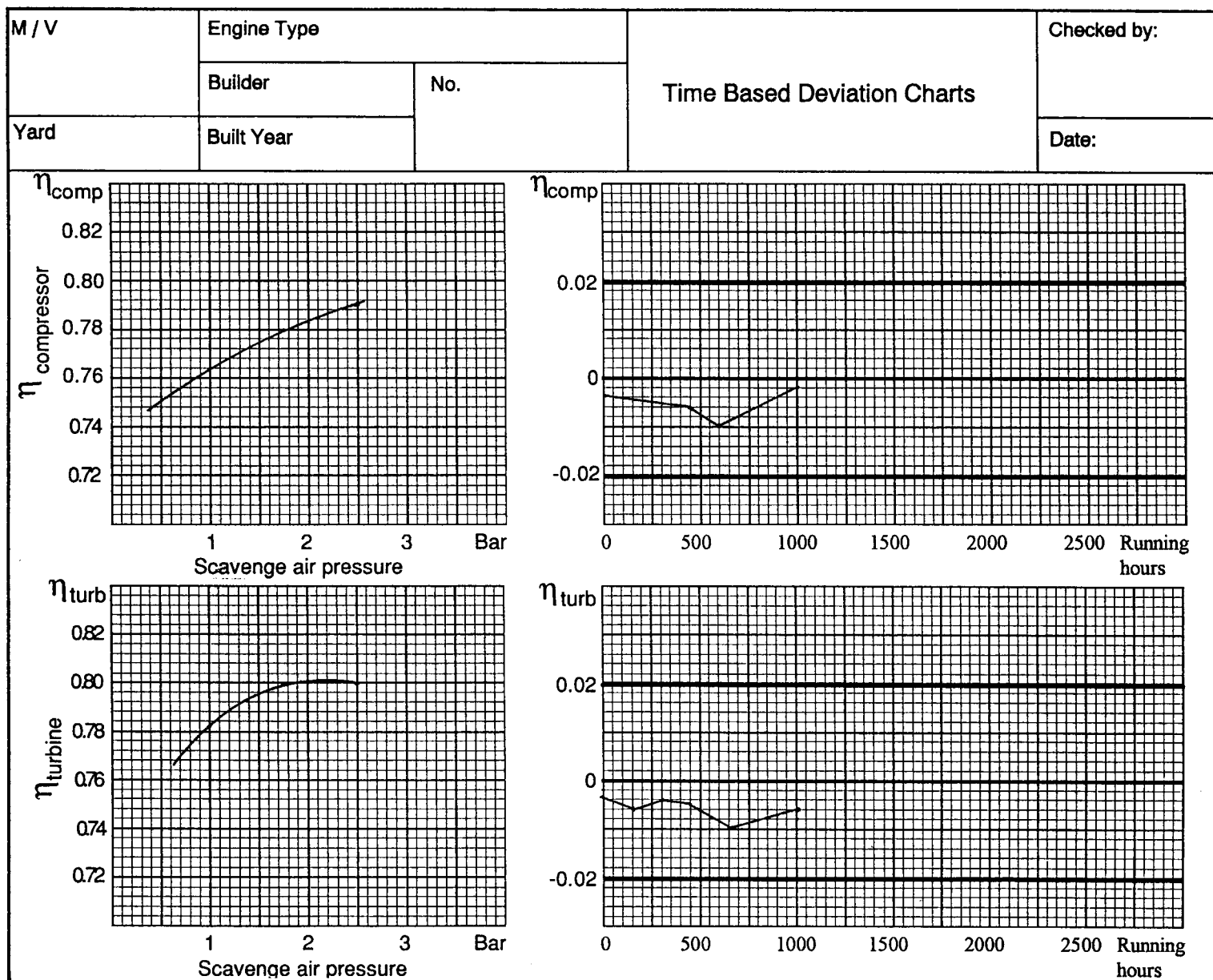
rpm
1000
500
0
-500

T/C rpm deviation
Running hours

mmWC
20
10
0
-10
-20

**T/C air filter
 Δp_f deviation**
Running hours

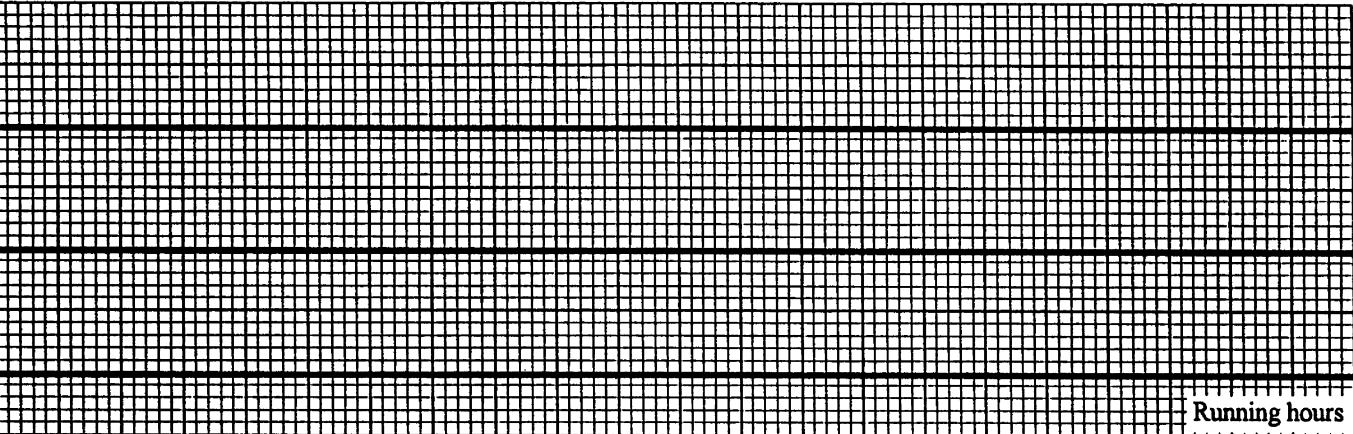
Model curves and time based deviation charts for:
compressor and turbine efficiencies as a function of P_{scav}



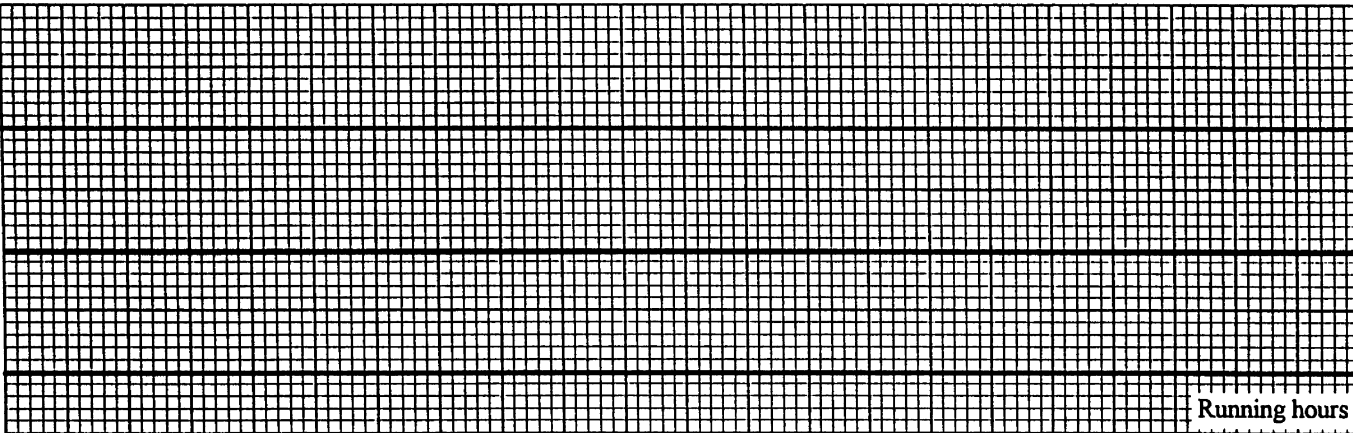
Time based deviation charts for:
compressor and turbine efficiencies

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

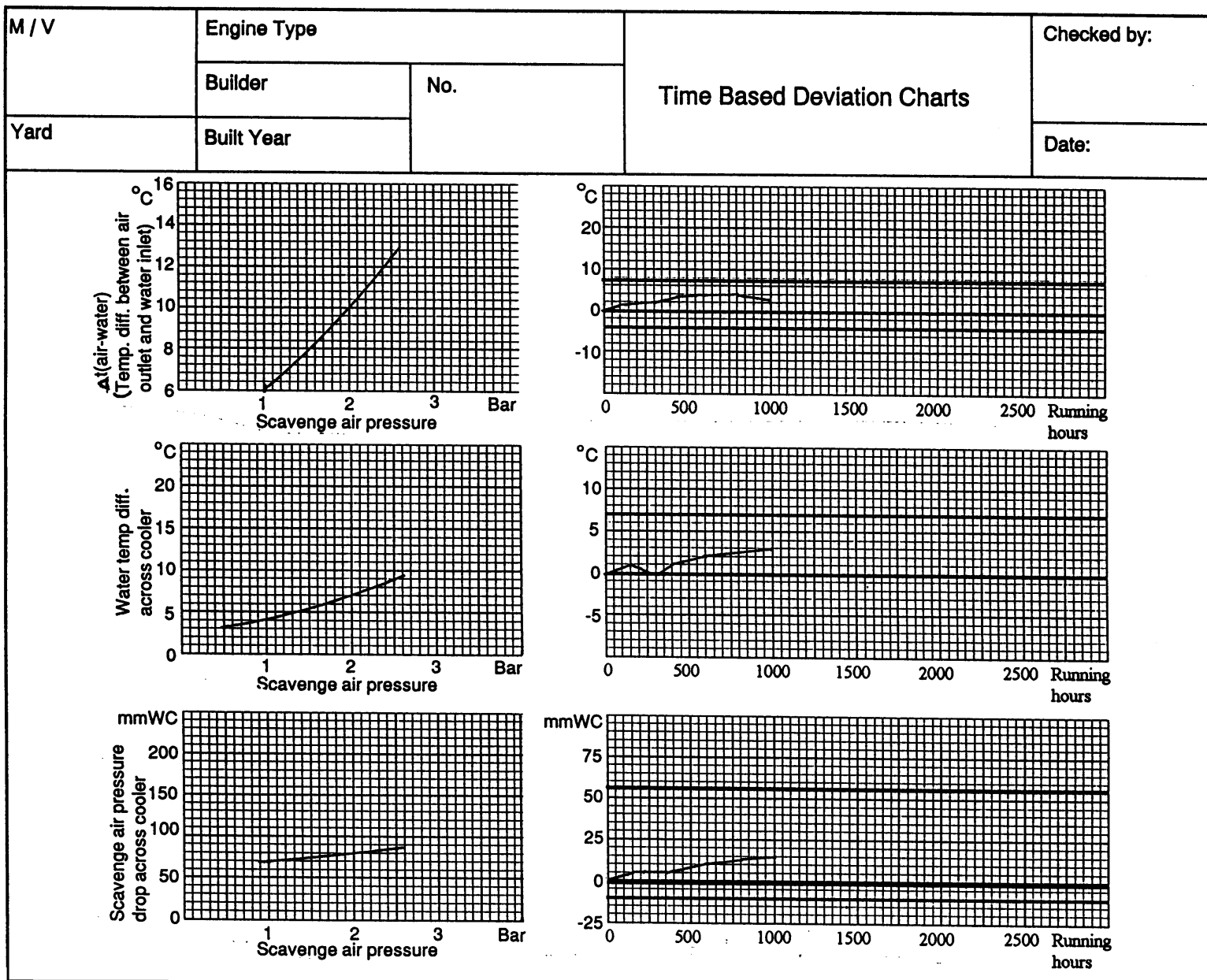
η_{comp}
Compressor efficiency deviation



η_{turb}
Turbine efficiency deviation



Model curves and time based deviation charts for:
 $\Delta t_{\text{air-water}}$, Δt_{water} , and Δp_{air} as functions of p_{scav}



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

$\Delta t_{\text{(air-water) deviation}}$ °C

Running hours

$\Delta t_{\text{water deviation}}$ °C

Running hours

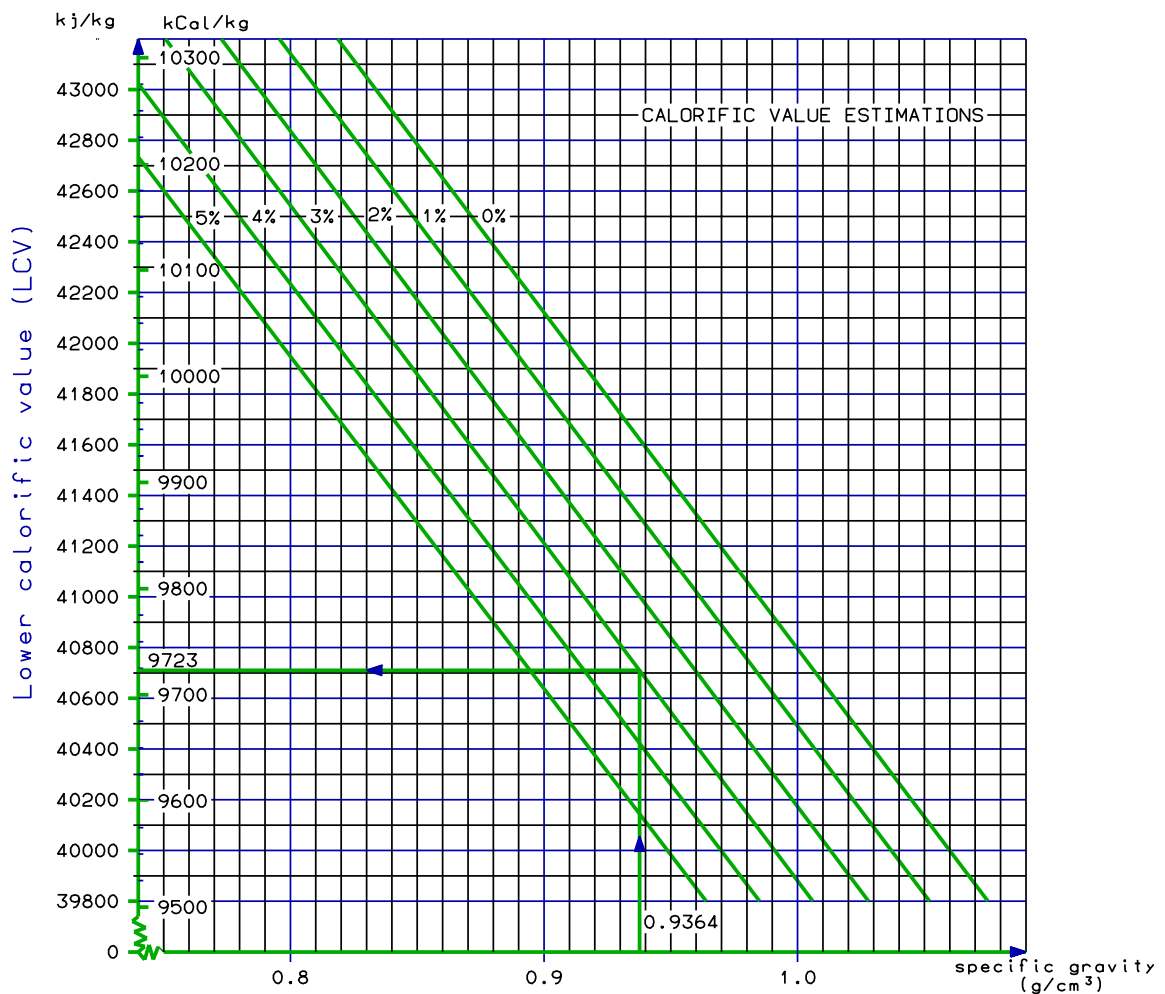
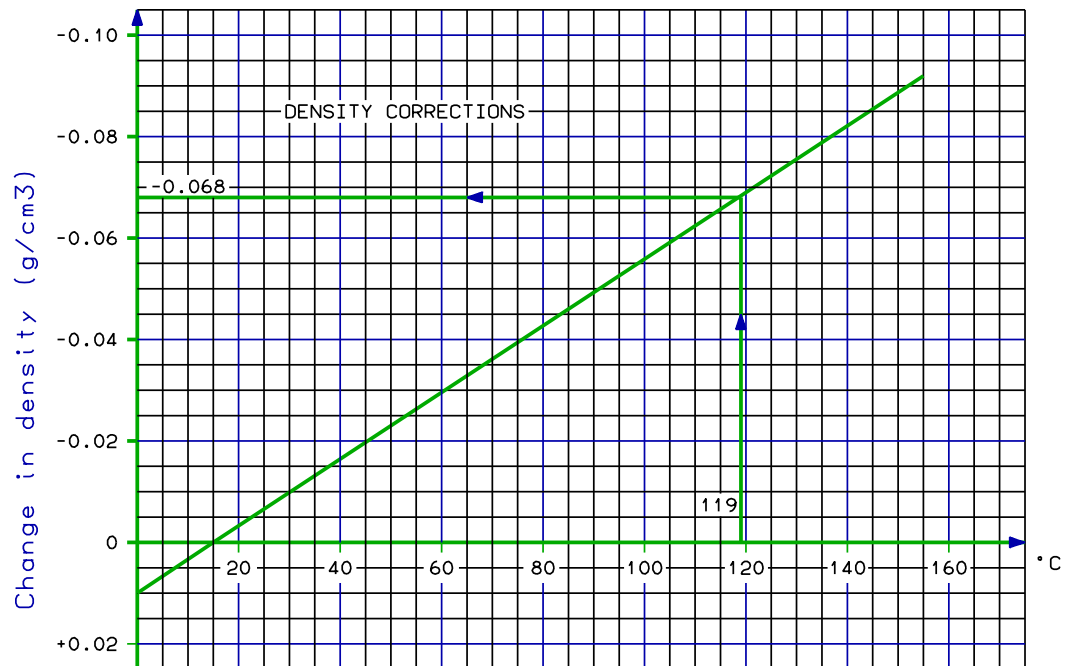
$\Delta P_{\text{air deviations}}$ mmWC

Running hours

Time based deviation charts for:
 $\Delta t_{\text{air-water}}$, Δt_{water} , and ΔP_{air}

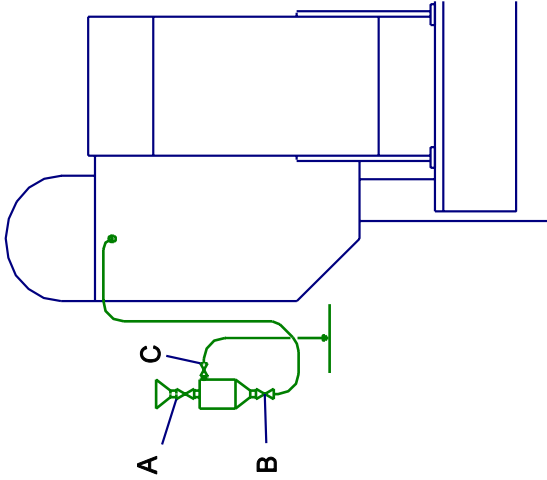


Correction for Fuel Temperature (Density) and
Sulphur Content (Calorific Value)



Dry cleaning of turbocharger (turbine side)

1. Carry out cleaning for every 24 to 50 hours of operation, based on observations.
2. Preferably clean the turbocharger at full load.
Do not clean below half load.
3. Close valve A.
4. Open valves B and C, to blow out possible deposits and/or condensate in the connecting pipe.
After about 2 minutes, close valves B and C.
5. Slowly open valve A to vent the container.
6. Fill the container with the quantity of granules specified in the table.
7. Close valve A.
8. Open valves B and C to blow-in the granules.
After 1 to 2 minutes, close valves B and C.
9. Slowly open valve A to vent the container.



TC Type	Amount litres
NA24	0.4
NA26	0.4
NA34	0.5
NA40	1.0
NA48	1.5
NA57	2.0
NA70	3.0
NA83	3.5
VTR354	1.5
VTR454	2.0
VTR564	2.5
VTR714	3.0
MET 53 SD/E	1.6
MET 66 SD/E	2.6
MET 71 SD/E	2.6
MET 83 SD/E	3.5

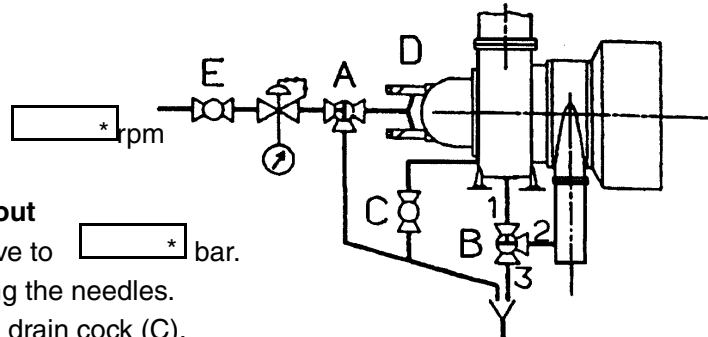


Water Washing (Not MET-Turbochargers)

Cleaning of MAN Turbocharger

- Turbine Side -

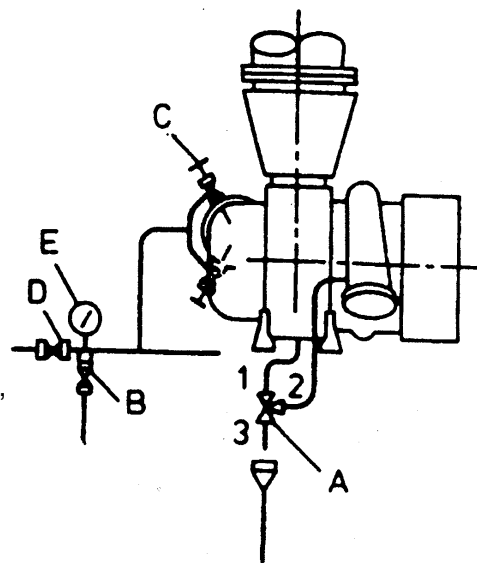
1. Reduce engine load to T.C.RPM = * rpm
2. Wait about 10 minutes.
3. Set three way cock (A) to **blowing out**
4. Open cock (E) and set reducing valve to * bar.
5. Open all spray nozzles (D) by turning the needles.
6. Open drain cock (B) to Pos. 1-3 and drain cock (C).
7. Set three way cock (A) to **washing**.
8. Water wash for 10 minutes.
9. Close cock (E).
10. Set three way cock (A) for a short period of time to **blowing out**, then to **zero position**.
11. Close all spray nozzles (D).
12. Close drain cock (B) (Pos. 2-1) and drain cock (C).
13. Run engine at same load for approx. 10 minutes. Then increase load slowly and check for undue vibrations that did not exist before or clean again.
14. Slight noise indicating contact of rotating parts is harmless due to running inlayer of cover ring.
15. Check spray nozzles from time to time.

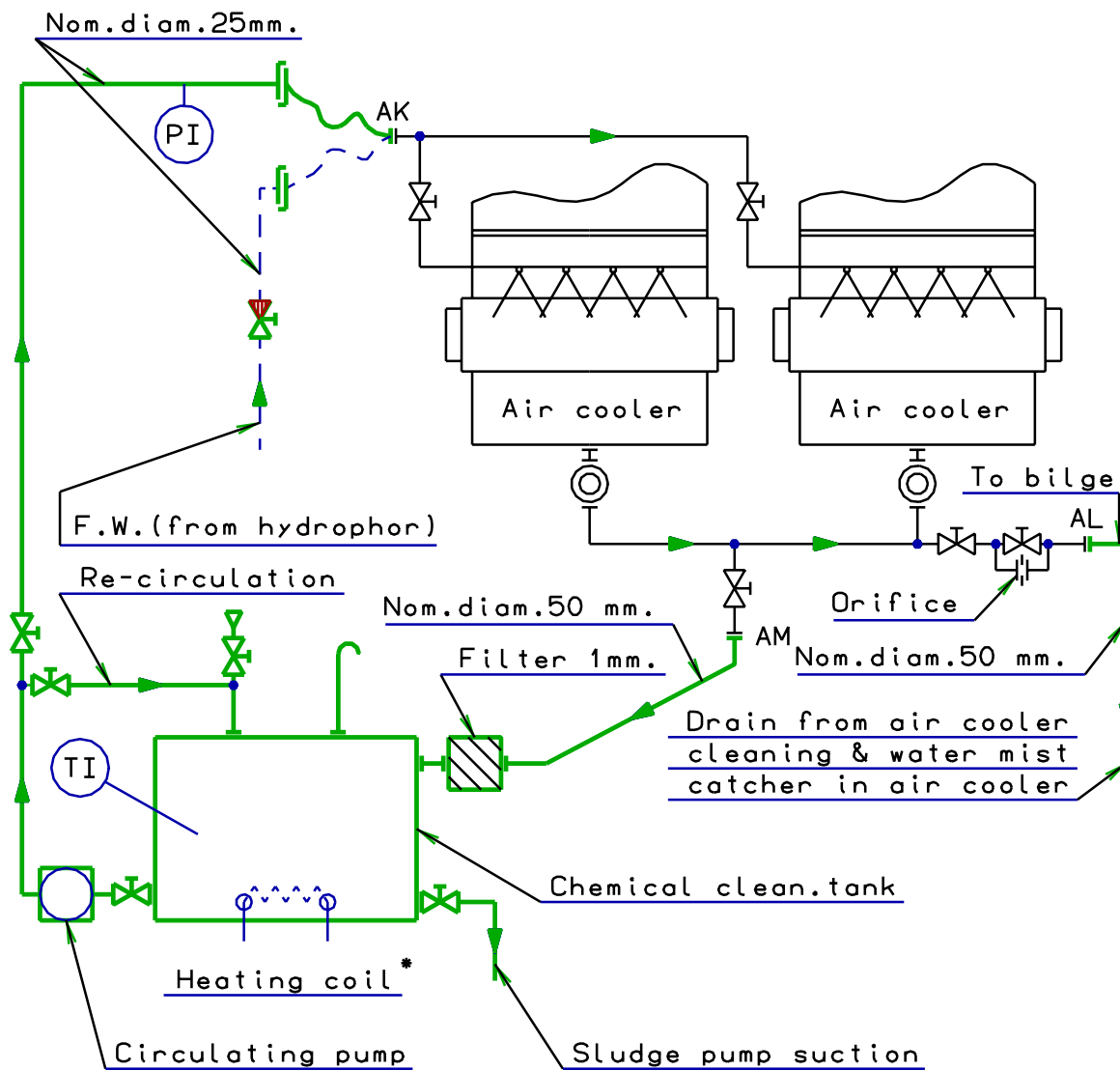


Cleaning of BBC Turbocharger

- Turbine Side -

1. Reduce the rpm to 50% load.
2. Open the drain cock (A) (Pos. 1-3).
3. Close the drain cock (B).
4. Open valve (C).
5. Open the valve (D) slowly !
until the pressure gauge shows 2.5 bar.
6. When the water from the drain pipe 3 appears clean,
the cleaning is completed (after about 10 minutes).
7. Close the valve (D).
8. Close the valve (C).
9. Open the drain cock (B).
10. Close the drain cock (A) (Pos. 2-1).
11. After completing the cleaning, operate at the same load for 5 minutes.
12. Listen to the turbocharger, to make sure that it runs smoothly (without vibrations) when increasing the rpm. If not, repeat the cleaning.

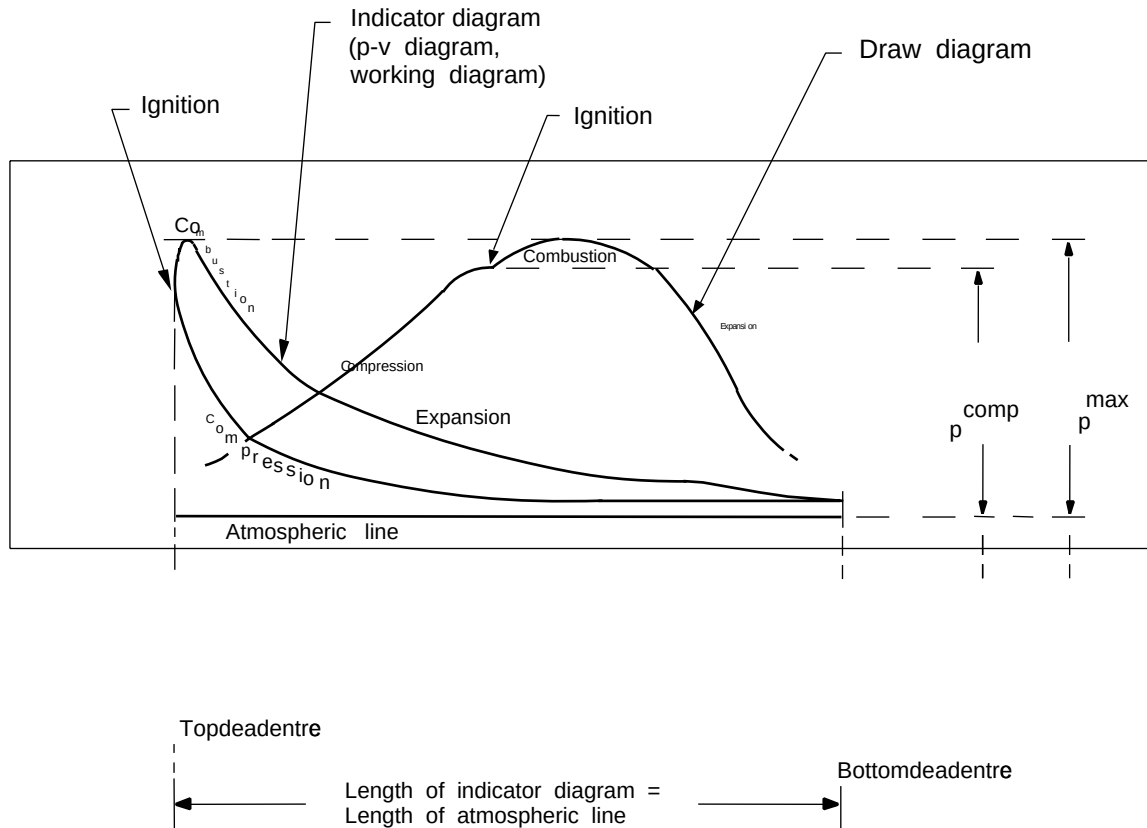




* Capacity for heating coils according to requirement from supplier of the chemical.



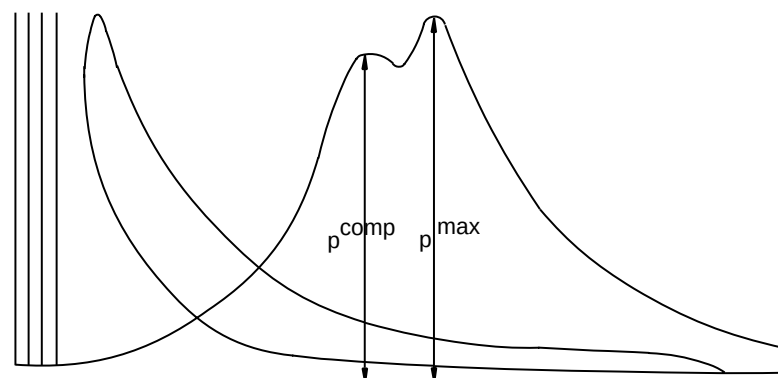
K/L-MC Engines:



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.



Correctly adjusted indicator drive/cam

The compression and expansion lines coincide, no area visible between the curves. (Fig. 1)

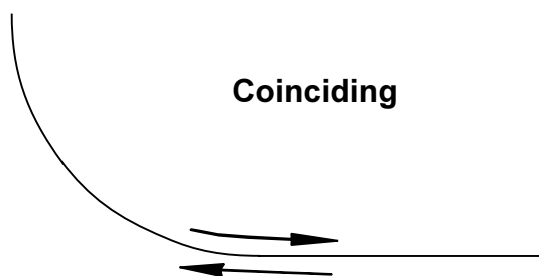


Fig. 1

Incorrectly adjusted indicator drive/cam

The compression and expansion lines do not coincide - an area is visible between the curves. (Fig. 2)

NB: The compression line is normally thicker than the expansion line.

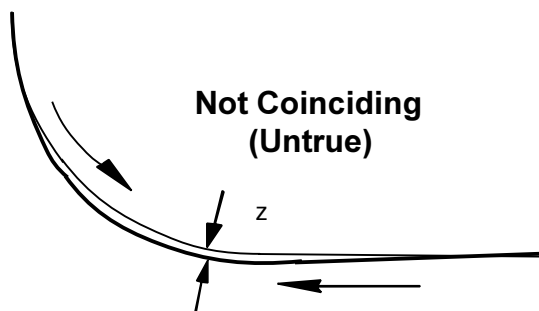


Fig. 2

Case A

The expansion line above the compression line, as shown.

The discrepancy 'Z' is positive: Displace the indicator drive or turn the cam "back", Fig. 3.

Case B

The expansion line below the compression line. 'Z' is negative: Displace the indicator drive or turn the cam "forward", Fig. 3.

(For $z = 1$ mm, turn the cam 2 mm or displace the drive approx. 2.5 mm, when using an indicator spring of 0.5 mm or 0.6 mm per bar).

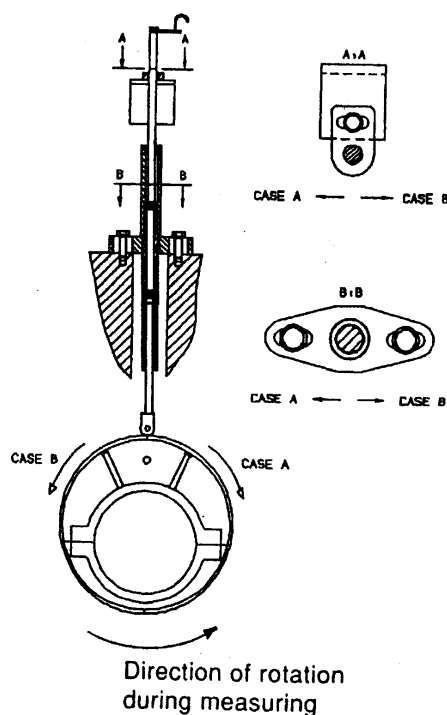


Fig. 3

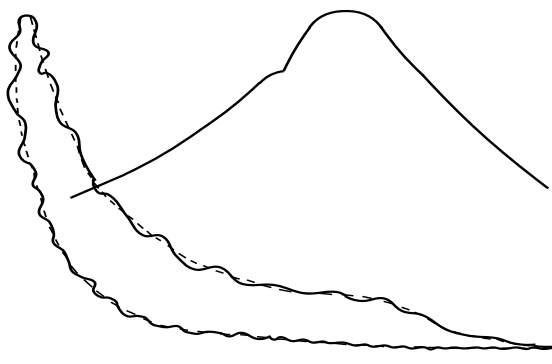
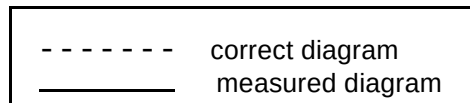


Fig. 1. Vibrations in drive.

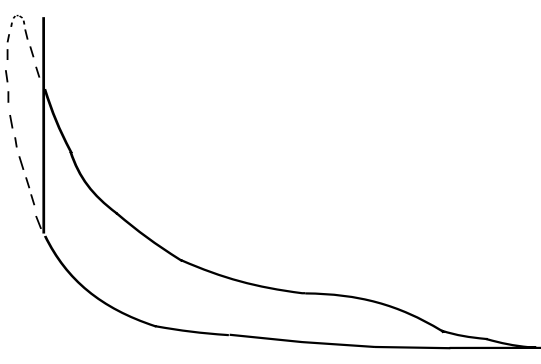


Fig. 2. Length of cord **too long**.

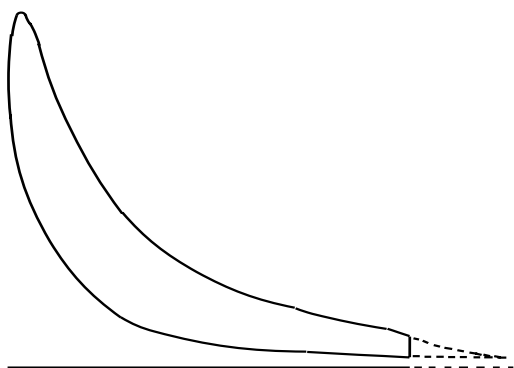


Fig. 3. Length of cord **too short**.
B.D.C.-part missing.

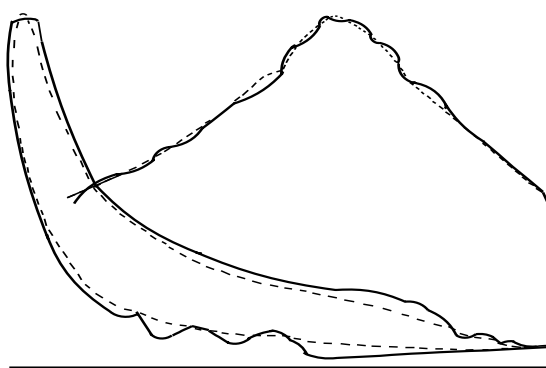


Fig. 4. Friction in indicator piston.
Draw-diagram also affected. This fault gives a

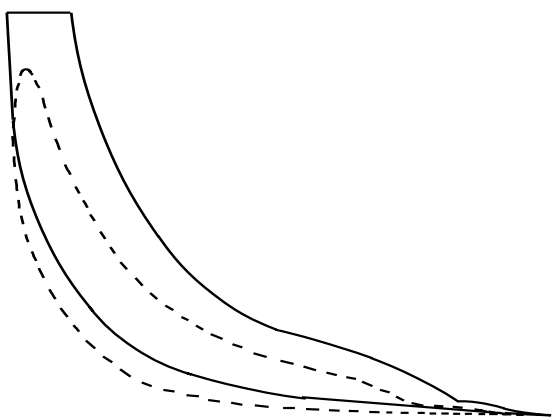


Fig. 5. Spring too weak. Indicator piston strikes top end of cylinder.

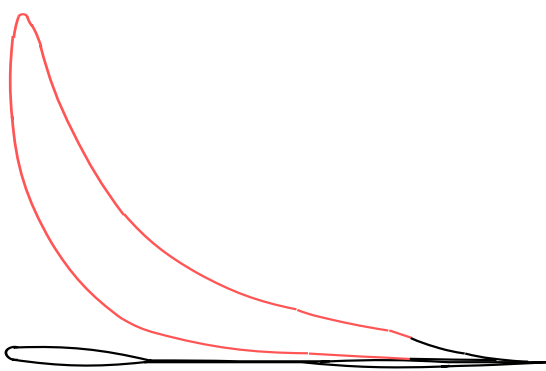


Fig. 6. Indicator cock leaking.
Atmospheric line untrue.

Fig. 1:

Fuel injection too late.

- Fuel pressure too low.
- Defective fuel valve(s).
- Defective fuel pump suction valve or shock absorber.
- Exceptionally poor fuel (bad ignition properties)
- Fuel pump lead too little.

(see also the text)

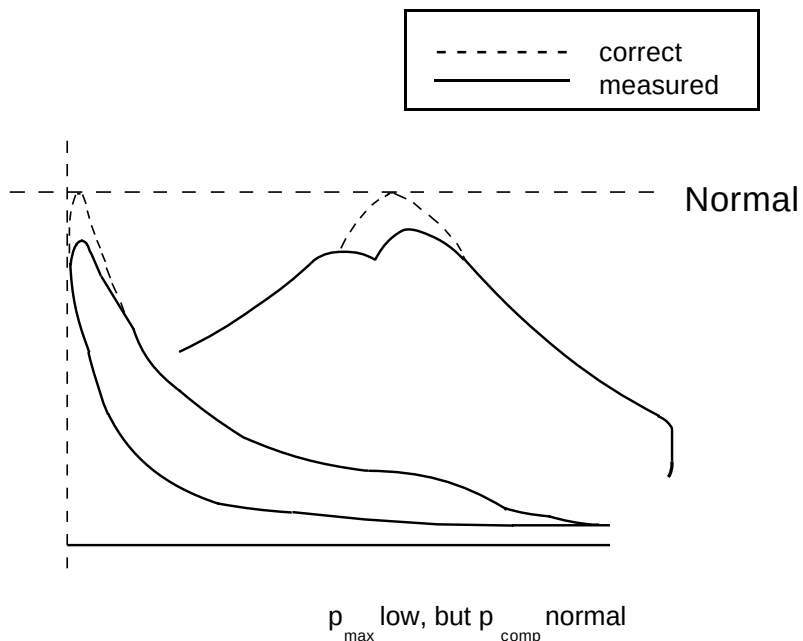


Fig. 2

Fuel injection too early.

- VIT index wrong.
- Fuel pump lead too large.

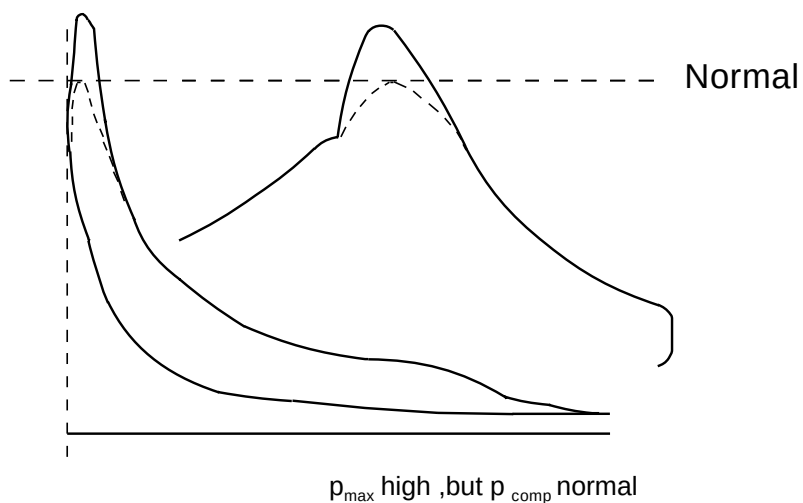
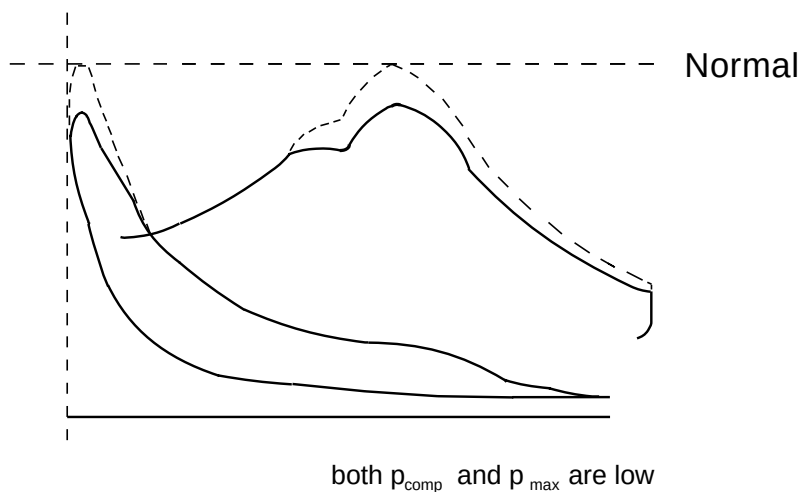
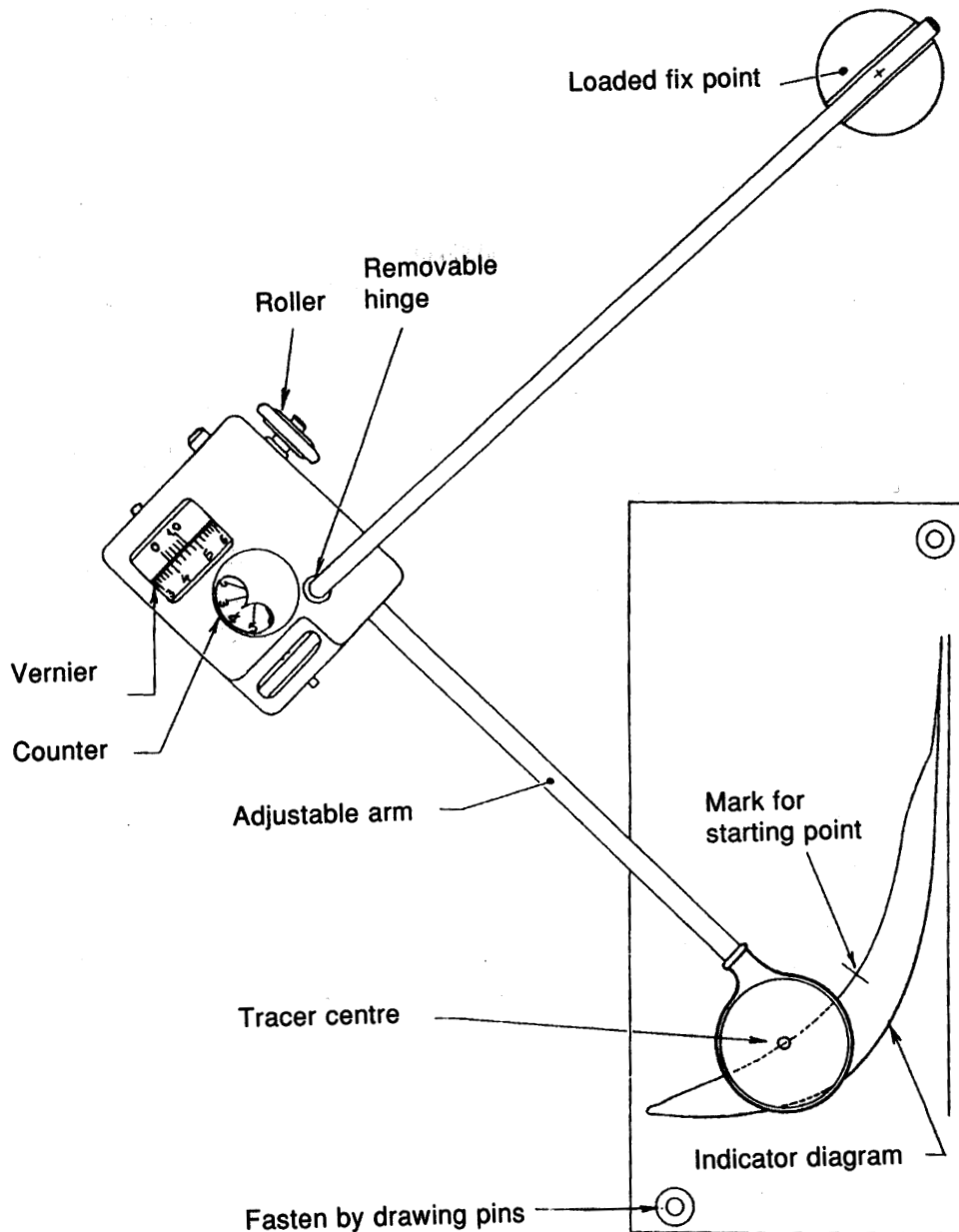


Fig. 3:

Leakages, increased cyl. volume, or fouling.

- Piston ring blow-by.
- Exhaust valve seat leakage.
- Piston crown burnt.
- Low scavenge pressure, fouling of exhaust and/or air system.





Planimetry:

Position the indicator as illustrated above.

Mark a starting point on the expansion line (to exactly localize the start/stop position of the diagram circumscription).

Begin tracing from the starting point, and circumscribe the diagram at even speed, and not too slowly.

Employ good illumination and, if necessary, use a magnifying glass for accurate reading of the vernier, before and after circumscription.

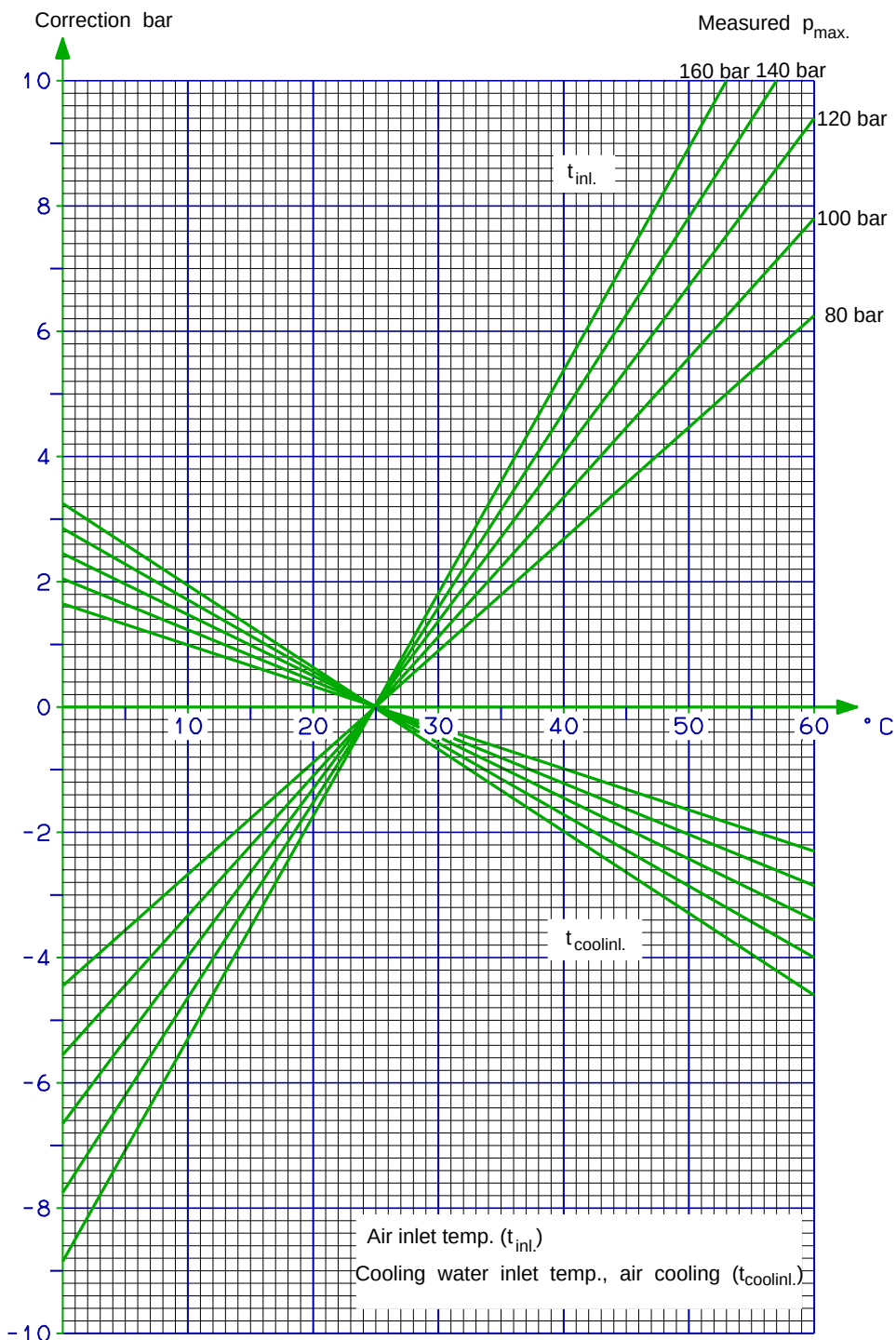
The difference in readings is proportional to the area of the indicator diagram.

NB: The calibration should be checked by measuring a known area, e.g. a precisely-drawn rectangle.



Maximum Combustion Pressure

Correction of measured p_{max}
because of deviations between $t_{inl} / t_{coolinl}$ and standard conditions.



Calculating the corrections:

$$t_{inl} : A_{corr} = (t_{meas} - 25) \times 2.198 \times 10^{-3} \times (1 + A_{meas}) \text{ Bar}$$

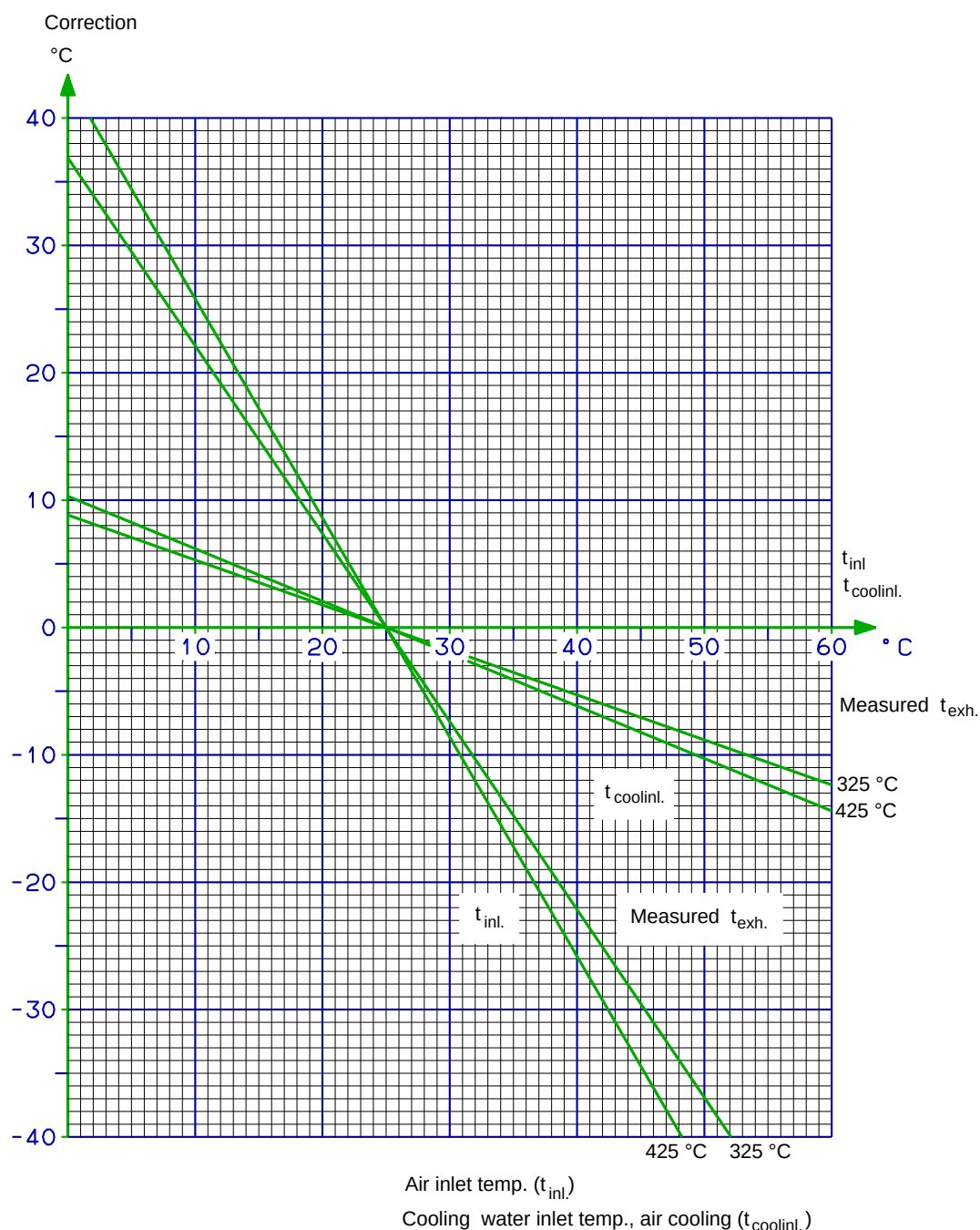
$$t_{coolinl} : A_{corr} = (t_{meas} - 25) \times 0.810 \times 10^{-3} \times (1 + A_{meas}) \text{ Bar}$$

See also Plate 70624.



Exhaust Temperature (after exhaust valves)

Correction of measured exhaust temperature (t_{exhv})
because of deviations between $t_{\text{inl}} / t_{\text{coolinl}}$ and standard conditions.



Calculating the corrections:

$$t_{\text{inl}} : A_{\text{corr}} = (t_{\text{meas}} - 25) \times -2.466 \times 10^{-3} \times (273 + A_{\text{meas}}) \text{ °C °}$$

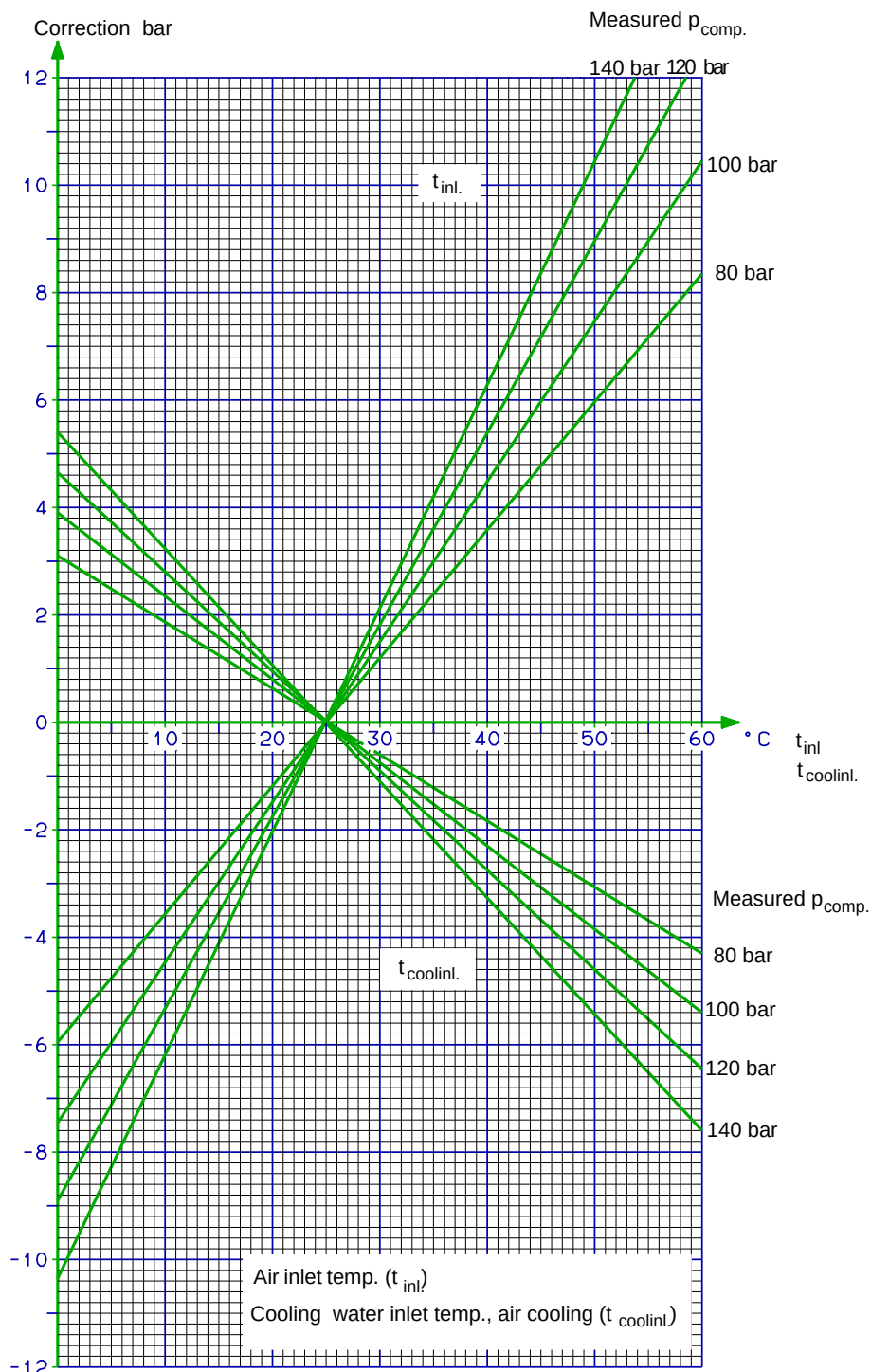
$$t_{\text{coolinl}} : A_{\text{corr}} = (t_{\text{meas}} - 25) \times -0.590 \times 10^{-3} \times (273 + A_{\text{meas}}) \text{ °C °}$$

See also Plate 70624.



Compression Pressure

Correction of measured compression pressure because of deviations between $t_{inl} / t_{coolinl}$ and standard conditions.



Calculating the corrections:

$$t_{inl} : A_{corr} = (t_{meas} - 25) \times -2.955 \times 10^{-3} \times (1 + A_{meas}) \text{ Bar}$$

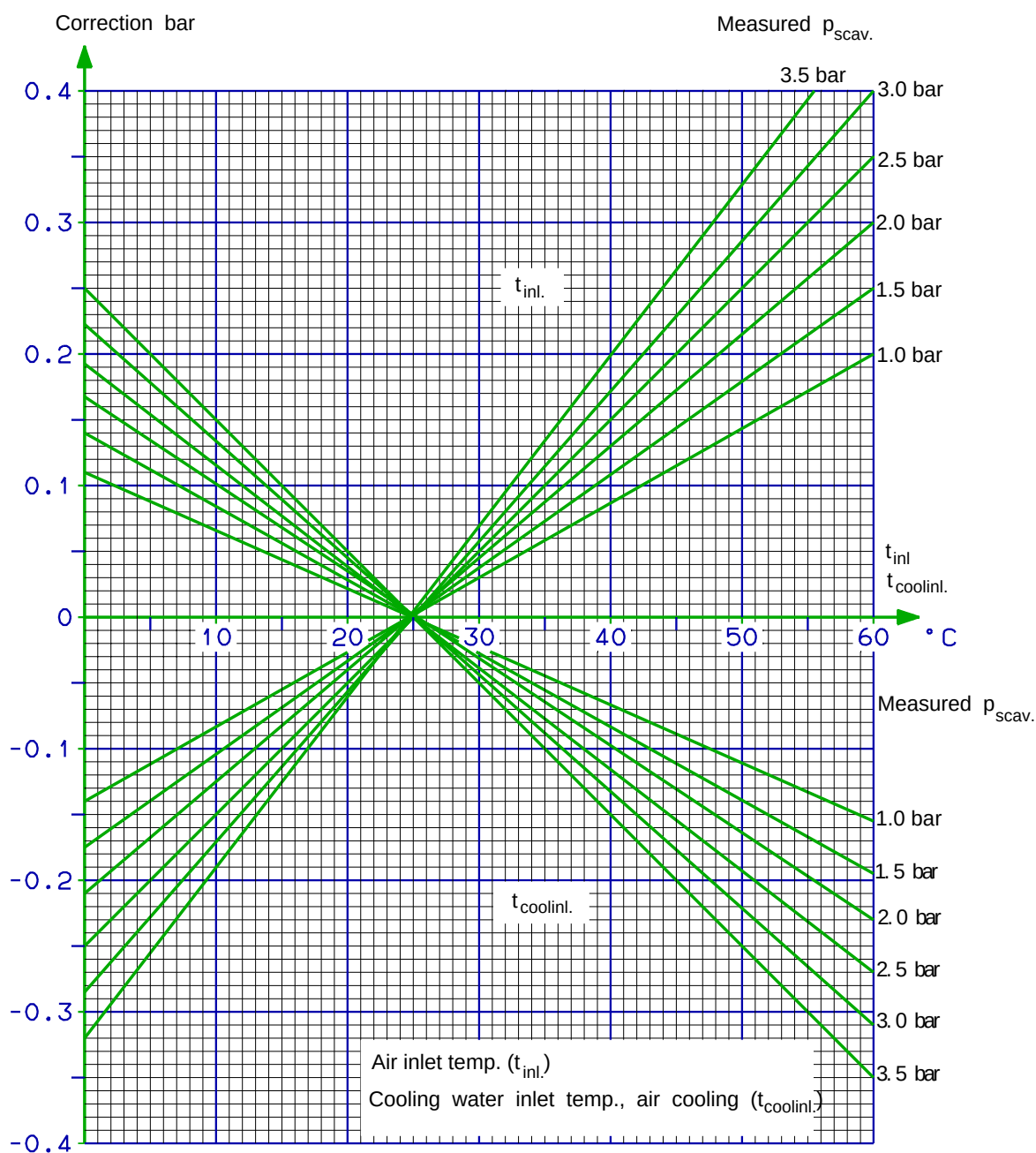
$$t_{coolinl} : A_{corr} = (t_{meas} - 25) \times -1.530 \times 10^{-3} \times (1 + A_{meas}) \text{ Bar}$$

See Plate 70624.



Scavenge Pressure

Correction of measured scavenge pressure because of deviations between $t_{inl} / t_{coolinl}$ and standard conditions.



Calculating the corrections:

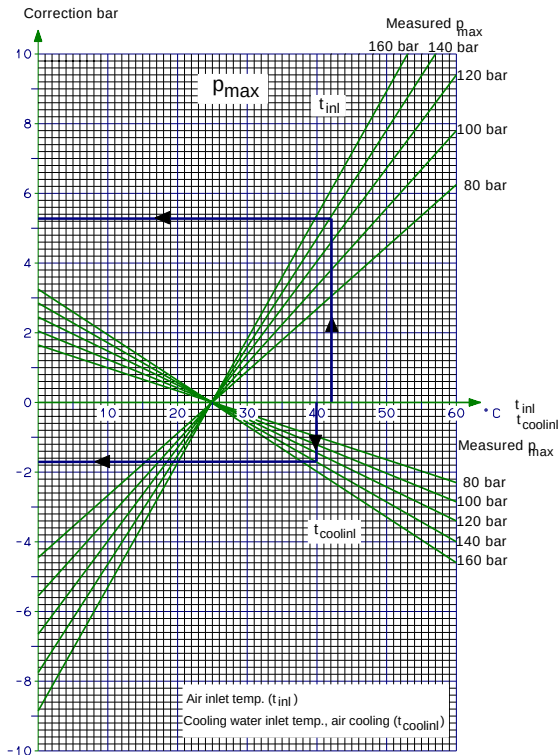
$$t_{inl} : A_{corr} = (t_{meas} - 25) \times 2.856 \times 10^{-3} \times (1 + A_{meas}) \text{ Bar}$$

$$t_{coolinl} : A_{corr} = (t_{meas} - 25) \times 2.220 \times 10^{-3} \times (1 + A_{meas}) \text{ Bar}$$

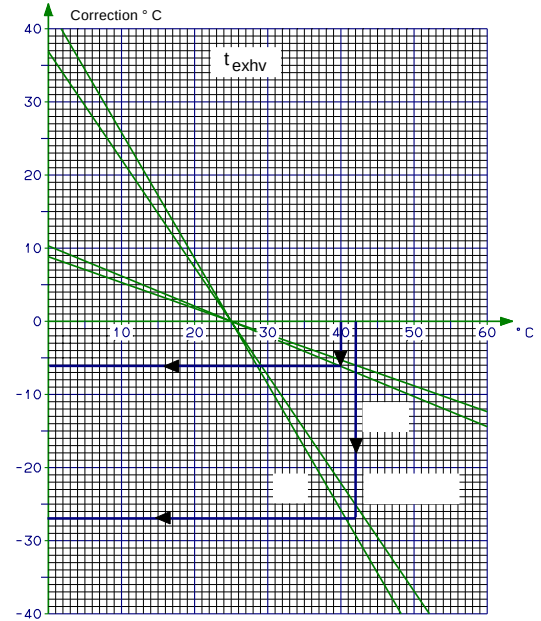
See Plate 70624.



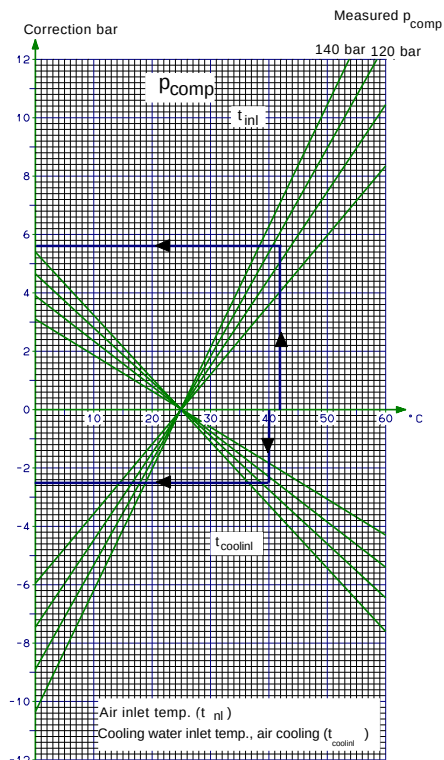
Example of readings: p_{max} : 140 bar p_{scav} : 2.0 bar
 t_{exhv} : 425 °C t_{inl} : 42 °C
 p_{comp} : 110 bar $t_{coolinl}$: 40 °C



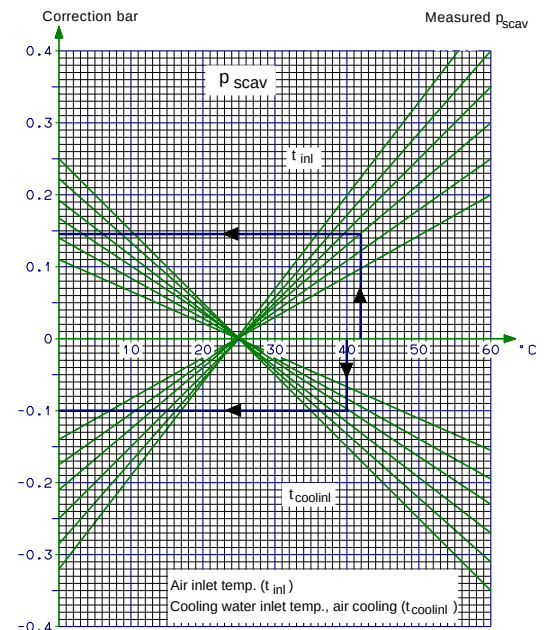
Correction for t_{inl} : +5.3 bar
 Correction for $t_{coolinl}$: -1.7 bar
 Correction 5.3 - 1.7 : +3.6 bar



Correction for t_{inl} : -27 °C
 Correction for $t_{coolinl}$: -6 °C
 Correction -29-6 : -33 °C

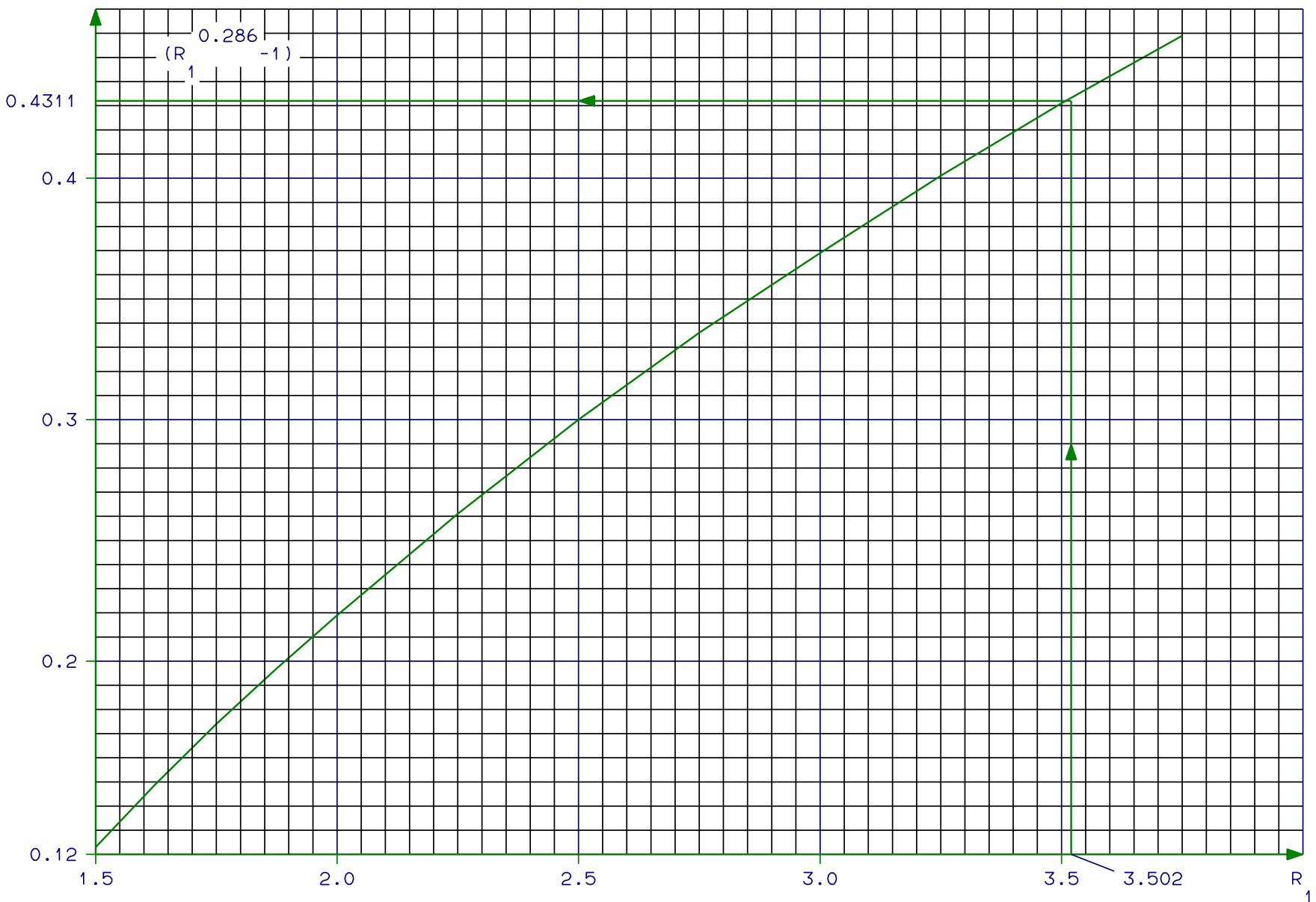


Correction for t_{inl} : +5.6 bar
 Correction for $t_{coolinl}$: -2.5 bar
 Correction 5.6-2.5 : +3.1 bar

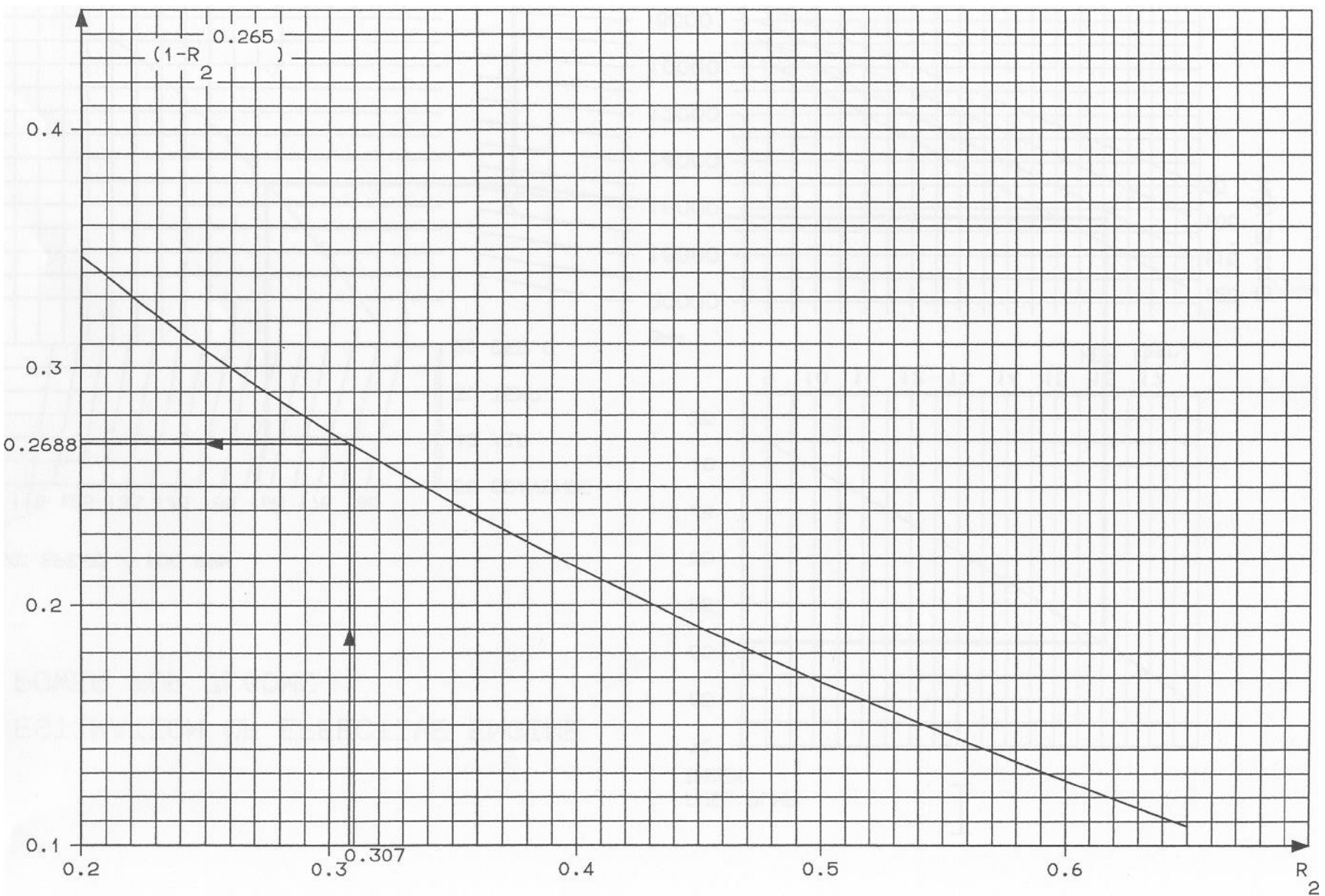


Correction for t_{inl} : +0.145 bar
 Correction for $t_{coolinl}$: -0.1 bar
 Correction 0.145-0.1 : +0.045 bar

Curve for the factor $(R_1^{0.286-1})$

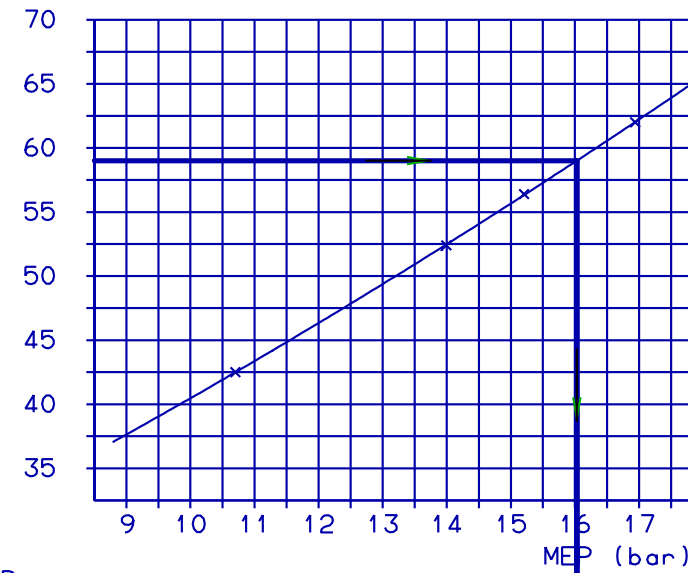


Curve for the factor $(1 - R_2^{0.265})$

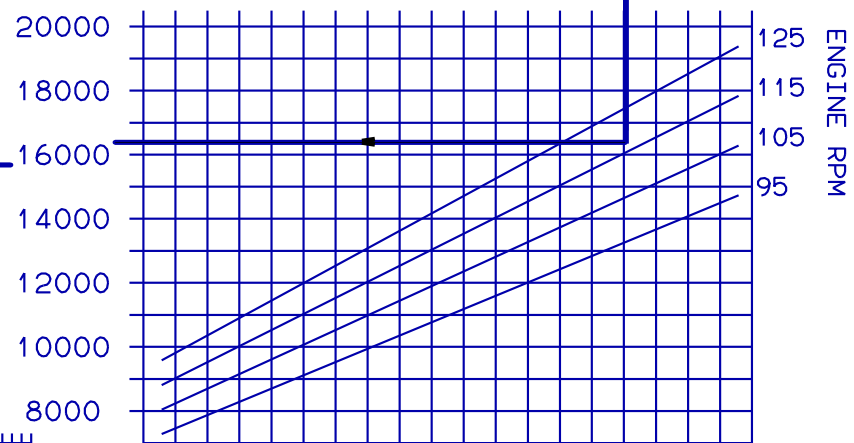


The Charts and values, in the example below, refer to a particular 7L60MC engine. For a specific plant, see the actual Tested Report concerned.

I

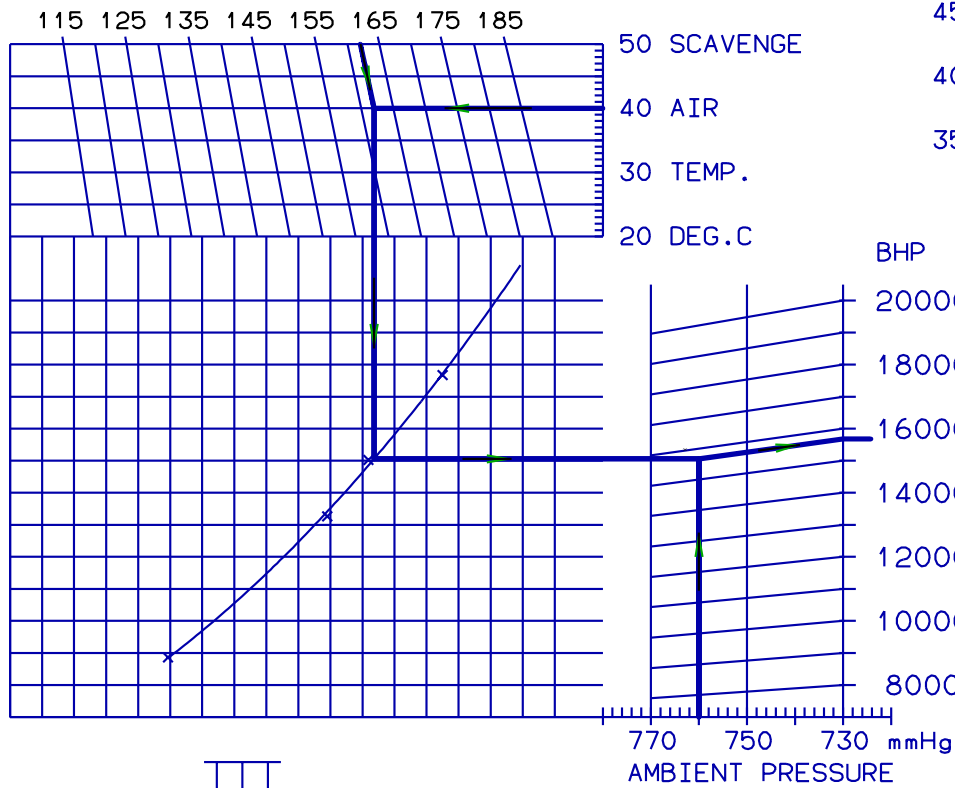
FUEL PUMP
INDEX


BHP



II

T/C SPEED / 100 RPM



III



Turbocharger Make	Type Designation	Diameter, D (m)	No. of Blades	Slip Factor, μ
MAN B&W	NR 24/R	0.276	-	0.76
	NR 26/R	0.322	-	0.76
	NA 34/S	0.408	17	0.70
	NA 40/S	0.480	20	0.70
	NA 48/S	0.576	20	0.70
	NA 57/T9	0.684	20	0.70
		0.684	18	0.74
	NA 70/T9	0.840	22	0.76
		0.840	18	0.74

Turbocharger Make	Type Designation	Diameter, D (m)	Slip Factor μ		
BBC/ABB	VTR 254	0.2942	-	A	E
	VTR 304	0.3497	0.79		0.69
	354	0.4157			
	454	0.5233			
	564	0.6588			
	714	0.8294			

Turbocharger Make	Type Designation	Diameter, D (m)		Slip Factor μ			
Mitsubishi H.I. (MET)	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				
	MET83SD,SE	0.873	0.924				



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Appendix 1

Inspection of Nimonic Exhaust Valve Spindles

707.19

PLATES

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Cylinder Liner Wear Points, High-Topland Piston	Plate 70712B
Calculating of Condensate Amount	Plate 70713
Running-in Load	Plate 70714
Cylinder Lubricating Oil Pipes	Plate 70716





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.

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 : $901.3 \times 0.99964 = 900.98$

(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*. Inspect the crown for cracks.

Pressure-test the piston assembly to check for possible oil leakages, see *Vol. II, Procedure 902*.

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 See Plate 70711

Check the piston ring grooves as described in Vol. II, Procedure 902.

If the ring groove wear exceeds the values stated in Procedure 902, 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.

4.9 Piston Ring Gap (New Rings)

As the piston rings work at a somewhat higher temperature than the liner, it is important that they have a gap which is sufficient to permit the extra thermal expansion.

Place the ring in the special tool (guide ring) which is used when mounting the piston in the cylinder liner. The upper part of a clean, new liner (above the ring travel) can also be used. Check the gap as described in *Vol. II, Procedure 902*.

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, 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.*

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 Plate 70710.*



- *Refer to Section 703-03.*
- *Refer to the Alpha Lubricator Manual on how to adjust the lubricator feedrate.*

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 Alpha Lubricator Manual.

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. Pos.387*
- 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, *see the Alpha Lubricator Manual.*
- 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.E 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 , 'Cleaning of Turbochargers and Air coolers', 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 (clover-leaving) 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 , 'Cleaning of Turbochargers and Air coolers', Item 3.

See also Plate 70713 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, 'Cleaning of Turbochargers and Air coolers', Item 1,3 regarding the use of a thin foam filter. See also Section 701, 'Cleanliness'.*

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 error



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, Section 2*, 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 chapter 706, item 2, 1, i.e. beyond line 4*), continued service may cause thermal overload of the components in the combustion chamber and thereby create heat cracks.

1. Lubricators *Plate 70716*

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 70716, Fig. 2.*

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).

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 step-wise 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 that the 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.

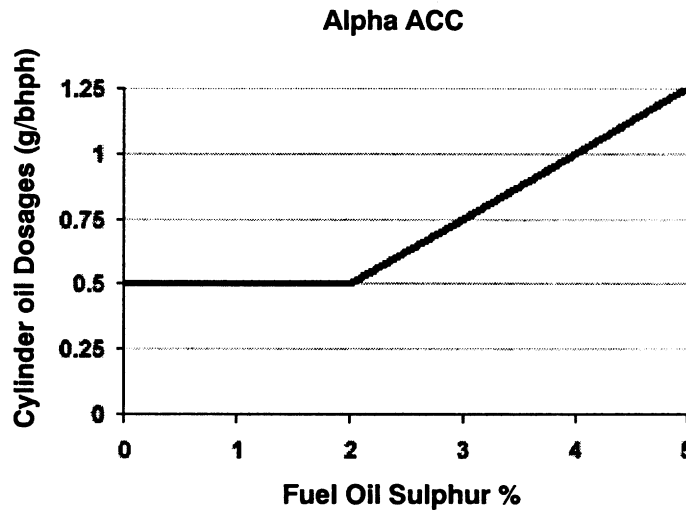
This new cylinder oil control principle is called the “**Alpha Adaptive Cylinder oil Control**”, or abbreviated “**Alpha ACC**”.

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:

$$\text{Basic lube oil setting} = 0.25 \text{ g/bhph} \times \text{S\%,}$$

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%.





Inspection of Nimonic Exhaust Valve Spindles

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 seven sections:

1. Spindle identification	Page 707.19
2. Inspection intervals	707.20
3. Inspecting the contact condition of the seat.....	707.20
4. Checking the seat for gas leakage	707.22
5. Cleaning and evaluation	707.24
6. Inspecting the valve stem wear layer.....	707.27
7. Grinding the spindle seat	707.28

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

Note: 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.

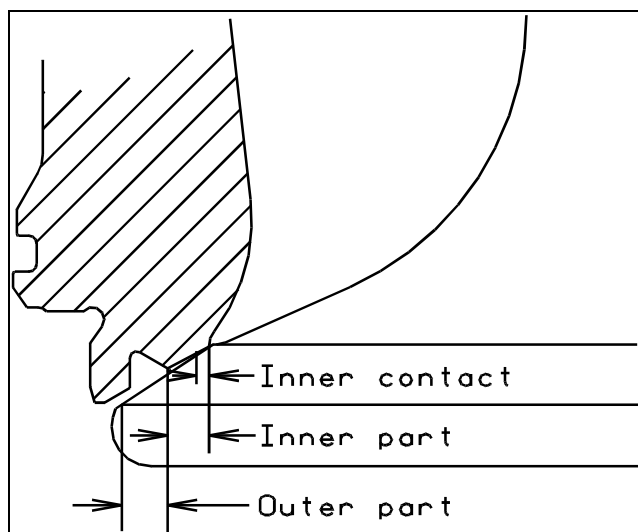


Fig. 1: Inner contact, and zone designation



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.

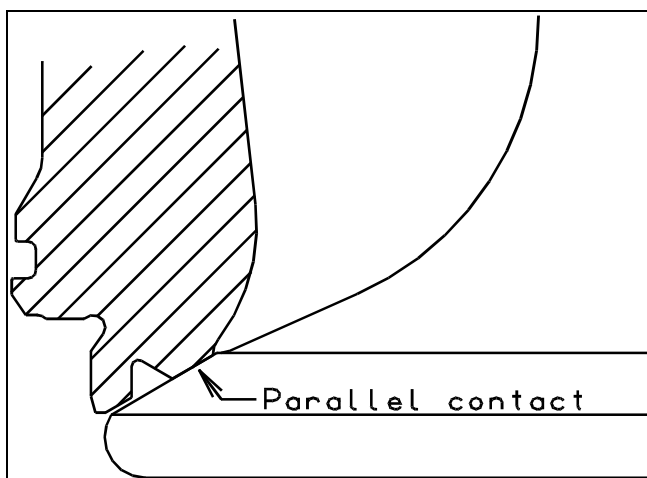


Fig. 2: Contact condition during running

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

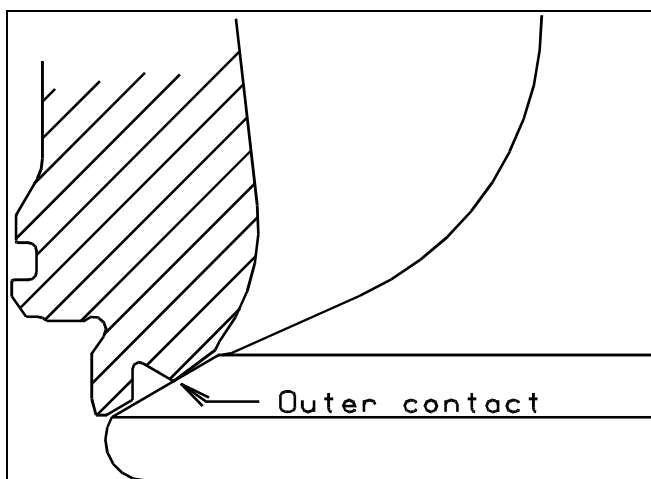


Fig. 3: Outer contact, increased risk of blow-by

Further action Fill in Page 707.30, "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 **Note: Do not clean the spindle disc before inspection**



- Visually check the inner part of the seating for blow-by (Fig. 4 and Photo 1).

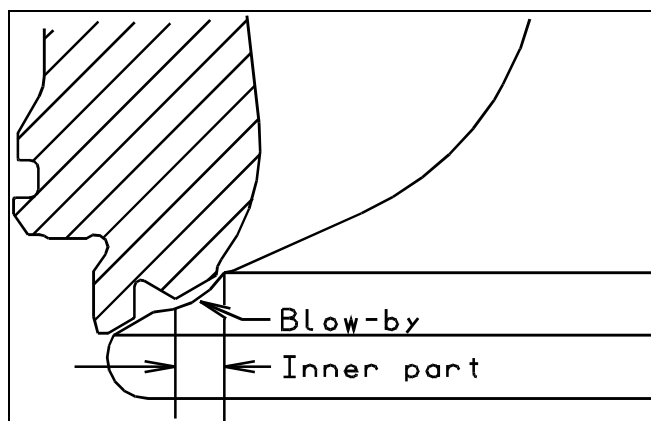


Fig. 4: Blow-by



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 707.30, “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

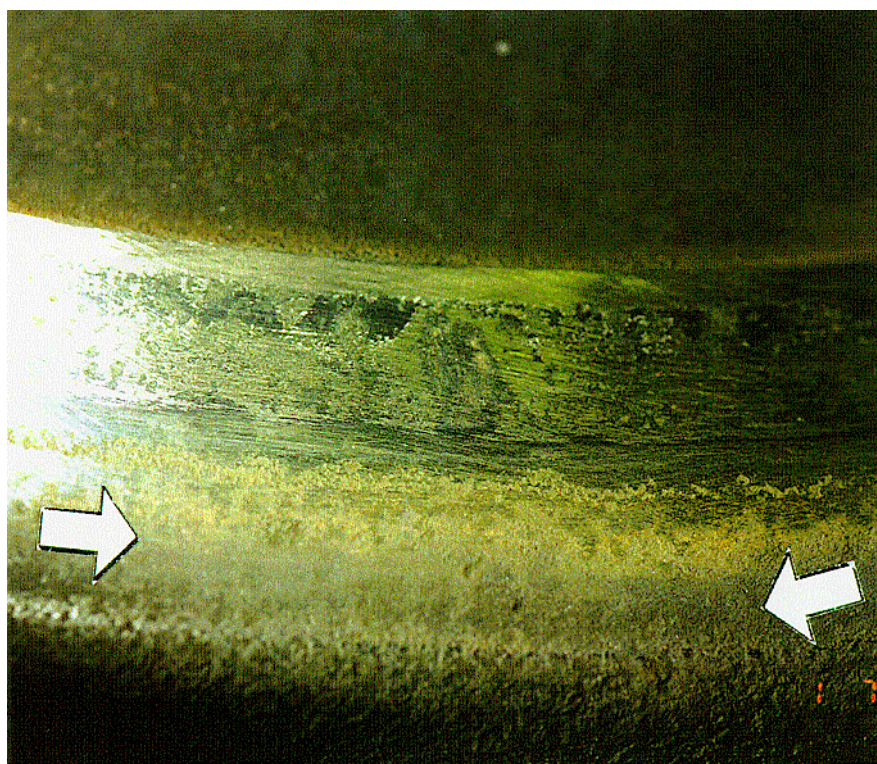


Photo 3: Example of high-temperature corrosion at outer part after 33,000 hours

- Clean the contact faces on which the measuring template is to be applied, and measure:
 - 1) the burn-off on the disc underside,
 - 2) 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.

Wear allowances:

- Burn-off on disc underside, (F_1).
- Total grinding of seat, (G_1).

Fill in data from Procedure 908-2
F_1 :
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*).

During welding-up of the disc, the seat area will also be reconditioned up to its original dimensions.

For this reason we recommend that the interval between seat grindings is adjusted **in order to make full use of the 2 mm seat-grinding allowance, before the spindle is sent ashore for reconditioning 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	8
60MC/MC-C	9
70MC/MC-C	10
80MC/MC-C	11
90MC/MC-C	12
98MC/MC-C	14

*) Also valid for stationary engines (power plants)

Table 1: Permissible burn-off rate before reconditioning of spindle disc underside

Further action

—

Fill in Page 707.30, “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.

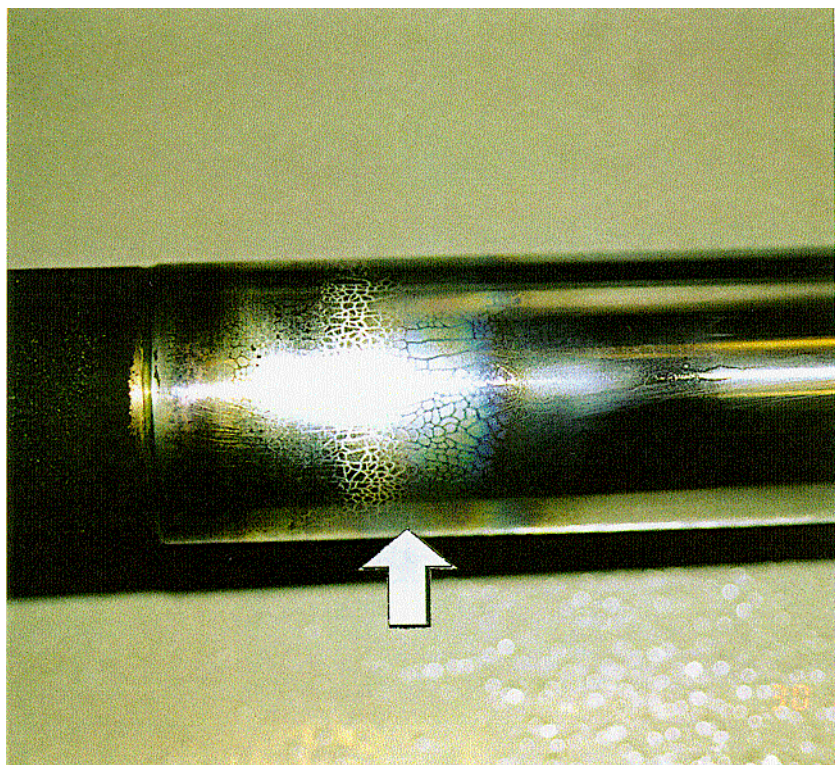


Photo 4: Slight cracking (“network cracking”) of wear layer



Further action Fill in Page 707.30: "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.

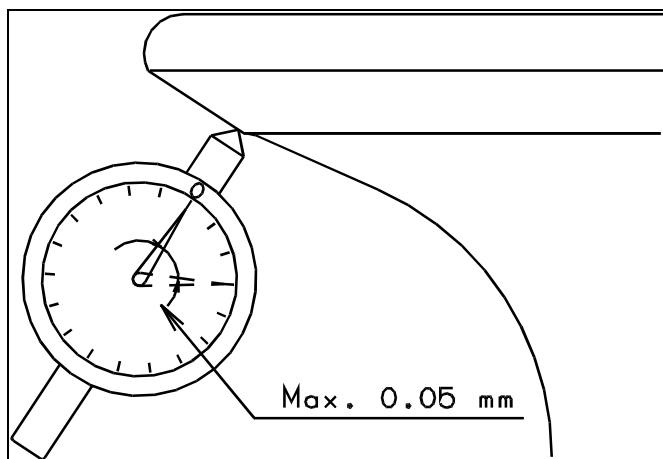


Fig. 5: Truing-up the spindle

Fill in data from
DATA 908-2

D-_____:
Offset angle:

- 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".



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.

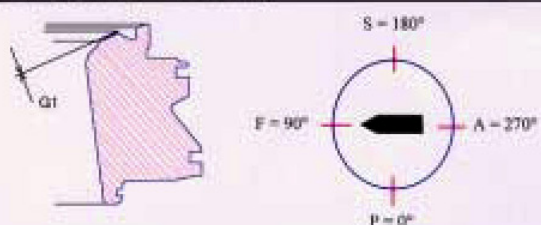
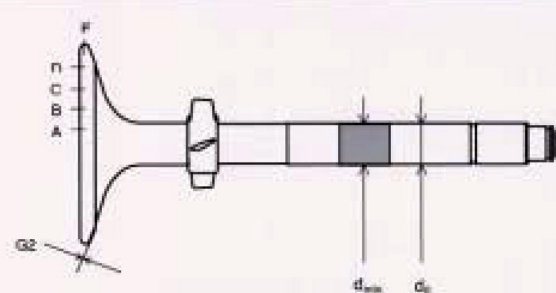
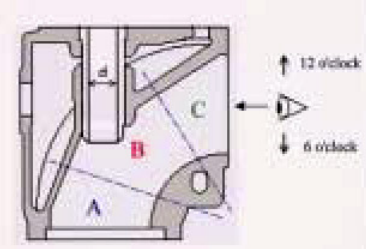
Max. grinding depth: must not exceed the limit (G_1) stated in Vol. II, Procedure 908-2, DATA.

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.

Fill in data from
Procedure 908-2

G_1 :



Exhaust Valve Condition Report									
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 $\varnothing = 7$ mm:				
Cracks (yes/no):		Blow-by (yes/no):			Maximum deposit thickness in duct (mm):				
Deposit in chamber: Extend (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 $\varnothing = 7$ mm:					Total grinding, G2 (mm):				
Stem diameter d_0 above sealing area (mm):					Note! Max. grinding, G2 = 2.0 mm				
Min. stem diameter d_{min} at sealings (mm):									
Extent of reconditioning		1st.	2nd.	3rd.					
Welding of seat. (Tick off)									
Seat welding material:									
Welding of disc. (Tick off)									
Disc welding material:									
Stem recon.	Cr.-plating								
	HVOF-Cermet								
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.

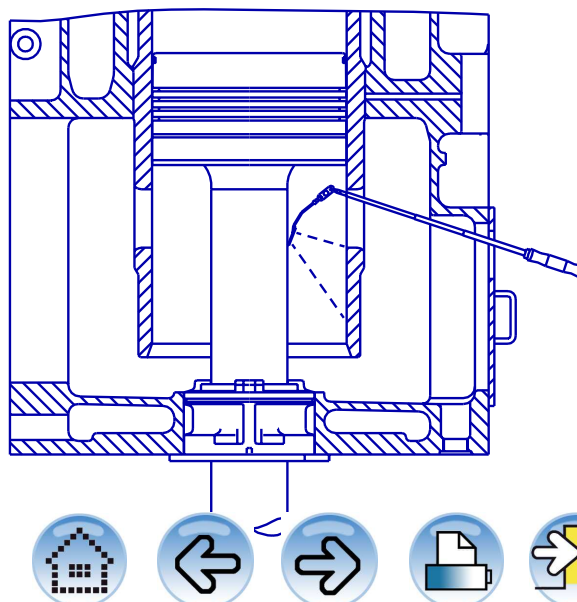
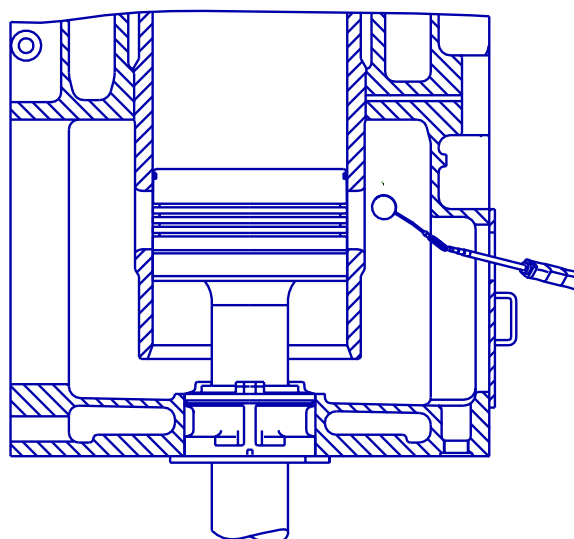
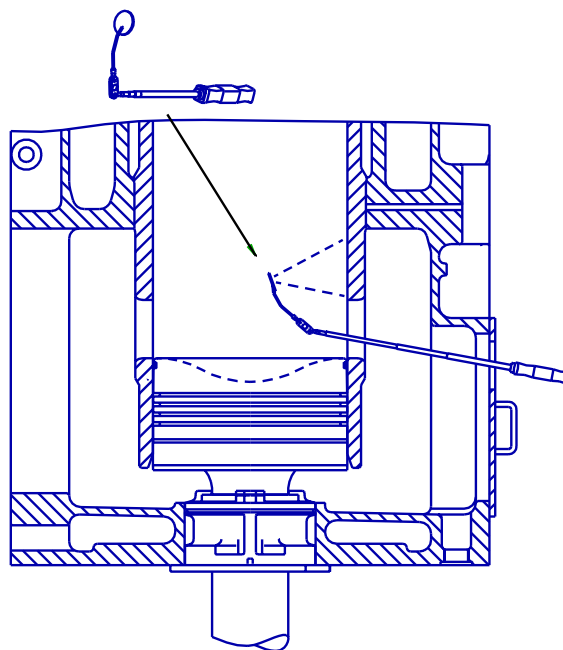
4) In order to inspect a larger area of the cylinder liner and piston, it is expedient to enter the scavenge air receiver and make observations from the "exhaust side". This should be done every time the sludge is cleaned out from the scavenge air receiver and box.

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.

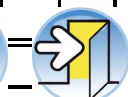
6) When the piston has been turned upwards past the scavenge air ports, inspect the piston rod.

7) Note down the results on Plate 70702.

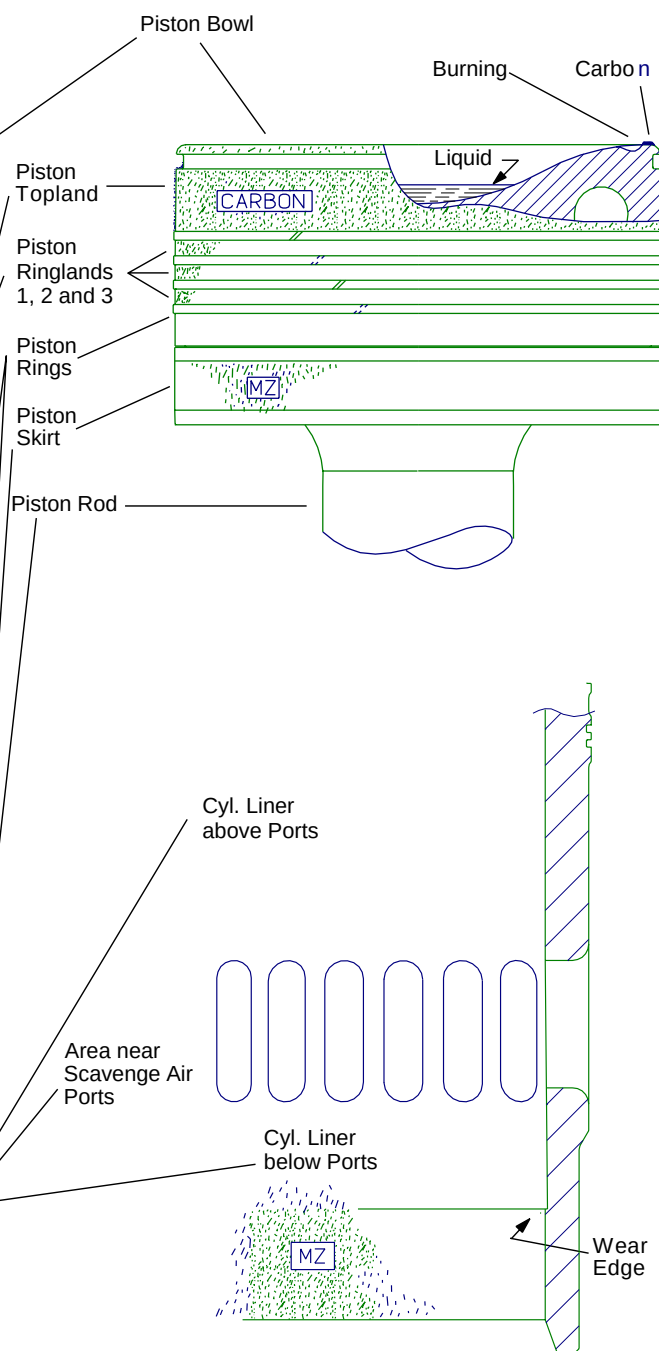


M/V		Engine Type:		Running hours		Checked by:	
Yard:		Builder:		Total:			
No.:		Built year:		Engine No.:		Cylinder oil dosage:	
						Date:	

	Condition and Symbol	Engine Part	Cylinder No.											
			1	2	3	4	5	6	7	8	9	10	11	12
	Carbon C Burning BU Leakage oil LO Leakage water LW	Piston Crown												
Deposits	No deposit •	Topland												
	Light deposit LC	Ringland 1												
	Excessive deposit EC	Ringland 2												
	Polished deposit PC	Ringland 3												
Breakage	Intact •	Ring 1												
	Broken opposite ring gap BO	Ring 2												
	Broken near gap BN	Ring 3												
	Several pieces SP	Ring 4												
Ring Movement	Entirely missing M													
	Collapsed COL													
	Loose •	Ring 1												
	Sluggish SL	Ring 2												
Surface Condition	Sticking ST	Ring 3												
	Running surface, - Black, overall B	Ring 4												
	- Black, partly (B)													
	Black ring ends > 100 mm BR													
Lubrication Condition	Clean, smooth •	Ring 1												
	Scratches (vertical) S	Ring 2												
	Micro-seizures (local) mz	Ring 3												
	Micro-seizures (all over) MZ	Ring 4												
	Micro-seizures, still active MAZ													
	Old MZ OZ													
	Machining marks still visible ••	Piston skirt												
	Wear ridges near bottom WR	Piston rod												
Deposits	Scuffing SC	Cylinder liner												
	Clover-leaf wear CL													
	Corrosion CO													
	T/B													
Deposits	Optimal •	Ring 1												
	Too much oil O	Ring 2												
	Slightly dry D	Ring 3												
	Very dry DO	Ring 4												
Deposits	Black oil BO	Piston skirt												
		Piston rod												
		Cylinder liner												
Deposits	Little sludge LS	Scavenge box												
	Much sludge MS	Scav. receiver												
	Movable M	Flaps and non-												
Running hours since last overhaul														



Symbol	Condition of inspected part	
•	Satisfactory	
C	Carbon Deposit	
BU	Burning	
LO	Leakage Oil	
LW	Leakage Water	
•	Satisfactory (no deposits)	
LC	Light carbon deposit	
EC	Excessive carbon deposit	
PC	Thick carbon deposit worn bright by rubbing against cyl. liner	
•	Intact	
BO	Broken, opposite ring gap	
BN	Broken, near ring gap	
SP	Broken in several pieces	
M	Entirely missing	
COL	Collapsed	
•	Loose	
SL	Sluggish in groove	
ST	Sticking	
B	Black running surface, overall	
(B)	Black running surface, partly	
•	Clean, smooth	
S	Vertical scratches (abrasive particles)	
mz	Micro Seizures in spots (local)	
MZ	Micro Seizures, all over	
MAZ	Micro Seizures still active	
OZ	Old (nearly recovered) MZ	
WR	Wear ridges near bottom	
CO	Corrosion	
CL	Clover-leaf wear	
T/B	Rings sharp-edged Top/Bot	
•	Oil film normal	
O	Too much oil	
D	Too dry	
DD	Very dry	
BO	Black oil	

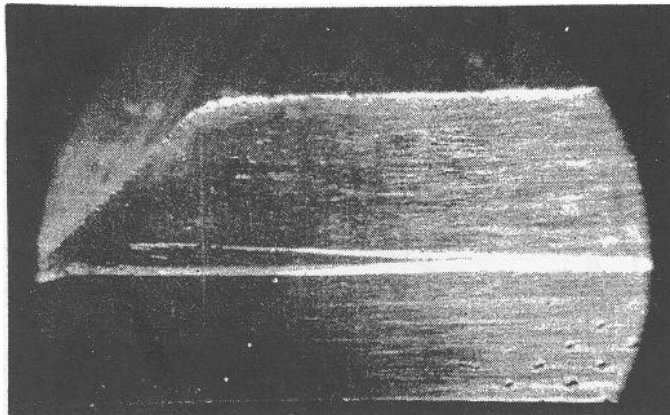


A dot (•) always means that the inspected condition is satisfactory, e.g. small deposits, no leakage, no breakages, no sticking, clean smooth surface, normal oil film, etc. However, this shall be recorded in order to show that the condition has been noted.



Running Surface of Piston Rings (see also Plate 70705)

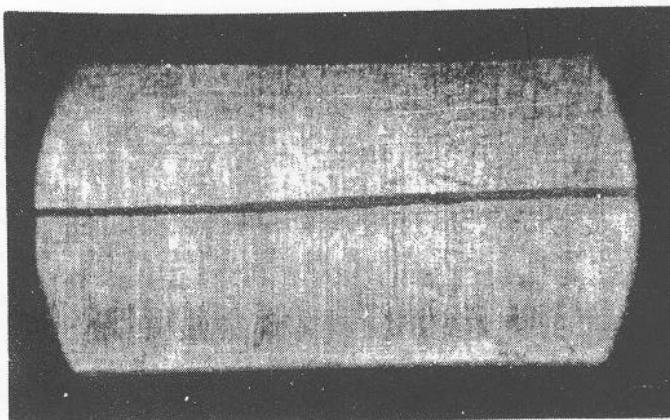
NB: In file tests, use a new very finely cut file



"Polished Mirror Surface"

Photo 1 (about X3)

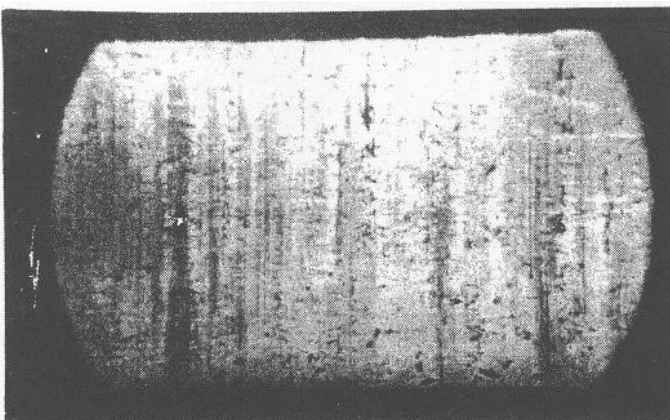
A normal, good running surface is smooth, clean, and without scratches. The horizontal line is a scratch mark resulting from a file test, which indicates that the surface is not hardened.



"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.

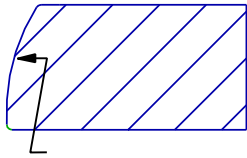
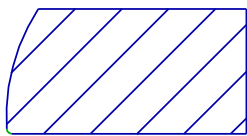
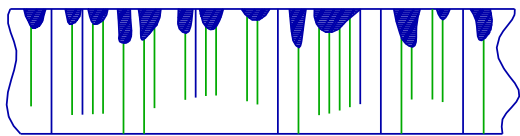
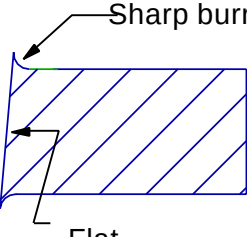
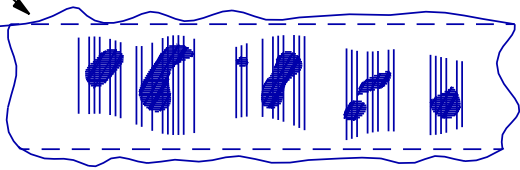
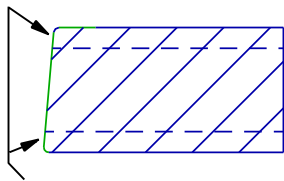
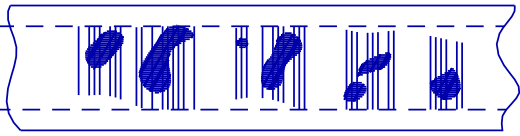
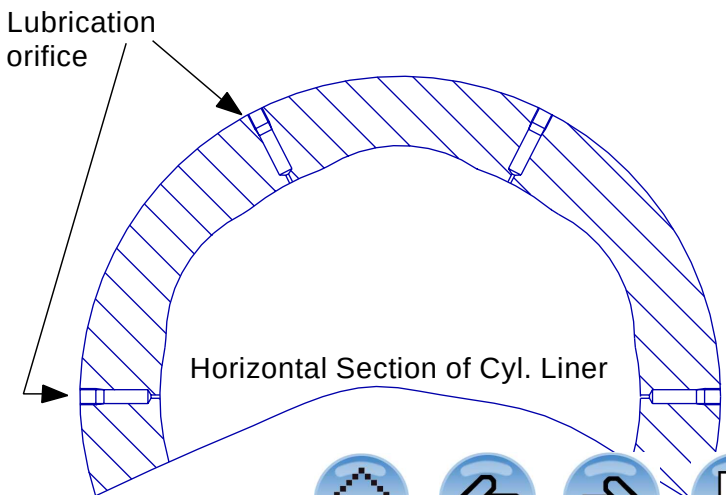


"Micro-Seizures"

Photo 3 (about X3)

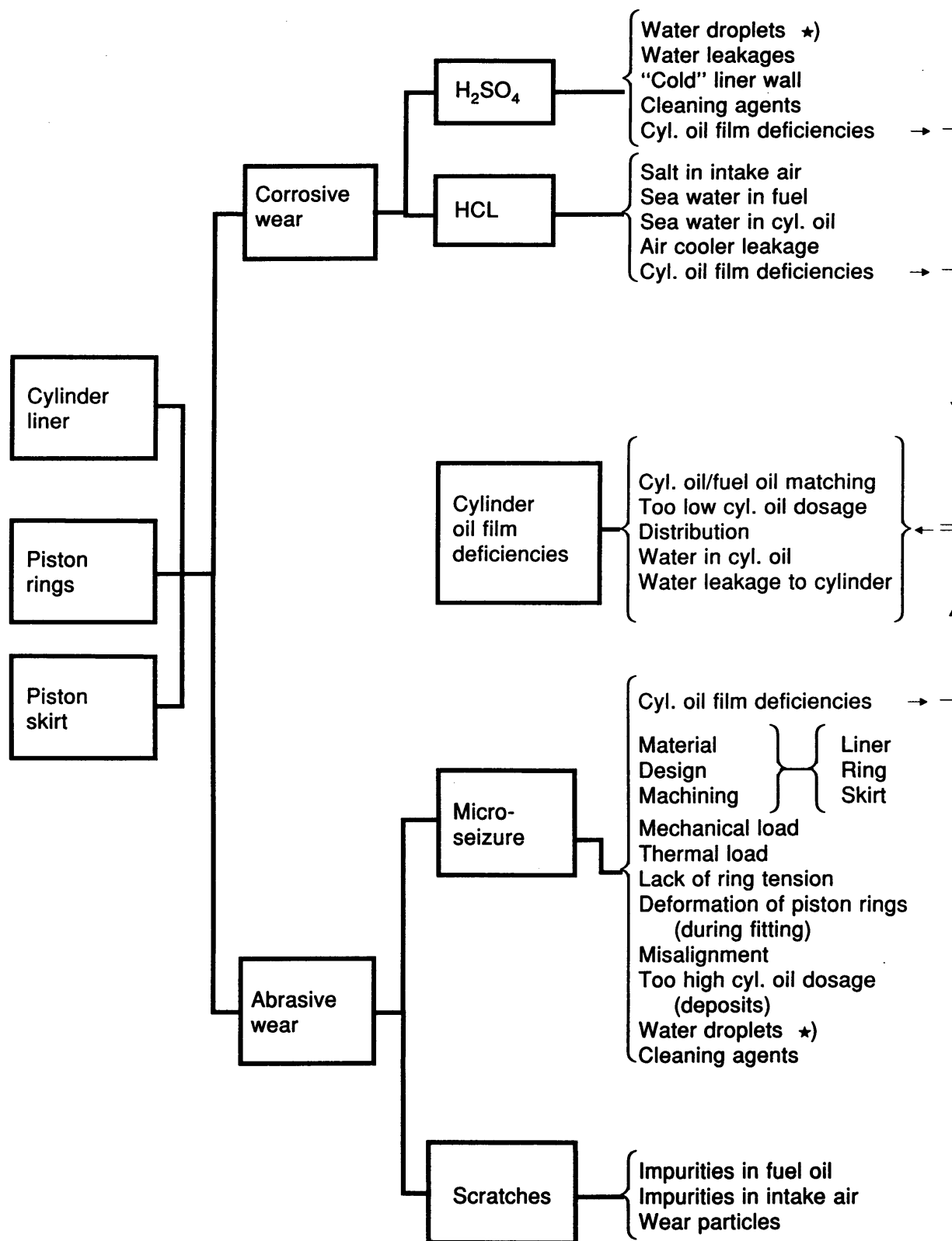
A micro-seized running surface can appear as shown here. The file test gives almost no horizontal scratch, which indicates that the surface is covered by a hard glaze, i.e. has been hardened due to micro-seizure.



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"	 Lubrication orifice Horizontal Section of Cyl. Liner	



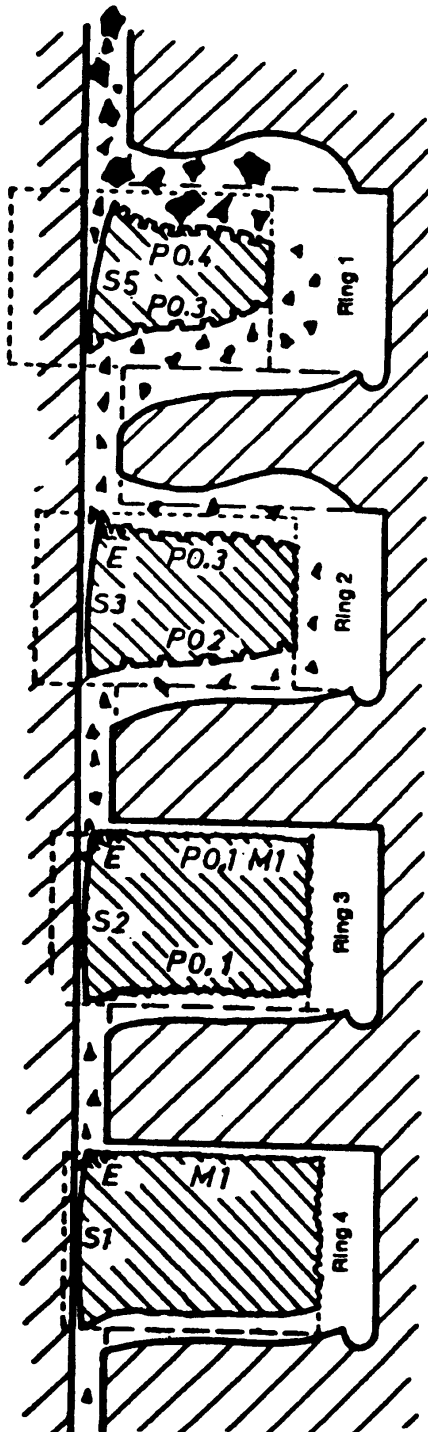
Schematic summary of the most widely recognized causes of "cylinder wear"



*) Drain for condensed water in scavenge air receiver blocked or out of function.
See also Chapter 706, 'Cleaning of Turbochargers and Air Coolers', Item 3.



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.



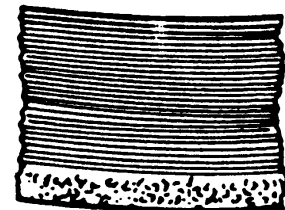
Upper side of the uppermost rings

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).



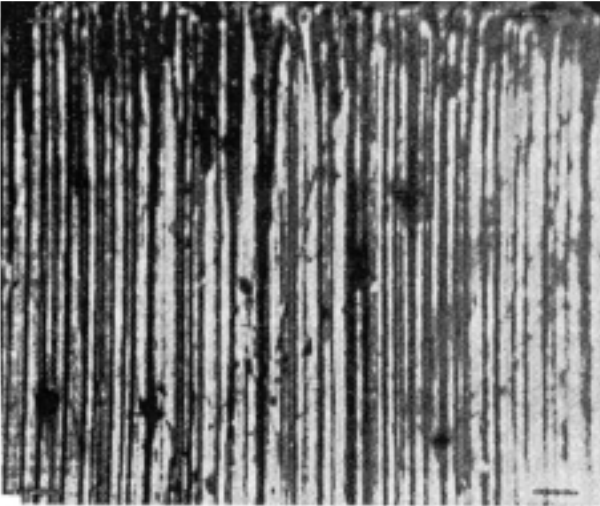


Photo 1 (X30)
Rough scratching
 (degree 5) of a top
 piston ring running
 face. The photo shows
 the upper edge, where
 the hard particles enter
 between ring and liner
 wall. This scratching is
 quite fresh, i.e. recovery
 or restoration has
 not yet commenced.
 Designation S5NEW.

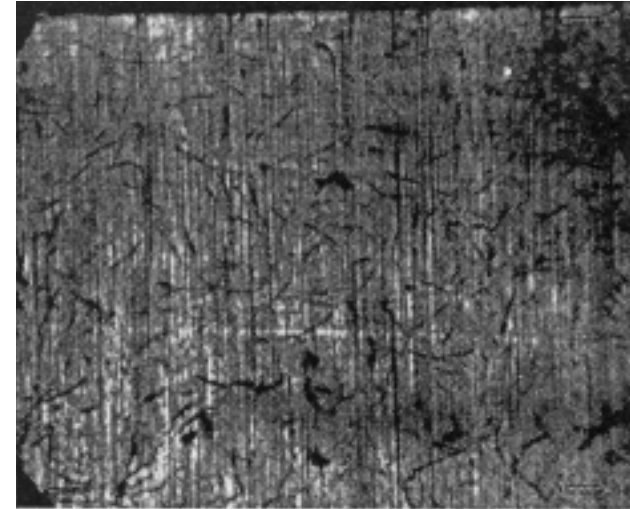


Photo 2 (X30)
 Typical "older" much
 finer scratching.
 That recovery or resto-
 ration is at work, can
 be seen from the fact
 that the graphite flakes
 are distinct.
 Designation S2OLD.

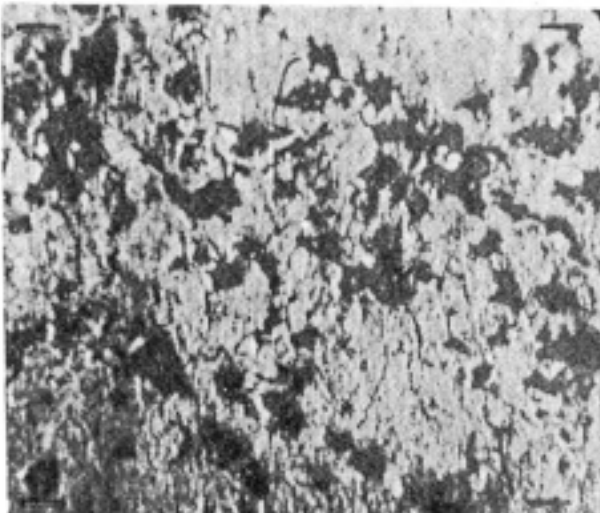


Photo 3 (X30)
 Typical "pock-mark-
 ing" of a ring upper
 side, caused by hard
 particles penetrating
 into the clearance
 above the ring and
 being crushed. This is
 most often seen on the
 two uppermost rings,
 which, during the last
 part of the expansion
 stroke, are pressed
 upwards, against the
 ceiling of the groove,
 by the gas trapped
 between the rings.

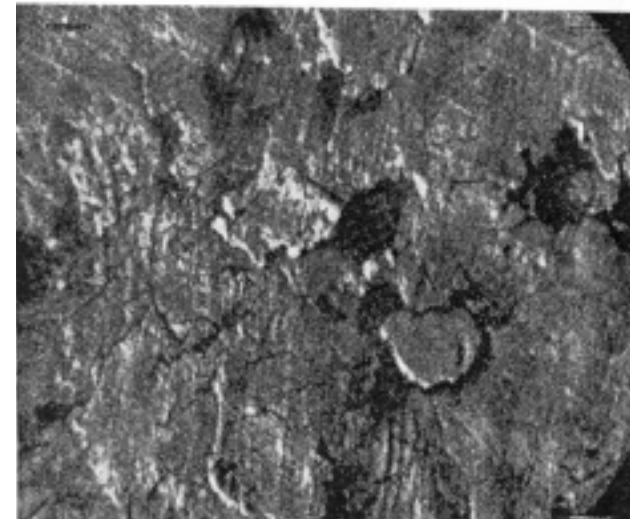


Photo 4 (X30)
 This photo illustrates
 how small pieces of
 cast iron are "torn out"
 of the top surface, by
 the masticating effect
 of the hard particles.
 The pieces probably
 loosen due to shear
 stresses, which cause
 fractures in the material
 between the graphite
 flakes.
 Also ring collapse can
 cause "torn out" material.



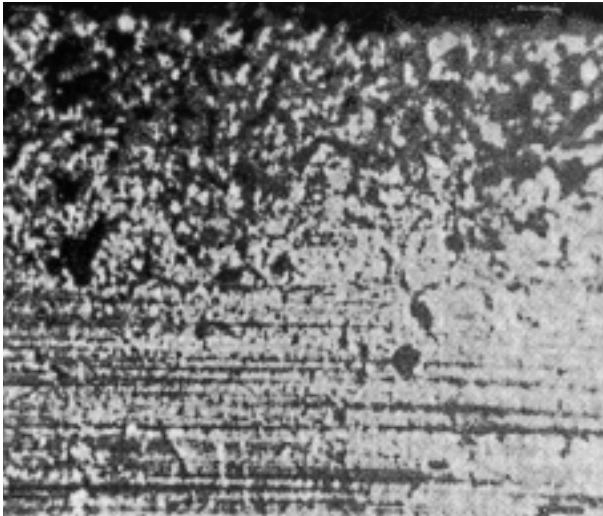


Photo 1 (X30)
Typical erosion or sand-blasting on the part of the ring topside which protrudes out of the groove. This is due to hard grains being blown down through the gap in the ring above (NB: The rings "turn" in the grooves). Such erosion is only seen on rings No. 2, 3 and 4.

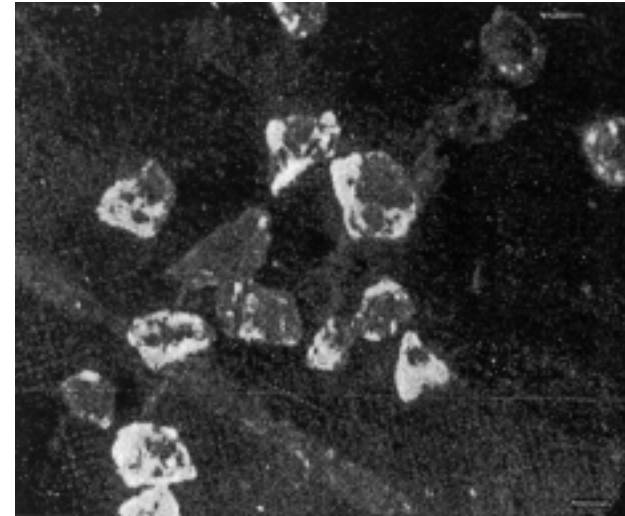


Photo 2 (X30)
Hard particles (sand) separated from a sample of piston crown deposit. Oil and carbon have been removed by incineration, other matter by acid, magnetic separation and filtration. Theoretically these particles could have come into the combustion chamber either with the air or with the fuel.

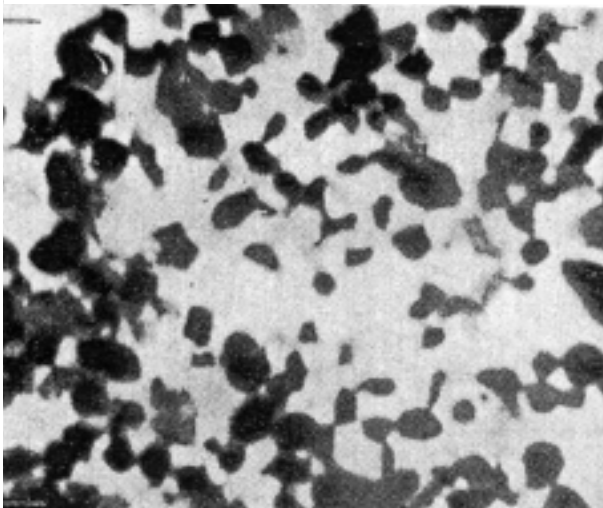


Photo 3 (X250)
Sand (or sand-like grains) separated from centrifuge sludge. In this case the centrifuge treated the fuel oil after the oil had passed a full flow (fabric) filter. The particles size is 10μ to 15μ .

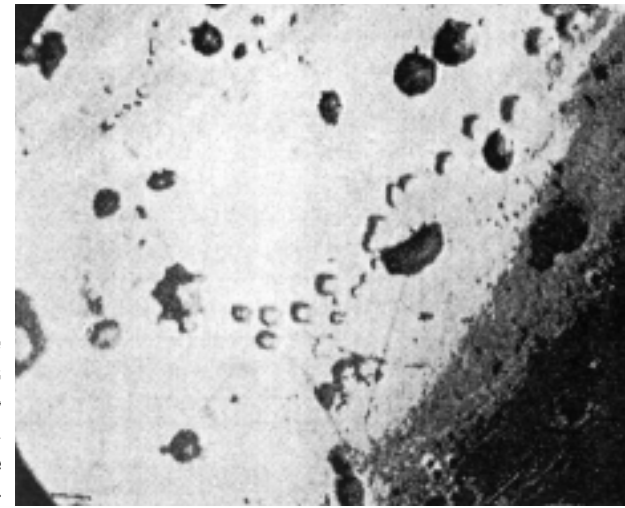
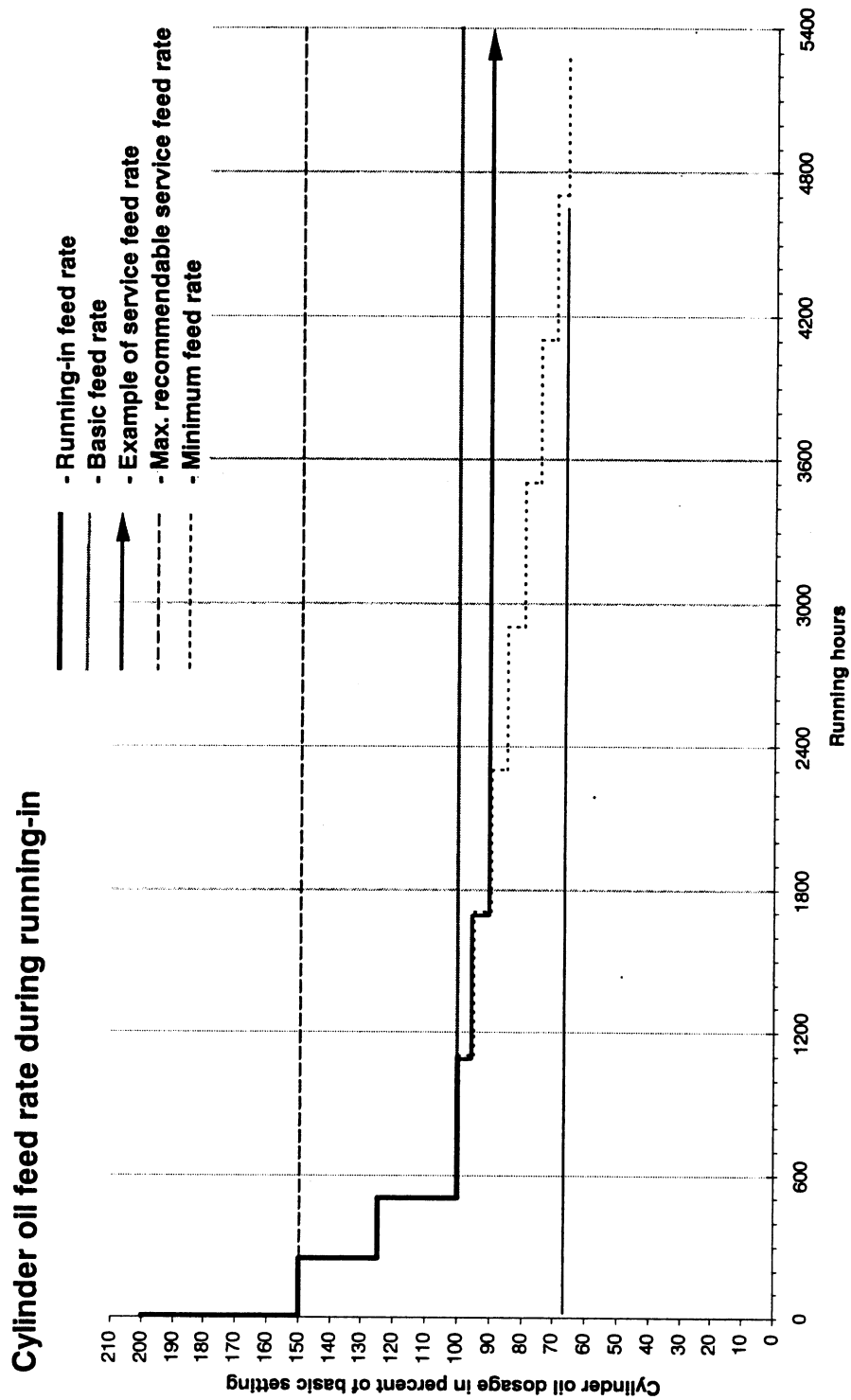
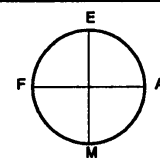
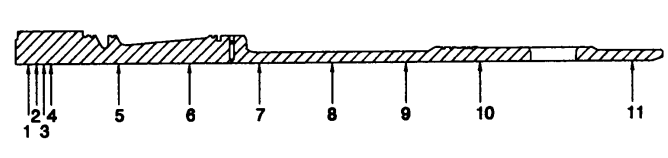
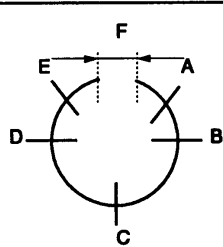
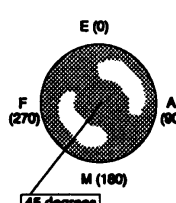


Photo 4 (X30)
Fuel pump suction valve flap after only a few service hours (the lapping marks are still visible. The depressions in the surface are in many cases made by one and the same particle (repeated and identical in shape and size). Usually the edge around the holes is raised, and often the original lapping marks are still visible in the bottom of the depressions.

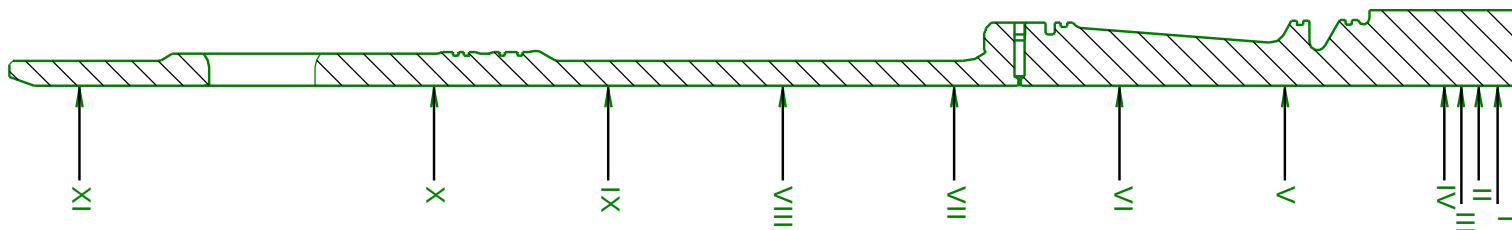




M/:	Engine Type:	No. of cyl.:	Cylinder No.:	Checked by:									
Yard:	Builder:	Engine No.:											
No.:	Built year:		Engine hrs.:	Date:									
Voyage Info:													
Weeks pr. Port calls:		Normal service load in % of MCR:	Lubricator type (rpm/mep):										
Cyl. oil consump. (l/24 hrs):		at load %:	Cyl. oil type:										
Cylinder liner													
Liner hrs.:		Insulation pipe (Y/N):	Liner material:										
Drawing no.:		Insulation in cyl. frame (Y/N):	Liner cool type:										
Producer/Marking:													
Measuring point	1	2	3	4	5	6	7	8	9	10	11		
Depth (mm)													
Diameter (mm)	F-A												
	E-M												
 E : Exhaust A : Aft M : Manoeuvre F : Fore 													
Cyl. cover tightened (Y/N):		Temp. betw. liner and measuring tool (°C):				Shims (mm):							
Liner Remarks:													
Piston rings					Hours since last overhaul:					 "F" to be measured before dismantling			
Width of ring (mm)					Height of ring (mm)								
A B C D E					A B C D E								
Degrees													
Ring 1													
Ring 2													
Ring 3													
Ring 4													
Piston ring type					Free ring gap "F" (mm)	Lock type (r/l/cpr)	Broken (Y/N)	Pist. skirt Guide ring (Y/N)	Reason for examination (Y)				
Ring 1									Routine overhaul:				
Ring 2									Broken rings:				
Ring 3									Routine check:				
Ring 4									Collapsed rings:				
									Low P _{comp} :				
									Leaking piston:				
									Blow-by:				
									Change of piston:				
									Scavenge fire:				
									Pist. skirt scuffing:				
									Change of liner:				
									Other:				
Ring grooves					Piston top								
H (mm)					Piston no.:					 45 degree			
F E A M					Crown (hrs.):								
Ring 1					Max. burning 1. (mm):								
Ring 2					Position 1. (degree):								
Ring 3					Max. burning 2. (mm):								
Ring 4					Position 2. (degree):								
Piston Remarks:													

PS. If a liner or piston crown is exchanged, two reports must be filled-in!





Cylinder Liner

Measuring points for wear

MC / MC-C MK V and MK VI Engines with 2 x 2 piston rings Unit: mm

		L50	L60	L70	L80	L90	S50	S60	S70	S80	K50	K60	K90	K80-CK90-C	
Distance from I	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	II	28	32	38	43	45	28	32	38	43	28	32	45	43	45
	III	54	62	74	84	87	54	62	74	84	54	62	87	84	87
	IV	76	90	108	123	127	76	90	108	123	76	90	127	123	127
	V	210	240	270	335	360	300	360	400	490	210	240	360	310	285
	VI	345	400	430	550	590	540	640	700	860	345	400	600	500	440
	VII	480	560	650	760	825	775	920	1070	1240	480	560	850	690	600
	VIII	730	870	1000	1170	1280	1015	1210	1410	1625	630	800	1200	1025	965
	IV	990	1185	1380	1585	1740	1260	1505	1750	2010	790	1050	1550	1360	1330
	X	1250	1500	1750	2000	2200	1500	1800	2100	2400	950	1300	1900	1700	1700
	XI	1725	2050	2400	2800	3100	2000	2400	2820	3200	1475	1775	2700	2450	2500
	X	28	36	44	53	44	28	42	46	51	19	12	42	17	25

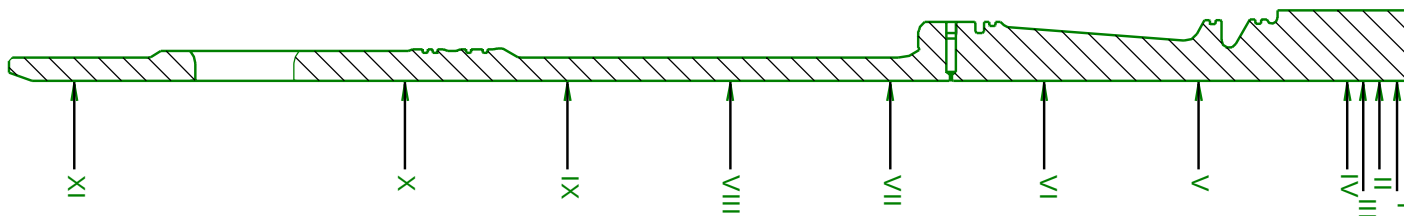
X = Max. piston rod shim

Note:
Before measuring, the measuring point "I" should be adjusted to 5 mm below upper edge of uppermost ring at TDC.

Cylinder Liner Wear Points

Plate 70712A-40D





Cylinder Liner
Measuring points for wear
MC / MC-C MK V and MK VI Engines with high-topland piston Unit: mm

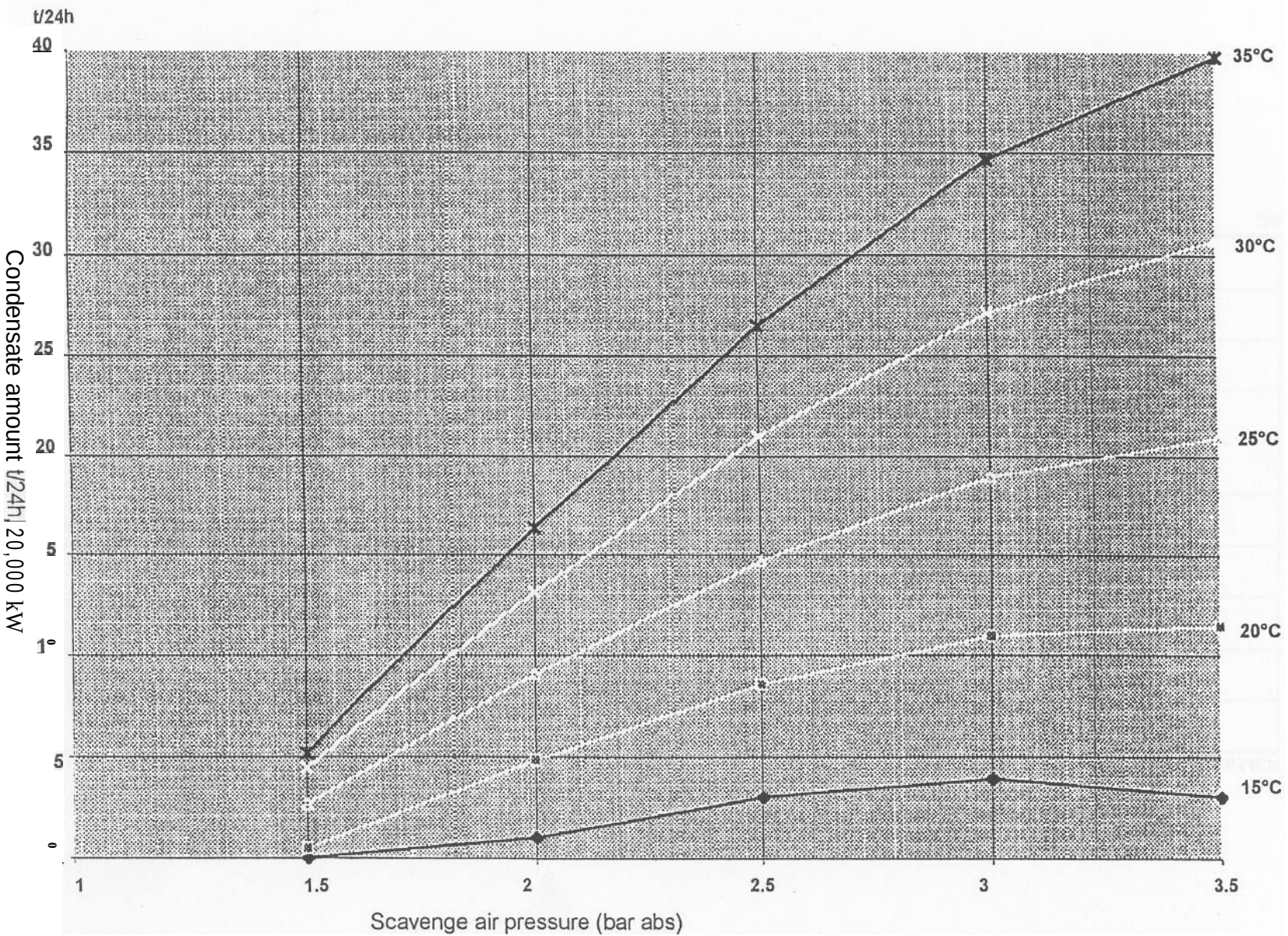
		L50	L60	L70	L80	L90	S50	S60	S70	S80	S46-C	S50-C	S60-C	S70-C	K50	K60	K90	K80-C	K90-C
Distance from I	I			0	0			0	0	0	0	0	0	0				0	0
	II			40	45			30	40	45	25	28	35	40				45	45
	III			75	85			60	75	85	55	55	65	75				85	90
	IV			110	125			90	110	125	75	78	95	110				125	130
	V			225	265			300	350	380	320	330	370	425				310	285
	VI			345	405			512	600	635	560	580	645	735				500	440
	VII			460	545			725	850	895	800	830	915	1050				690	600
	VIII			900	1050			1090	1300	1405	1050	1080	1255	1455				1025	965
	IV			1400	1555			1450	1750	1915	1290	1330	1595	1865				1360	1330
	X			1800	2065			1815	2200	2425	1530	1580	1930	2275				1700	1700
	XI			2400	2800			2400	2800	3195	2020	2095	2510	2925				2425	2500
	X			44	53			32	44	49	24	31	49	46				29	36

X = Max. piston rod shim

Note:
Before measuring, the measuring point "I" should be adjusted to 5 mm below upper edge of uppermost ring at TDC.

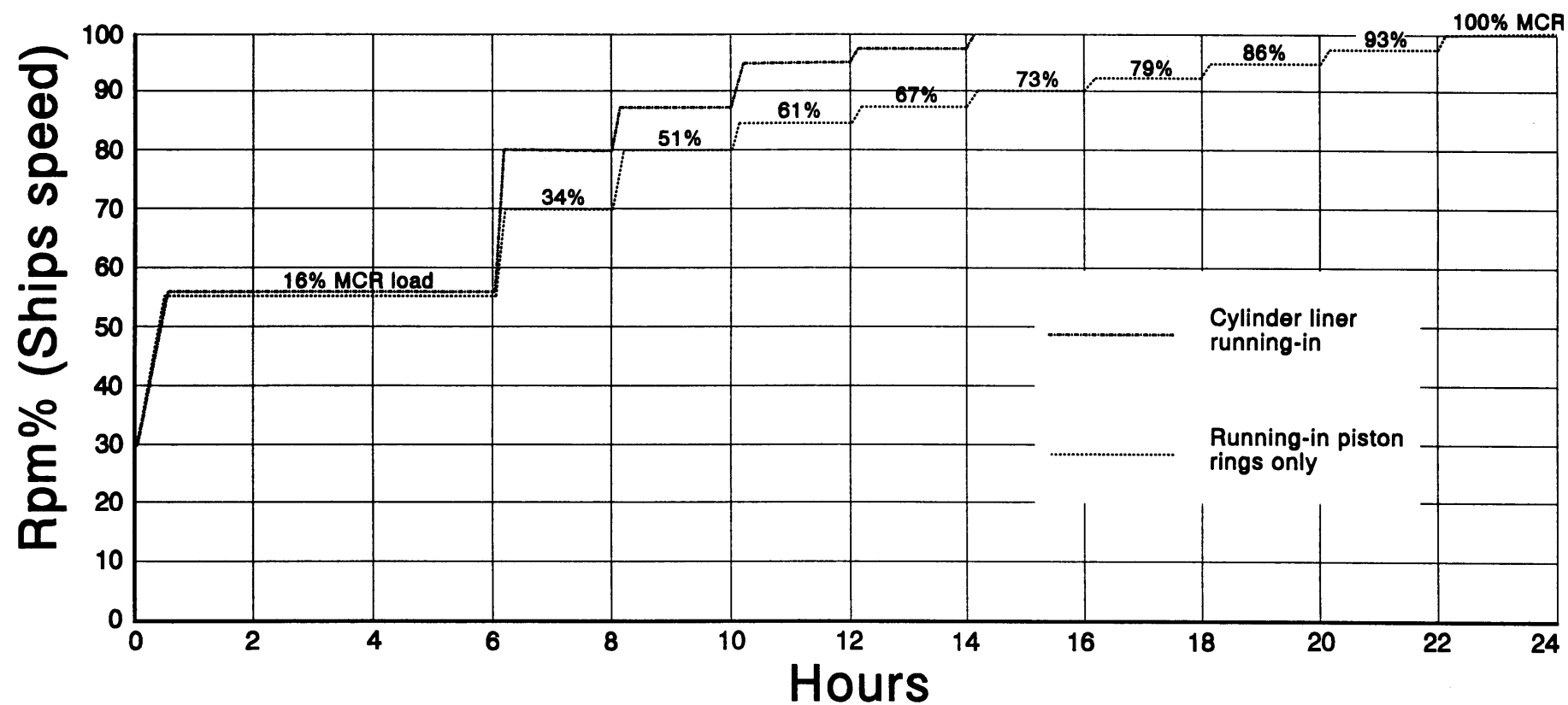


Condensate amount per 24 hours, related to average ambient temperature and scavenge air pressure



For other MC- engines – nominal rated or derated with nominal mean effective pressure – the water condensation is approximately proportional to the MCR shaft power.

Running-in Cylinder Liners and Piston Rings

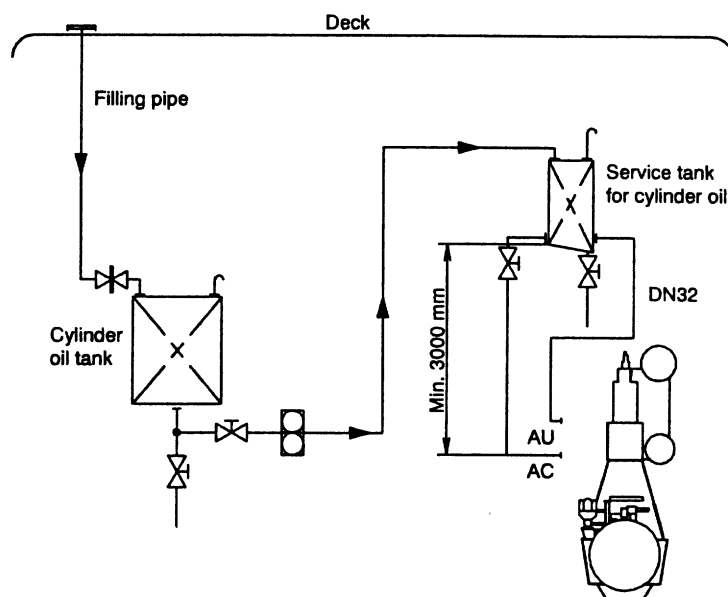


Running-in Load

Plate 70714-40



Fig. 1

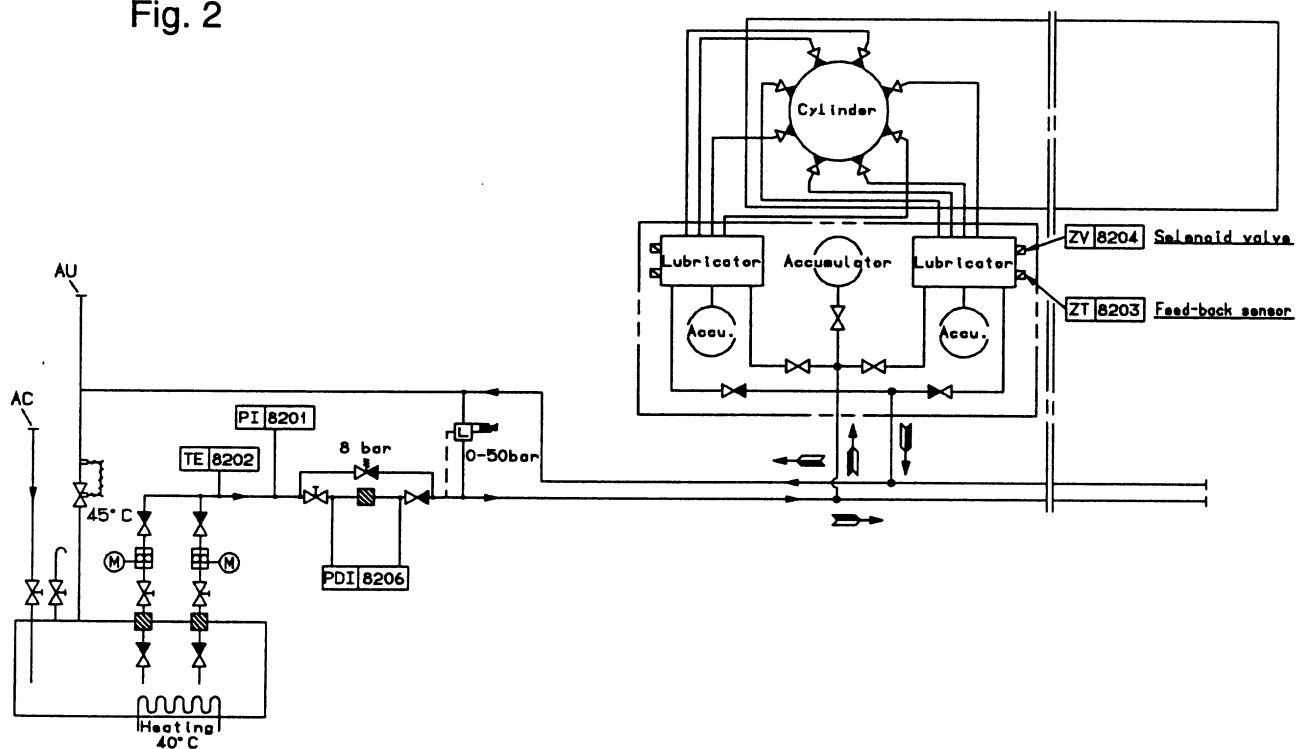


Cylinder Lubricating Oil Pipes

Plate 70713

Edition 0001

Fig. 2



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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 sliding surface geometry.
- b) The surface roughness of the journal or pin, which determines the permissible bearing pressure and required oil film thickness. This is necessary to ensure effective and safe functioning of the bearing.
- c) The correct flow of cooling oil to prevent heat accumulation, which is obtained through a flow area, provided either through the clearance between the journal and the bearing bore or through axial grooves in the bearing sliding surface (see Item 5.3 concerning grooves and wedges).

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 an absolute necessity. (See Item 3).

Scraping of the bearing surfaces is strictly prohibited, 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 galvanically applied intermediate layer, 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 embedability and conformity between the bearing sliding surface and the pin surface geometry.



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. 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 *tangential run-outs*, *oil wedges* and/or *bore reliefs*.

5.1 Tangential Runout of Oil Groove

(Plates 70801, 70802, 70804, Fig. B-B)

A tangential runout is a 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 with Tangential Runout

(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:

- To enhance the oil distribution over the load carrying surfaces. (The tapered areas give improved oil inlet conditions).
- Especially in the case of *crosshead bearings* (Plate 70803) - to assist the formation of a hydrodynamic oil film between the load carrying surfaces.
- 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

- To ensure against distortion of the sliding surface geometry, and
- 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.



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 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 necessary to sustain the required oil flow through the bearing, and hence stabilize the bearing temperature at a level that will ensure the fatigue strength of the bearing metal. In the main and crankpin bearings, the clearance ensures the necessary space to accommodate the journal orbit so as to avoid mechanical overload tendencies on the bearing sliding surface (especially in the main bearing).

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 must 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, 'Checks without opening-up'*
The stated maximum top clearance does not influence the functioning of the bearing nor does it have any relation to the wear limit rejection criteria for bearings (see *Item 7.8: Bearing Wear Rate*).

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

Under normal service conditions, bearing wear is negligible, 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

- a) Crankpin bearings are thin shell bearings. Due to relatively long production time, the engine builder has a ready stock of semi-produced shells (*blanks*) that cover a range from nominal diameter to 3 mm undersize, see also *Item 6.4. 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.



b) The main bearings for the MC engine series can be of the thick or thin shell type ([see 70801, 70802](#)); the information under point a) is also valid here.

c) Crosshead bearings are only available as standard shells, as the reconditioning proposal for offset grinding of the pin (refer to 6.4 b) 2) 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:

- a) Abrasive damage due to contamination of the system oil. *See also Item 7.4 b).*
- b) Corrosive damage due to sea water contamination of the system oil (acidic) or oxidation of the journals due to condensate. *See also Item 7.4 b).*
- c) Spark erosion (only in main bearings). *See also Item 6.2.*

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 undersize journals/pins, Item 6.4*).

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.

With increasing engine ratings, the specific load in the main bearing is increased. This will reduce the oil film thickness, and enable the discharge to take place at a lower voltage level.

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 today with a high efficiency earthing device. If an earthing device is installed, its effectiveness must be checked regularly. *Spark erosion is only observed in main bearings and main bearing journals.* Regarding repair of the journals, *see Item 7.11.*

The condition of the bearings must be evaluated to determine whether they can be reconditioned or have to be discarded.

It is recommended to contact MAN B&W Diesel if advice is required.



6.3 Surface Geometry

Surface geometries such as roundness defect, conicity, barrel form, and misalignment may give rise to operational difficulties. Such abnormal cases of journal/pin geometry and misalignment may occur after a repair.

It is recommended to contact MAN B&W Diesel for advice.

6.4 Undersize Journals/Pins

In case of severe damage, 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:

- a) 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.
- b) In service, crossheads pins can be:
 1. Polished to ($D_{\text{nominal}} - 0.15 \text{ mm}$) as the *minimum* diameter.
 2. Offset to a *maximum* of 0.3 mm and ground.

In both cases, since standard bearings are used, the bearing top clearances 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'.*

- a) Stop the engine and block the main starting valve and the starting air distributor.
- b) Engage the turning gear.
- c) 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. The oil flow from the main and crankpin bearings must be compared from unit to unit; there should be a similarity in the flow patterns.
- d) Turn the crankthrow for the relevant cylinder unit to BDC position and stop the lube oil circulating pump
- e)
 1. 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).
 2. For guide shoe and guide strip clearances and checking procedure, see *Vol. II: 'Maintenance', 904.*
- f) 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.



g) In the following cases, the bearings must be dismantled for inspection, see Item 7.2.

1. Bearing running hot.
2. Oil flow and oil jets uneven, reduced or missing.
3. Increase of clearance since previous reading larger than 0.05 mm.
See also Item 7.8
4. Bearing metal squeezed out, dislodged or missing at the bearing, guide shoe or guide strip ends.

If Item 1 is observed 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 1, 3 or 4 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 (Plate 70809)

Note: 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.

a) Tearing of the overlayer is due to sub-standard bonding. The damage is not confined to specific areas of the bear-

ing surface. The bearing metal/intermediate layer in the damaged area is seen clearly with a sharply defined overlayer border. For white metal bearings, this defect is regarded as a cosmetic defect, if it is confined to small areas of the bearing surface without interconnection.

Note: 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 70810B.

Whether the intermediate layer is exposed can be determined with a knife test, as the knife will leave only a faint or no cut mark in the intermediate layer.

b) Wiping of overlayer 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.
See also the 'Note' above.

c) Bearing metal wiping is due to metal contact between the sliding surfaces which causes increased frictional heat, resulting in plastic deformation (wiping) (see Item 7.4). *See also Item 7.10 b)*

7.4 Causes of Wiping

- a) Hard contact spots, e.g. originating from:
1. Defective pin/journal, bearing, or crosshead guide surfaces.
 2. Scraped bearing or guide shoe surfaces.
 3. Hard particles trapped between the housing bore and the back of the shell.
 4. Fretting on the back of the shell and in the housing bore.



- b) Increased pin/journal surface roughness.

In most cases the increase in roughness will have occurred in service, and is attributed to:

1. 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.

2. 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.

- c) Inadequate lube oil supply.

- d) 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 at 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

- a) Insufficient strength of the bonding between the white metal and the steel back (tinning or casting error).
- b) 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).
- c) High local loading: for example, if, during running-in, the load is concentrated on a few local high spots of the white metal.

Note: Bearings with cracks cannot be repaired.

7.7 Repair of Oil Transitions

(Wedges, tangential run out and bore relief)

Note: It is strongly recommended to contact MAN B&W Diesel for advice before starting any repairs. (See also Item 1, page 708.01)

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](#).

Note: Check the transition geometries before installing the bearings, see Item 14.



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, point g) 3.

For white metal crosshead bearings, 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 and 7.9.

For tin-aluminium crosshead bearings, see the 'Note' in Item 7.3 a).

For further advice, please contact MAN B&W Diesel A/S.

7.9 Surface Roughness (journal/pin)

a) Limits to surface roughness

The surface roughness of the journal/pin should always be within the specified limits.

1. For main and crankpin journals:

I New journals	0.8 Ra
II Roughness approaching	1.6 Ra
(journal to be reconditioned).	
2. For crosshead pins:

I New or repolished	0.05 Ra
II Acceptable in service	0.05-0.1 Ra
III Repolishing if over	0.1 Ra

b) Determination of the pin/journal roughness

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

Note: It is strongly recommended to contact MAN B&W Diesel for advice before starting any repairs. See also Item 1, Page 708.01).

- a) 1. Overlayer wiping 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 a).
2. 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.
- b) Bearing metal squeezed out or wiped:
 1. The wiped metal can accumulate in the oil grooves/ wedges, tangential 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). High spots on the bearing surface must be levelled out by light cross-scraping.
 2. In cases of wiping where the bearing surface geometry is to be re-established, it is important:



- I 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.
- II to check the surface roughness of the journal/pin.
3. In extreme cases of wiping, the oil wedges in *the crosshead bearing* may disappear. In that event, the shell should be replaced.

- c) For evaluation and repair of spark erosion damage, refer to Item 6.2.
- d) Cracked bearing metal surfaces cannot be repaired. The bearing must be replaced (see *Items 7.5 and 7.6*).

7.11 Repairs of Journals/Pins

a) Crosshead pins

Pin surface roughness should be less than 0.1 Ra (see *Item 7.9*). 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 situation and extent of the scratched areas must be evaluated. If there are also deep scratches, these must be levelled out carefully with 3M 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 after polishing should be 0.05 Ra.

The following methods are recommended for repolishing on the spot.

1. 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 recom-

mended as a fairly quick and easy method, although the best solution will often be 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.

2. Braided hemp rope method

This method is executed with a braided hemp rope and *jeweller's rouge*.

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 8.4*).

This is a very time consuming operation and, depending on the surface roughness, about three to six hours may be needed to complete the polishing.

b) Journals

(Main and crankpin journals)

1. The methods for polishing of crosshead pins can also be used here, and method 1) Polishing with microfinishing film, will be the most suitable method. A 30 micron microfinishing film is recommended here.
2. Local damage to the journal can also be repaired. The area is to be ground carefully and the transitions



to the journal sliding surface are to be rounded carefully and polished. *We recommend to contact MAN B&W Diesel for advice before such a repair is carried out.*

7.12 Inspection of Bearings

Regarding check of bearings before installation, see item 14.

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*). 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 and intermediate layer'*. The upper shell is a bi-metal 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*).

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*) 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 very important parameters for the assembly to function. A further requirement is effective cooling which is en-

sured by the transverse oil grooves. The pin surface is superfinished (see *Item 7.9 a) 2*). The lower shell is 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), which enables the pin sliding geometry to conform with the bearing surface.*

9. Main Bearings

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:

- central oil supply groove and oil inlet in the upper shell which ends in a *tangential run-out* (Item 5.1) in both sides of the lower shell, see [Plate 70801](#).
- 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 pre-tensioned, will ensure a secure 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 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 earlier in this section. For information regarding inspection and repair, see Item 7.

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. 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.

11. Guide Shoes and Guide Strips

(Plate 70806)

(See also Vol. III, 'Components', Plate 90401)

- a) 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 relatively 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-on white metal and furnished with transverse oil supply grooves and wedges (see Item 5.3, [Plate 70803](#) and [Plate 70806](#)).

For inspection of guide shoes and guide strips, see Item 7.1, 7.3 c) and 7.4 a) 1 and a) 2 and Vol. II, 'Maintenance', 904.

12. Thrust Bearing Assembly

(Plate 70807)

The thrust bearing, which is integrated into the chain drive, is a tilting-pad bearing of the Michell type. There are eight pads (segments) placed on each of the forward and aft sides of the thrust collar. They are held in place circumferentially by stops. 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.

13. Camshaft Bearing Assembly (Plate 70808)

The camshaft bearing assemblies are positioned between the exhaust and fuel cams of the individual cylinder units. The bearing assembly is of the underslung design, i.e. the shaft rests in rigid bearing caps that are bolted from below to the horizontal face in the cam housings. The correct position of the caps is ensured by dowel pins.

The bearings used are of the thin shell type without overlayer (Item 5.5) and the shell configuration can be:

- a) a two-shell assembly (upper and lower shell), [Plate 70808](#), Fig. 1.
- b) a one-shell assembly (lower shell only), [Plate 70808](#), Fig. 2.

In case b) the mating faces of the lower shell rest against the horizontal partition face in the cam housing. The wall thickness at the mating faces of the shell is reduced to ensure that the inner surface of the shell is flush with the bore in the cam housing.

The transition to the bearing sliding surface is wedge-shaped; this is to ensure unrestricted oil supply to the bearing sliding surface.

The specific load in the camshaft bearings is low, and the bearings function trouble free provided that the camshaft lub. oil/Uni-Lube system is well maintained, see [page 708.27](#). However, if practical information is needed, refer to Item 7, 'Check without opening up' and 'Open up inspection and overhaul' For clearances, please refer to Vol. II, 'Maintenance', 906.

14. Check of Bearings before Installation ([Plate 70827](#))

Clean the bearing shells thoroughly before inspecting.

14.1 Visual Inspection

- a) Check the condition of the bearing surfaces for impact marks and burrs.
- b) Check that the transition between the bore relief and the bearing sliding surface is smooth.

14.2 Check Measurements

Place the shell freely, as illustrated in [Plate 70827](#), 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 and [Plates 70809 - 70814](#).

This will facilitate the evaluation of the bearing wear during later overhauls.

14.3 Cautions

As the bearing shells are sensitive to deformations, care must be taken during handling, transport and storage, to avoid damaging the shell geometry.

The shells should be stored resting on one side, and be adequately protected against corrosion and mechanical damage.

Preferably, keep new bearing shells in the original packing, and check that the shells are in a good condition, especially if the packing shows signs of damage.

During transport from the store to the engine, avoid any impacts which could affect the shell geometry.



1. Alignment

During installation of the engine, intermediate shaft and propeller shaft, the yard aims to carry out a common alignment, to ensure that the bearing reactions are kept within the permitted limits, with regard to the different factors which influence the vessel and engine during service.

Factors like the ship's load condition, permanent sag of the vessel, movements in sea, wear of bearings etc., makes it necessary to regularly check the alignments:

Main bearings, *see Items 2.1-2.6*
Engine bedplate, *see Item 2.7*
Shafts, *see Item 2.8.*

2. Alignment of Main Bearings

[Plates 70815, 70817](#)

The bearing alignment can be checked by *deflection measurements (autolog)* as described in the following Section.

Example; If two adjacent main bearings at the centre of the engine are placed too high, then at this point the crankshaft centreline will be lifted to form an arc. This will cause the intermediate crank throw to deflect in such a way that it "opens" when turned into bottom position and "closes" in top position.

Since the magnitude of such axial lengthening and shortening increases in proportion to the difference in the height of the bearings, it can be used as a measure of the bearing alignment.

2.1 Deflection Measurements (autolog)

[Plate 70815](#)

As the alignment is influenced by the temperature of the engine and the load condition of the ship, 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 and load condition of the ship in [Plate 70815](#).

In addition, they should be taken while the ship is afloat (i.e. not while in dry dock).

Procedure

Turn the crankpin for the cylinder concerned to Pos. B1, *see Fig. 2*. Place a dial gauge axially in the crank throw, opposite the crankpin, and at the correct distance from the centre, as illustrated in Fig. 1. The correct mounting position is marked with punch marks on the crankthrow. Set the dial gauge to "Zero".

Take 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 taking deflection readings for the three aftmost cylinders, the turning gear should, at each stoppage, be turned a little backwards to ease off the tangential pressure on the turning wheel teeth. 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

Plate 70817 and page 701.14

The results of the deflection measurements (*see Plate 70815, Fig. 5*) should be evaluated with the testbed measurements (recorded by the engine builder on page 701.14). 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*.

Deviation from earlier measurements may be due to:

- human error
- journal eccentricity
- floating journals, see Item 2.3 furtheron
- the causes mentioned in Item 2.4 furtheron

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.

2.4 Causes of Crankshaft Deflection

1. Wear of main bearing
2. Displacement of bedplate (*see ‘Piano Wire Measurements’*)
3. Displacement of engine alignment and/or shafting alignment.

This normally manifests itself by large alteration in the deflection of the aftmost crank throw (*see Shafting Alignment*).

2.5 Piano Wire Measurements

A 0.5 mm piano wire is stretched along each side of the bedplate.

The wire is loaded with 40 kp 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.

2.6 Shafting Alignment

This can be checked by measuring the load at:

- the aftermost main bearing
- the intermediate shaft bearings (plummer blocks)
- in the stern tube bearing.

Taking 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 yard or repairshop 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 70818A](#), [70819](#) and [70824](#)

For engines without Uni-Lube system, see [Plates 70818B](#) and [70819](#)

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 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 three flanges: Y, U and R.

Y) Via the camshaft booster pumps, oil is supplied to camshaft bearings, roller guides and exhaust valve actuators.

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.

R) The remaining oil goes to lubrication of the main bearings, chain drive and thrust bearing.

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 [Plates 70819](#) and [70824](#).

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 Chapter 701, pos. 327 and pos. 328.*

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 Checks A1 and A2, Chapter 702*).

Feel over 15-30 minutes after starting, again one hour later, and finally also after reaching full load (*see also 'Checks during starting', Check 9 'Feel-over sequence', Chapter 703*).



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 bottom 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 yards 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 B&W 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 bottom 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

Regarding flushing of the camshaft lube oil pipes:

- Engines with Uni-Lube system, see 'Camshaft lubrication for engines with Uni-Lube system', Item 3.
- Engines without Uni-Lube system, see 'Separate camshaft lube oil system', Item 2.3.

However, 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 chain drive
 - e) The turbocharger(s) (MAN B&W, MET)
 - f) The axial vibration damper
 - g) The torsional vibration damper (if installed)
 - h) The moment compensators (if installed)
- See also Plates 70820, 70821.*

It is possible for dirt to enter the crosshead bearings due to the design of the open bearing cap. It is therefore essential to cover the bearing cap with rubber shielding throughout the flushing sequence.

As the circulating oil cannot by-pass the bottom tank, the whole oil content should partake in the flushing.

During the flushing, the oil should be heated to 60-65°C and circulated using the *full* capacity of the pump to ensure that all protective agents inside the pipes and components are removed.

It is essential to obtain an oil velocity which causes a turbulent flow in the pipes that are being flushed.

Turbulent flow is obtained with a Reynold number of 3000 and above.

$$R_e = \frac{V \times D}{\nu} \times 1000, \text{ where}$$

R_e = Reynold number
 V = Average flow velocity (m/s)
 ν = Kinematic viscosity (cSt)
 D = Pipe inner diameter (mm)

The preheating can be carried out, for instance, by filling the waterside of the circulating oil cooler (between the valves before and after the cooler) with fresh water and then leading steam into this space. During the process the deaerating pipe must be open, and the amount of steam held at such a level that the pressure in the cooler is kept low.

In order to obtain a representative control of the cleanliness of the oil system during flushing, "control bags" are used (e.g. 100 mm wide by 400 mm long, but with an area of not less than 1000 cm², and made from 0.050 mm filter gauze). Proposals for checkbag housings are shown on [Plate 70821](#).

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, flushing should not be accepted as being complete until the cleanliness is found to be within the range in ISO 4406 level $\leq 19/15$ (corresponding to NAS 1638, Class 10).

In order to improve the cleanliness, it is recommended that the circulating oil centrifuges are in operation during the flushing procedure. The centrifuge preheaters ought to be used to keep the oil heated to the proper level.

Note: 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 create fatigue failures in piping and welds.

A flushing log, [see Plate 70822](#), 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 bottom tank is again cleaned manually. The oil should be returned to the tank via the 10 μm filter.

If this bottom 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. 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 in-line 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/BHP 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 TBN and viscosity on an acceptable equilibrium level as a result of the fact that the oil consumed is with elevated figures and the new oil supplied has standard data.

In order to obtain effective separation in the centrifuges, it is important that the flow rate and the temperature are adjusted to their optimum, as described in the following.

3.2 The Centrifuging Process

Efficient oil cleaning relies on the principle that - provided the through-put is adequate and the treatment is effective - *an equilibrium* condition can be reached, where the



engine contamination rate is balanced by the centrifuge separation rate i.e.:

Contaminant quantity added to the oil per hour = contaminant quantity removed by the centrifuge per hour.

It is the purpose of the centrifuging process to ensure that this equilibrium condition is reached, with the oil insolubles content being as low as possible.

Since the cleaning efficiency of the centrifuge is largely dependent upon the flow-rate, it is very important that this is optimised.

The above considerations are further explained in the following.

3.3 The System Volume, in Relation to the Centrifuging Process

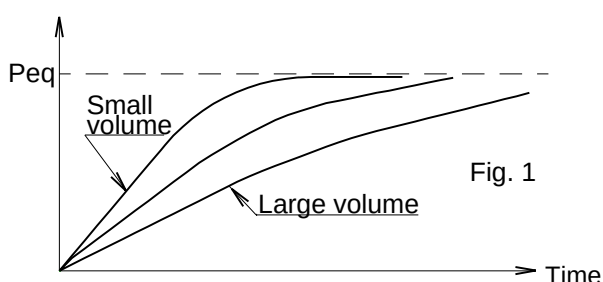
As mentioned above, a centrifuge working on a charge of oil will, in principle, after a certain time, remove an amount of contamination material per hour which is equal to the amount of contamination material produced by the engine in the same span of time.

This means that the system (engine, oil and centrifuges) is in equilibrium at a certain level of oil contamination (P_{eq}) which is usually measured as pentane insolubles %.

In a small oil system (small volume), the equilibrium level will be reached sooner than in a large system (Fig. 1) - but the final contamination level will be the same for both systems - because in this respect the system oil acts only as a carrier of contamination material.

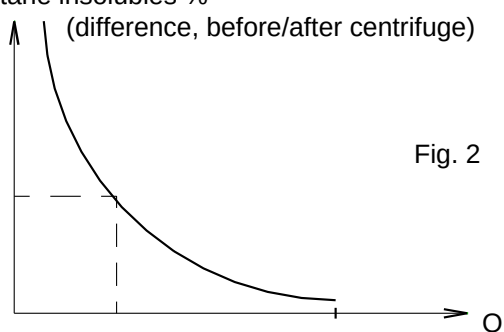
A centrifuge can be operated at greatly varying flow rates (Q).

Pentane insolubles %



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 Pentane insolubles %



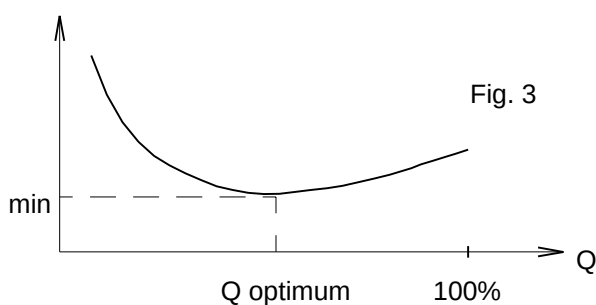
insolubles removed will decrease with rising Q .

It can be seen that:

- At low Q , only a small portion of the oil is passing the centrifuge/hour, but is being cleaned effectively.
- At high Q , a large quantity of oil is passing the centrifuge/hour, but the cleaning is less effective.

Thus, by correctly adjusting the flow rate, an optimal equilibrium cleaning level can be obtained (Fig. 3).

Pentane insolubles equilibrium level %



This minimum contamination level is obtained by employing a suitable flow rate that is only a fraction of the stated maximum capacity of the centrifuge (*see the centrifuge manual*).

3.4 Guidance Flow Rates

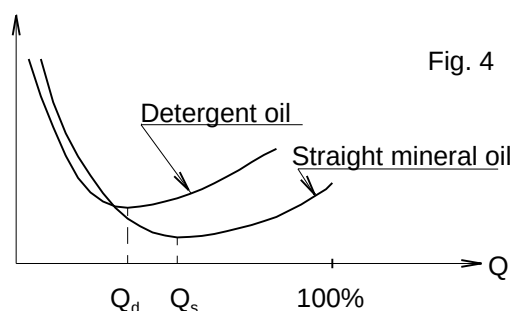
The ability of the system oil to “carry” contamination products is expressed by its detergency/dispersancy level.

This means that a given content of contamination - for instance 1% pentane insolubles - will, in a detergent oil, be present as smaller, but more numerous particles than in a straight oil.

Furthermore, the particles in the detergent oil will be surrounded by additives, which results in a specific gravity very close to that of the oil itself, thereby hampering particle settling in the centrifuge.

This influences the position of the minimum in Fig. 3, as illustrated in Fig. 4.

Pentane insolubles equilibrium level %



As can be seen, the equilibrium level in a detergent oil will be higher than in a straight oil, and the optimum flow rate will be lower.

However, since the most important factor is the particle size (risk of scratching and wear of the bearing journals), the above-mentioned difference in equilibrium levels is of relatively minor importance, and the following guidance figures can be used:

In general,

- the optimum centrifuge flow rate for a *detergent oil* is about 20-25% of the maximum centrifuge capacity,
- whereas, for a *straight oil*, it is about 50-60%.
- 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 sea 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:



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).

b) Air Admixture

Good venting of the bottom tank should be arranged.

The total oil quantity should be such that it is not circulated more than about 15-18 times per hour. This ensures that sufficient time exists for deaeration during the period of "rest" in the bottom tank.

It is important that the whole oil content takes part in the circulation, i.e. stagnant oil should be avoided.

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 [Chapter 702](#), point B5, concerning cleaning and rust prevention.

4.3 Signs of Deterioration

If oxidation becomes grave, prompt action is necessary because the final stages of deterioration can develop and accelerate very quickly, i.e. within one or two weeks.

Even if this seldom happens, it is prudent to be acquainted with the following signs of deterioration, which may occur singly or in combinations.

- The sludge precipitation in the centrifuge multiplies.
- The smell of the oil becomes bad (acid or pungent).
- Machined surfaces in crankcase become coffee-brown (thin layer of lacquer).
- Paint in crankcase peels off, or blisters.
- Excessive carbon deposits (coke) are formed in piston cooling chambers.

In serious cases of oil deterioration, the system should be cleaned and flushed thoroughly, before fresh oil is filled into it.

4.4 Water in the Oil

Water contamination of the circulating oil should always be avoided.

The presence of water, especially salt water, will:

- accelerate oil oxidation (tend to form organic and inorganic acids)
- tend to corrode machined surfaces and thereby increase the roughness of bearing journals and piston rods, etc. (see e.g. 'Crosshead Bearings' in this Chapter).
- tend to form tin-oxide on white metal (see 'Crosshead Bearings').

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 sea 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 on Oil Condition

As described in the foregoing sub-Sections 4.3 and 4.4, the on board surveillance of oil condition involves keeping a check on:

- 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 & 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.	$\pm 5\%$ (of initial value)
Viscosity	The viscosity increases with oil oxidation, and also by contamination with cylinder oil, heavy fuel, or water. A decrease in the viscosity may be due to dilution with diesel oil.	max. + 40% min. - 15% (of initial value)
Flash Point (open cup)	Lowest temperature at which the oil gives off a combustible vapour. Gives an indication of possible fuel oil contamination.	min. 180°C
TAN (Total Acid Number)	This expresses the total content of organic and inorganic acids in the oil. Organic (or weak) acids are due to oxidation. TAN = SAN + Weak acid number.	max. 2
SAN (Strong Acid Number)	This expresses the amount of inorganic (or strong) acids in the oil. These are usually sulphuric acid from the combustion chamber, or hydrochloric acid arising from sea water (ought to be stated in the analysis). SAN makes the oil corrosive (especially if water is present) and should be zero.	0
Alkalinity/TBN (Total Base Number)	Gives the alkalinity level in oils containing acid neutralizing additives.	max. + 1 00% min. - 30% (of initial values)
Water	Risky if TAN and SAN are high. Sea water has a higher corrosive effect than fresh water (see previous point 4.4).	fresh: 0.2% (0.5% for short periods) Saline: trace
Conradson Carbon	Residue from incomplete combustion, or cracked lubricating and cylinder oil.	max. + 3%
Ash	Some additives leave ash, which may thereby be used to indicate the amount of additives in the oil. The ash can also consist of wear particles, sand and rust. The ash content of a used oil can only be evaluated by comparison with the ash content of the unused oil.	max. + 2%
Insolubles	Usually stated as pentane/heptane and benzene insolubles. The amount of <i>insoluble ingredients</i> in the oil is checked as follows: Equal parts of the oil sample are diluted with benzene (C ₆ H ₆) and normal pentane (C ₅ H ₁₂) or heptane (C ₇ H ₁₄). As oxidized oil (lacquer and varnish-like components) is only soluble in benzene, and not in pentane or heptane, the difference in the amount of insolubles is indicative of the degree of oil oxidation. The benzene insolubles are the solid contaminants.	Non-coagulated pentane insolubles max. 2%
		Non-coagulated benzene insolubles max. 1%

The above limiting values are given for reference 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 70823

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 70823 shows the cleaning installations. (Option)

The drain oil is collected in tank No. 1. When the tank is nearly full, the oil is transferred, via the centrifuge, to tank No. 2, and thereafter, via the centrifuge, recirculated a number of times.

When centrifuging the stuffing box drain oil, the flow-rate should be decreased to about 50% of what is normally used for the circulating oil, and the preheating temperature raised to about 90°C. This is because, in general, the drain oil is a little more viscous than the circulating oil, and also because part of the contamination products consist of oxidized cylinder oil, with a specific gravity which does not differ much from that of the circulating oil itself.

Water-washing should only be carried out if recommended by the oil supplier.

Finally, the centrifuged oil, in tank No. 2, should be filtered a number of times through the cellulose fine filter, at a temperature of 60-80°C.

This will remove any very fine soot and oxidation products not taken out by the centrifuging, and thus make the oil suitable for returning to the circulating system.

Provided that the *circulating oil is an alkaline detergent type*, it is not necessary to analyse each charge of cleaned drain oil before it is returned to the system. Regular sampling and analysis of the circulating oil and drain oil will be sufficient.

If, however, the *circulating oil is not alkaline*, all the cleaned drain oil should be checked for acidity, for instance by means of an analysis kit, before it is returned to the system.

The "total acid number" (TAN) should not exceed 2. See also Item 5, 'Circulating oil: Analyses & Characteristic Properties'.

If the TAN exceeds 2, the particular charge of drain oil should be disposed of.



1. System Details

Plate 70824B

To prevent the circulating oil in the crank-case from being contaminated with fuel, the engine is provided with a separate forced lubrication system which supplies oil to the camshaft bearings, roller guides and hydraulically operated exhaust valves.

This oil is taken from a special tank by one of the two circulating pumps, and is then passed through a cooler and a full flow filter.

The absolute fineness of the full flow filter should be 50 μm (0.05 mm), corresponding to a nominal fineness of 30 μm at a retaining rate of 90%.

From the bearings and roller guides, the oil drains to the bottom of the bearing housings, where a suitable oil level is maintained to lubricate the running surfaces of the cams.

1. The lub. oil is drained back to the tank through a magnetic filter.
2. The cleaning of the camshaft oil is done by the by-pass fine filter unit which is connected to the camshaft lub. oil tank. The lub. oil is drawn from the bottom of the tank by a screw pump and is returned to the tank through a fine filter.

For check of the by-pass filtration system, start the screw pump and check the pressure drop across the fine filter. Normal pressure drop is 0.8 bar. When 1.8 bar is reached, the filter cartridge should be replaced and discarded.

The system is fitted with pressure-switches, which are activated at low oil pressure for signal to an alarm device and for automatic start of the stand-by pump.

1.1 Pressure Adjustment

The oil pressure is adjusted in the following way:

1. Open the valves in the system and start circulating pump No. 1.
2. Check that the oil circulates and that there is sufficient oil in the tank.
3. Set the pump by-pass valve to open at the maximum working pressure of the pump - not, however, higher than 4 bar. Adjust in steps (while a valve in the pressure piping is slowly closed and opened) until the pressure, with closed valve, has the above-mentioned value.

Make the same adjustment with circulating pump No. 2.

4. In some cases, the pump capacity can be so large that problems can arise in draining the oil quickly enough out of the roller guide housing.

It may therefore become necessary to reduce the spring-pressure on the pump by-pass valve, so that the surplus capacity flows back to the tank.

2. Camshaft oil

(NB: The camshaft oil also operates the hydraulic exhaust valves).

The same oil as in the engine circulating system is normally used.

H.D. oils, as used in auxiliary engines, may also be employed.

2.1 Fuel Contamination

Regularly check the camshaft lub. oil for fuel contamination, and *change it if the fuel content exceeds 10%*.



Checking is recommended at intervals of max. three months.

The dilution will be indicated by:

- increasing oil level in the tank;
- smell of the oil;
- increasing oil viscosity
(in the case of HFO contamination)

It can also be "measured" by a flash-point test, but this can only be done ashore.

2.2 Water Contamination

Also regularly check the oil for water contamination.

Water ingress is indicated by:

1. Increased level in the oil tank
2. Discolouration of the lub. oil
3. Sudden (momentary) increase of pressure differential across the by-pass filter.

The water will spoil the by-pass filter cartridge. Consequently, the water has to be removed from the oil by means of centrifuging, before the cartridge is replaced.

NB: Before the oil is returned to the system, it should be checked for possible fuel oil content.

2.3 Flushing Procedure, Separate Camshaft Lub. Oil System.

[Plate 70825](#)

In principle, the flushing procedure for the main lub. oil system is used (see 'Maintenance of the lubricating oil', Item 2.2 'Flushing procedure'), with the following modifications:

1. The standard 50 micron filter basket should be either exchanged with a 6-10 micron filter basket, or additional 6-10

micron filter material should be inserted inside the filter basket.

2. Remove one inspection hole cover on each camshaft roller guide housing.
3. Remove the lub. oil inlet pipe sections to all camshaft roller guide housings, (see diagram, [Plate 70825](#)), and inspect internal cleanliness of all opened pipes.
4. Connect a flexible hose with a valve to the open end of the lub. oil pipe at point (B) of each cylinder unit, and suspend the flexible hose through the open inspection hole into the corresponding camshaft oil pan.
5. In order to monitor the cleanliness of the system while the flushing is in progress, a 50 micron checkbag may be fitted to the end of the flexible hose in the outmost cylinder unit.

Regarding recommended design of the checkbag housing, see [Plate 70821](#).

6. To improve the cleanliness, it is recommended to operate the CJC-filter (fine filter) or an additional 6-10 µm filter, see [Plate 70825](#).
7. After flushing, the lub. oil pipe blank flanges at points Y & Z, other possible "blind ends" and the camshaft lub. oil tank should be opened for inspection and manual cleaning.

Flushing log, [see Plate 70822](#), is to be used during flushing and for later reference.



1. System details

(Plate 70824A)

The camshaft bearings and the fuel and exhaust roller guides are lubricated by the main lub. oil pumps.

The exhaust valve actuators also receive oil from the main lub. oil system.

Booster pumps are installed in order to increase the oil inlet pressure.

From the bearings, roller guides and exhaust valve actuators, the oil drains to the bottom of the bearing housings, where a suitable oil level is maintained to lubricate the running surfaces of the cams. From here, the lub. oil is drained back to the bottom tank.

2. Pressure Adjustment

1. Start the main lub. oil pumps and booster pump No. 1.
2. Set the pump by-pass valve to open at the maximum working pressure of the pump - not, however, below 3 bar.

Adjust in steps (while the outlet valve is slowly closed and opened) until the pressure, with closed valve, has the above-mentioned value.

Adjust booster pump No. 2, using the same method.

3. Adjust the pressure control valve fitted at the end of the inlet pipe, so as to obtain the pressure indicated in [Chapter 701](#), pos. 357.
4. When the engine is running, it may become necessary to readjust the pressure control valve, to maintain the required pressure.

3. Flushing Procedure

Note: Follow these instructions together with the instructions given in 'Maintenance of the circulating oil', Item 2.2 'Flushing procedure'.

1. Remove the inspection hole cover of each camshaft roller guide section.
2. Remove the oil inlet pipes to all camshaft roller guide sections and exhaust valve actuators, [see Plate 70825](#). Also blank off to governor drive/starting air distributor, etc.
Inspect internal cleanliness of all opened pipes.
3. Connect a flexible hose with a valve to the open end of the lub. oil pipes at point (B) of each cylinder unit. [See also Plate 70825](#).

Suspend the flexible hoses through the open inspection hole into the corresponding camshaft section.

4. Keep the booster pumps running during the flushing procedure.
5. In order to monitor the cleanliness of the system while the flushing is in progress, a 50 micron checkbag may be fitted to the end of the flexible hoses in the outmost cylinder unit.

Regarding recommended design of the checkbag housing, [see Plate 70821](#).

6. After flushing, open the lub. oil blank flanges and any other possible "blind ends" for inspection and manual cleaning.
7. Use the flushing log, [Plate 70822](#), during flushing and for later reference.



1. MAN B&W T/C, System Details

Plate 70826

The lub. oil system for the MAN B&W type of turbocharger is shown separately on [Plate 70826](#).

The system is supplied from the main lub. oil system, via inlet, U.
[See also Plate 70819](#).

The oil is discharged to the main lub. oil bottom tank via outlet, AB.
The discharge line is connected to the venting pipe, E, which leads to the deck.
[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

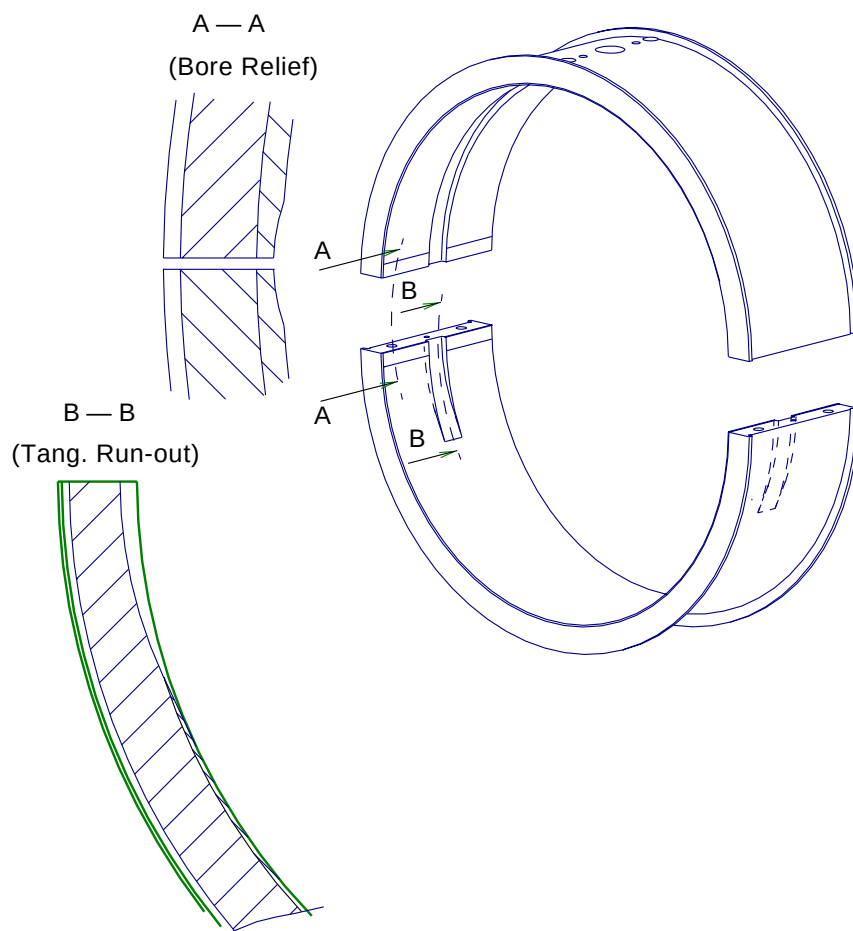
The MET turboborchargers are also lubricated via the main lub. oil system. *See description of turbocharger lub. oil system in Item 1 'MAN B&W T/C, System Details'.*

3. BBC T/C, System Details

The BBC/ABB turbochargers are designed with an integrated lub. oil system, please refer to the relevant BBC/ABB-instruction manual.

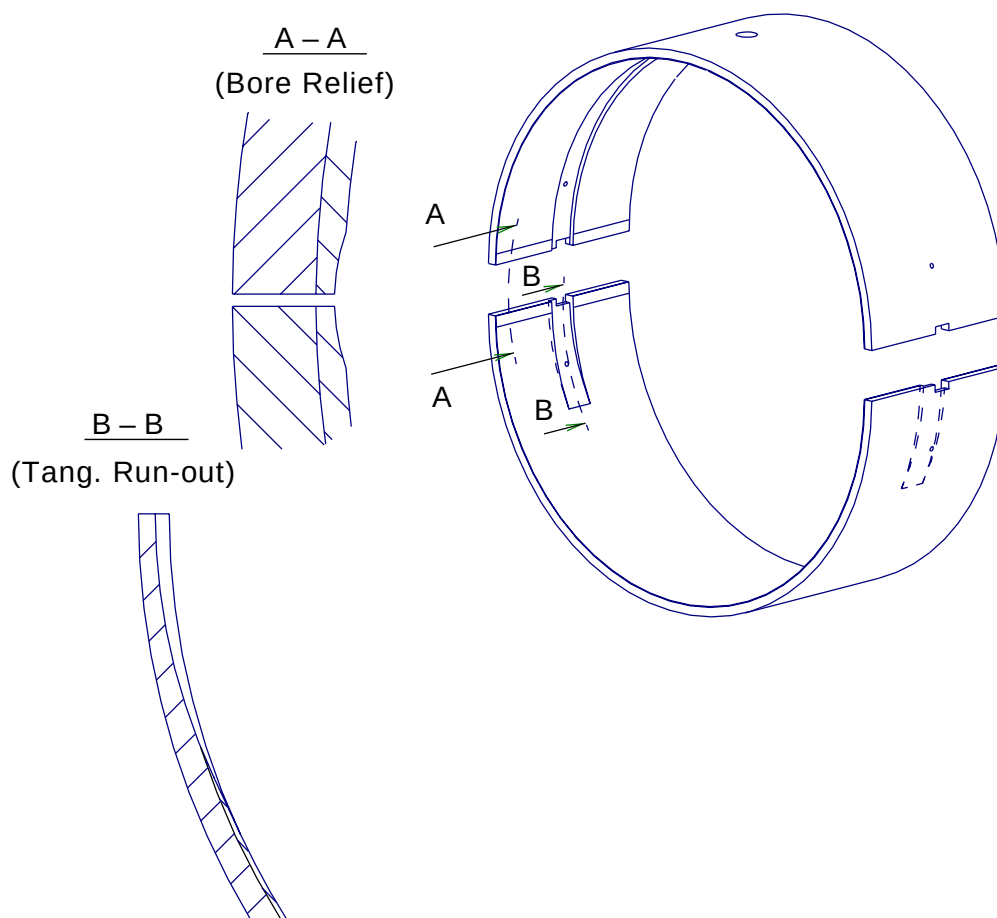
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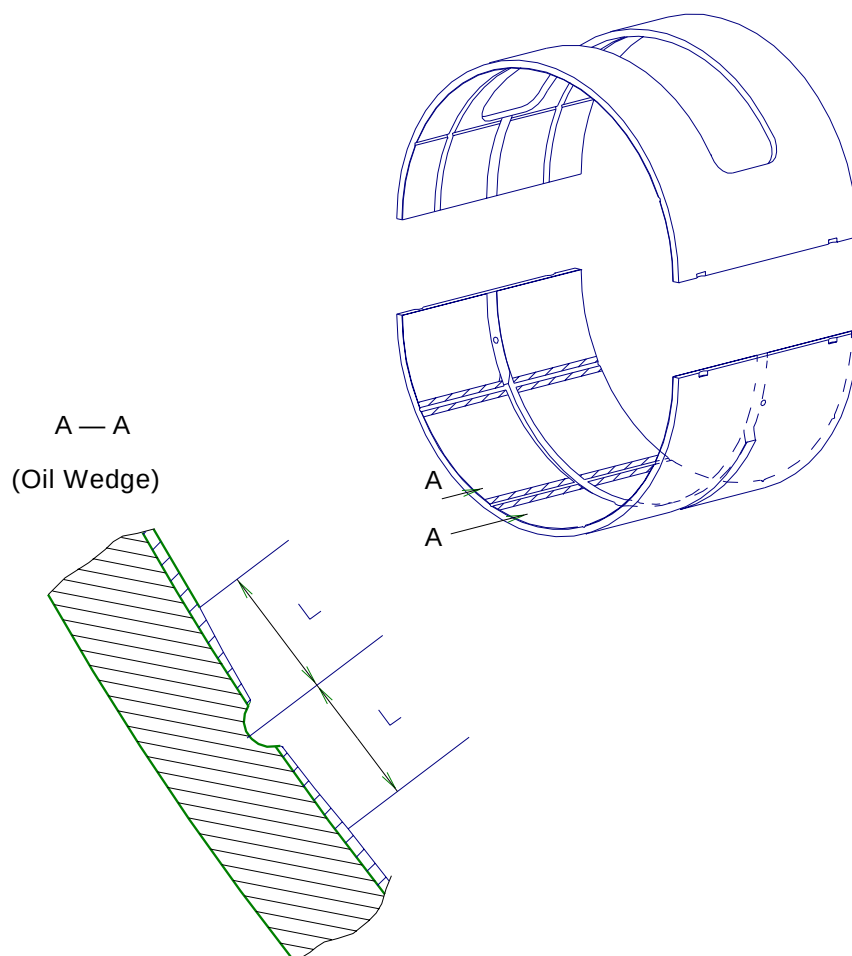
Engine types with thick shell main bearing assemblies:

S/K/L50MC
 S/K/L60MC
 S/K/L70MC
 S/K/L80MC
 K/L90MC



Engine types with thin shell main bearing assemblies:

S46MC-C
 S50MC-C
 S60MC-C
 S70MC-C
 K80MC-C
 S90MC-T
 K90-98MC-C

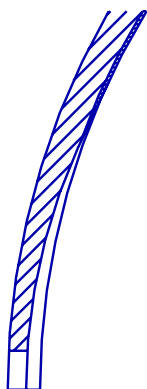


Extent of oil wedges in crosshead bearing lower shell

Engine Type	Extent L (mm) ★
S46MC-C	10
S/K/L50MC	15
S50MC-C	10
S/K/L60MC	15
S/K/L70MC	15
S/K/L80MC	15
K80MC-C	15
K/L90MC, S90MC-T	18
K90-98MC-C	18

★ On each side of the axial oil groove.

B-B
(Tang. Run-out)



A-A
(Bore Relief)

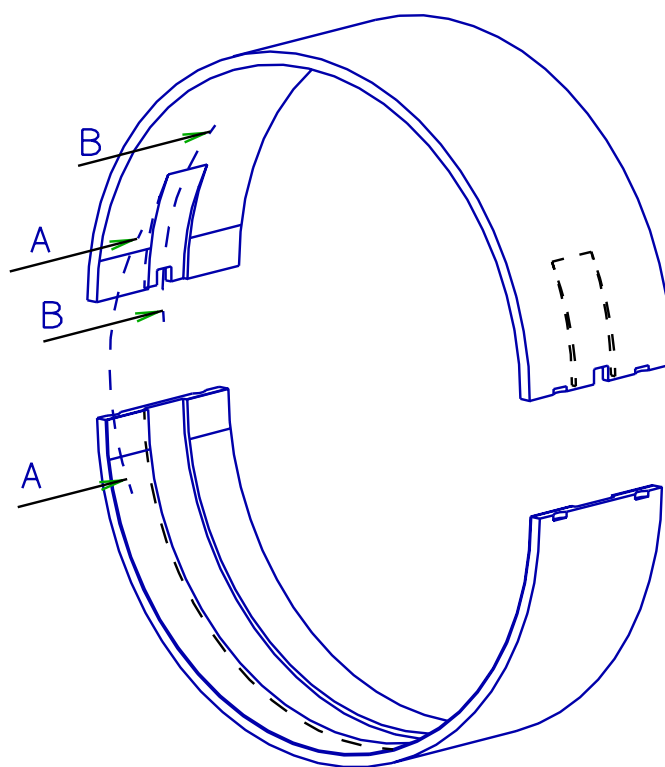
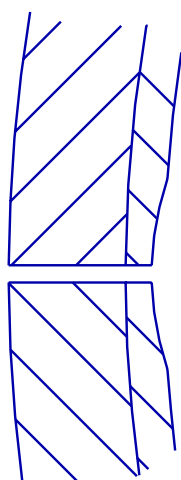


Fig. 1 Thick Shell

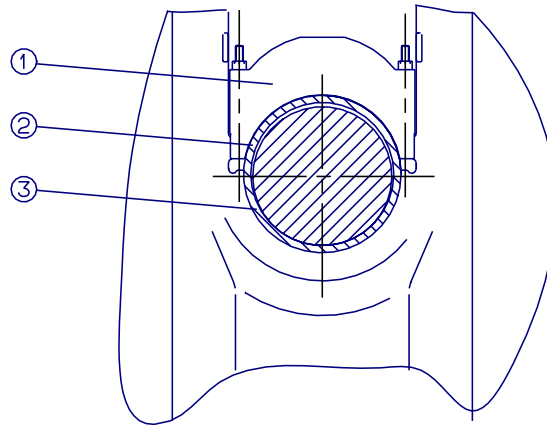
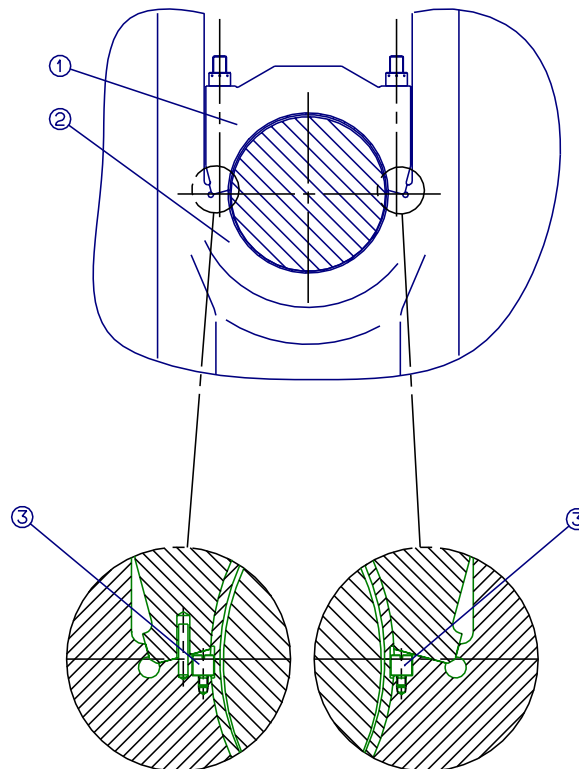
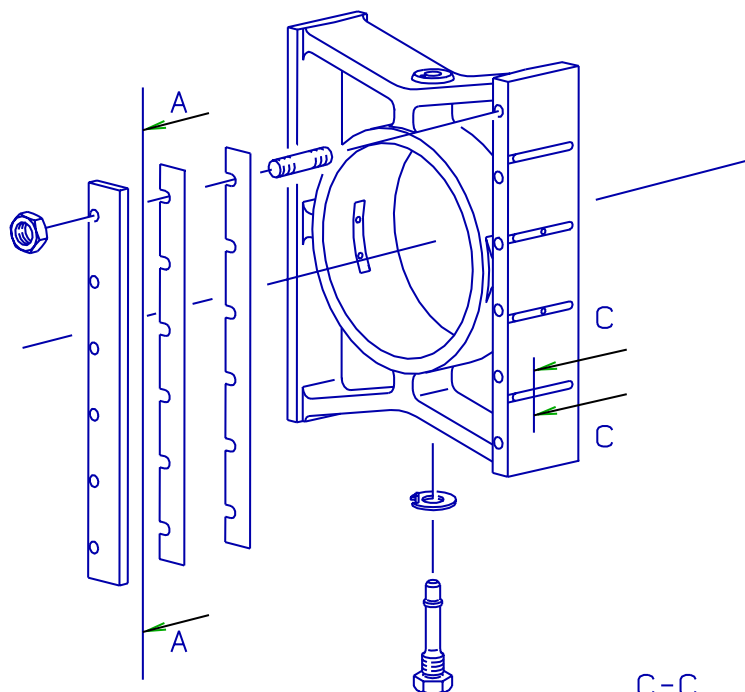


Fig. 2 Thin Shell

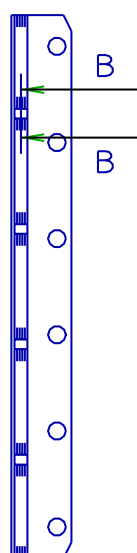




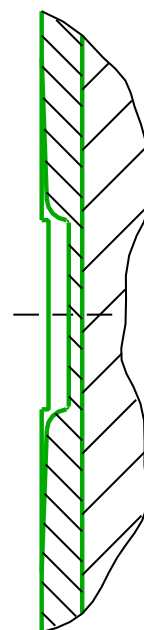
B-B



A-A



C-C



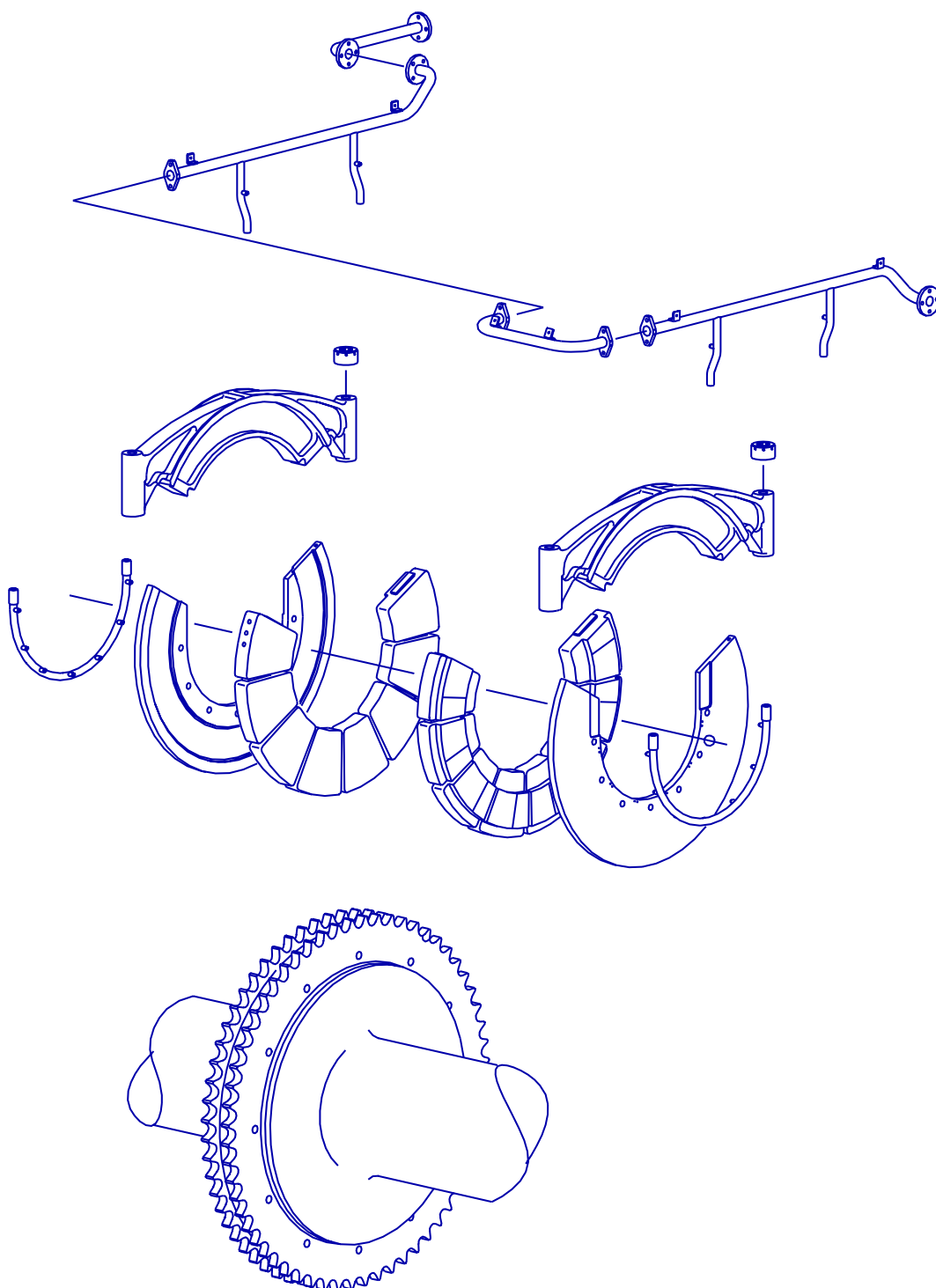


Fig. 1 Two-Shell Assembly

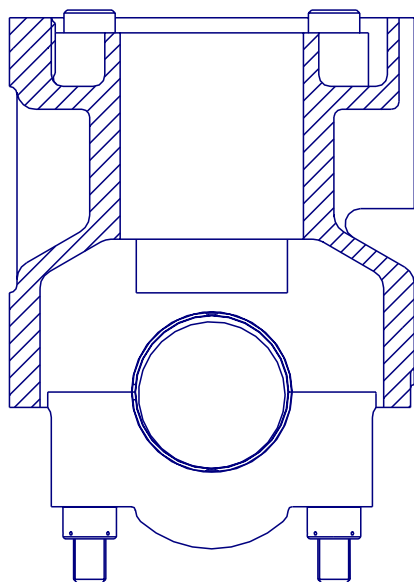
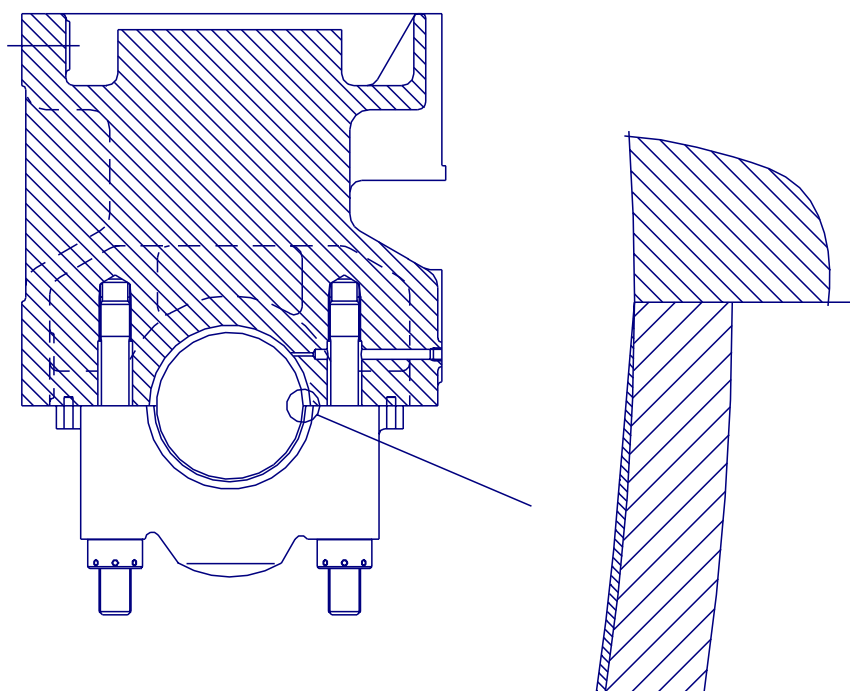


Fig. 2 One-Shell Assembly



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	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:

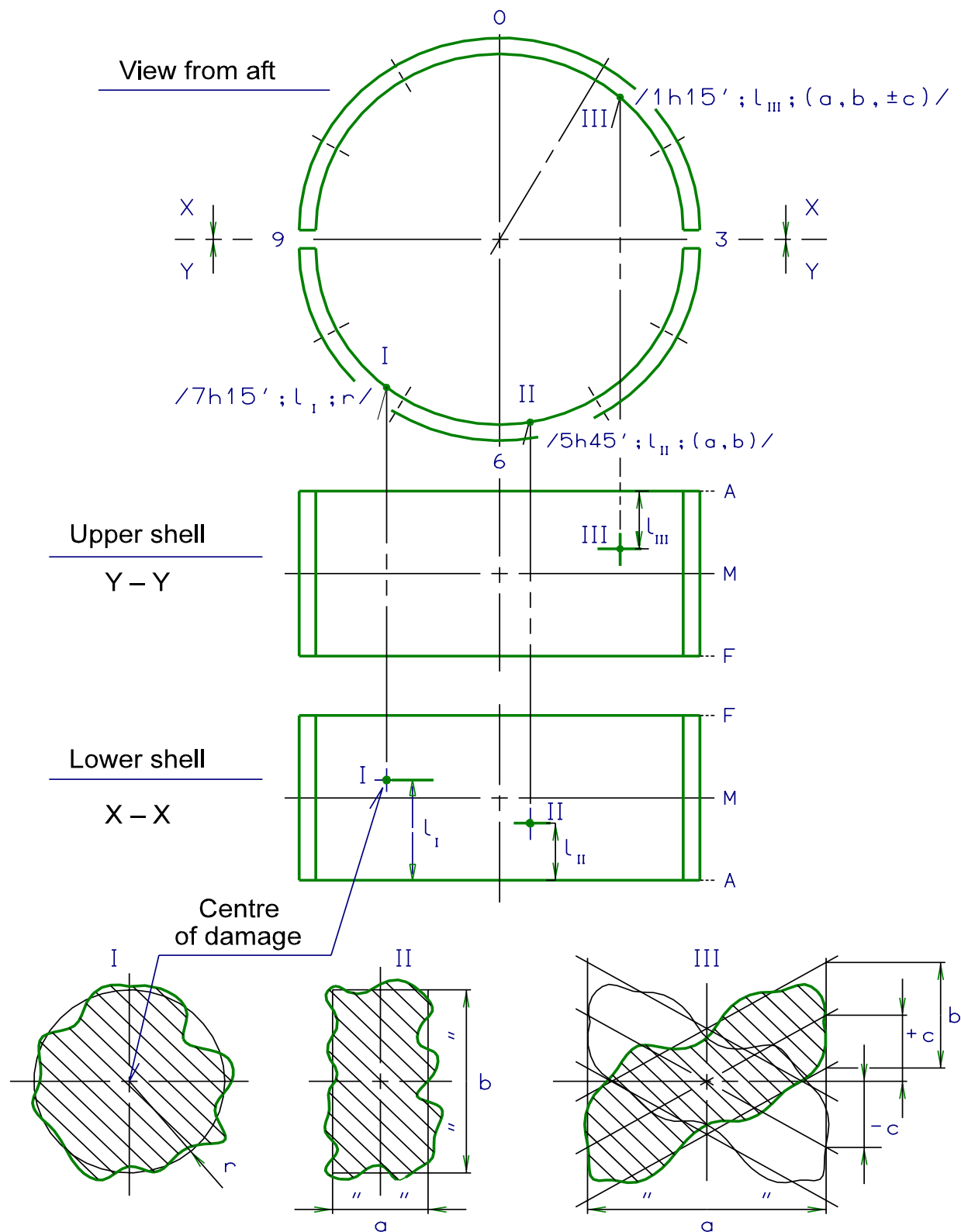
Bearing Type	
Main Bearing	MB
Crankpin Bearing	CRB
Crosshead Bearing	CHB
Guide Shoes	GS
Crosshead Guides	CG
Thrust Bearing	TB
Camshaft Bearing	CSB

Table 2:

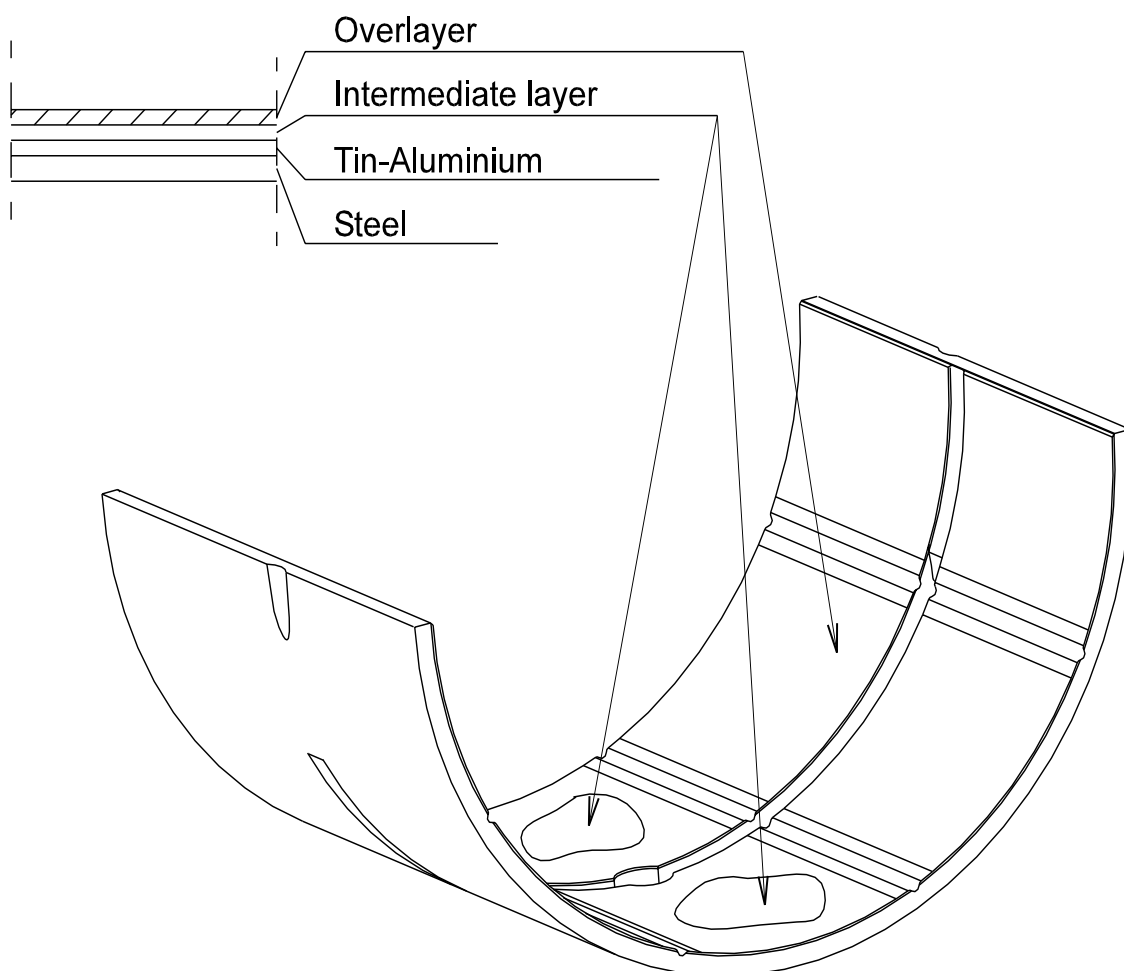
Damage	
Overlayer	OL
White Metal	WM
Journal	J
Pin	P
<u>Transitions:</u>	
Oil Wedge	OW
Bore Relief	BR
Bore Roughness	Ru
Bore Shrinkage	Sh



Inspection of bearings (Location of damage and size)



(Crosshead Bearing Lower Shells)

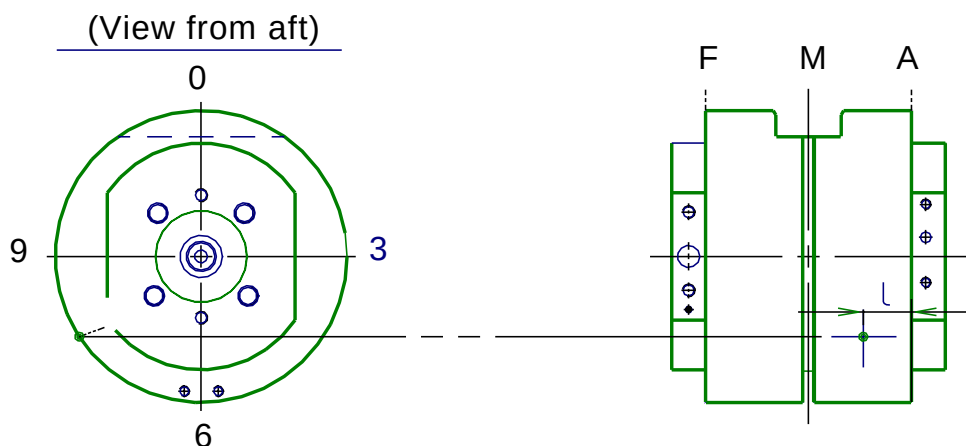


Engine Type:	Max. allowed exposure (mm ²)
46MC	4400
50MC	4700
60MC	5500
70MC	7000
80MC	10300
90MC	13000
98MC	15000

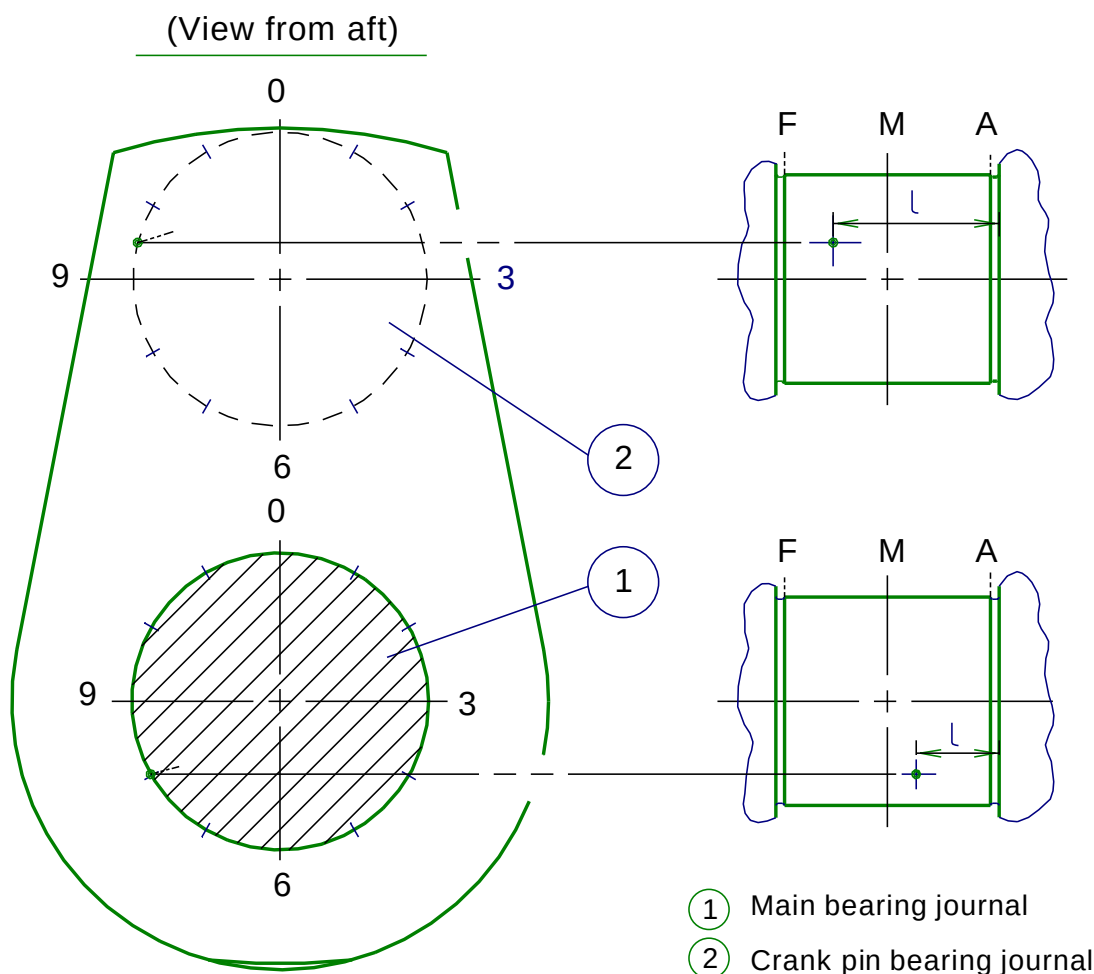
Table 1. Maximum allowable exposure of the intermediate layer

Location of Damage on Pin/Journal

Crosshead pin



Main and crank bearing journals



Observations

Table 3

Inspection without Opening-up (7.1)			
Checks		Symbol	Observations
Oil Flow	OF	• U	OK, similarity Uneven
Oil Jets (Crosshead, Guide Strips)	OJ	• R M TW	OK, similarity Reduced Missing Twisted
White Metal	WM	• SQ CR L M	OK Squeezed out Cracks Loose Missing
Crosshead Guides	CG	• SC CO SW	OK Scratches Corrosion Silvery White
Oil Pan	OP	• WM	OK, clean White metal fragments
Oil Condition	OC	• DK WT	OK Dark Water traces

Table 4

Open-up Inspection and Overhaul (7.2)				
Checks		Symbol	Observations	Ref.
White Metal	WM	• W HC OS CR CRC L M SE 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 (Crosshead only)	OL	• TE W	OK Tearing Wiping	7.3 I 7.3 II
<u>Transitions:</u> Oil Wedge Bore Relief Tang. Run-out	OW BR TR	• RR W D	OK Ragged Ridges Wiping Disappeared	7.7 7.7 7.10B II
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 Tearing	7.4 7.4

M/V	Engine type:		CW / CCW 1)		Running hours	Checked by:	4)
Yard:	Builder:		Engine		Total		
No.:	Built year:		No.:			Date:	4)

Journal/pin Roughness 3)	Hydr. open. pressure	Clearance (mm)		Description of condition	Type of inspection 2)	Engine run- ning hours	Checked by	Date
		Top	Aft					
N6 (M)	880	0,5	0,5	MB/4 / MBD/WM / CR; L; M; HC / 7h 15'; l _I ; r //	7.2	10000	N.N.	8/3-93
N3 (E)	900	0,4	0,4	CHB/5 / MBD/WM; OW/W; RR / 5h 45'; l _{II} ; (a,b) //	7.2	15000	N.N.	8/3-93
N6 (E)	870	0,4	0,4	CRB/3 / MBD/WM / M; W / 1h 15'; l _{III} ; (a,b, r/c) //	7.2	8000	N.N.	8/3-93
		0,45	0,45	CHB/6 / OF; u / OJ; R; TW / WM; SQ //	7.1	8000	N.N.	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 4)	Checked by: 4)
Yard:	Builder:	Engine No.:	Total	Date: 4)
No.:	Built year:			
Journal/pin Roughness 3)				
Hydr. open. pressure				
Clearance (mm)	Top			
	Fore	Aft		
Description of condition				
Type of inspection 2)				
Engine running hours				
Checked by				
Date				

- 1) For fine 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:		Total running hours	Checked by:	
	Builder:	Engine No.:		Date:	
Yard No.:	Built year:				
For comparison of measurements	Ships draught, aft measured (m)		Fully loaded (m)	Ballasted (m)	
	Jacket cooling water temp. (°C)		Main lub. oil temp. (°C)		

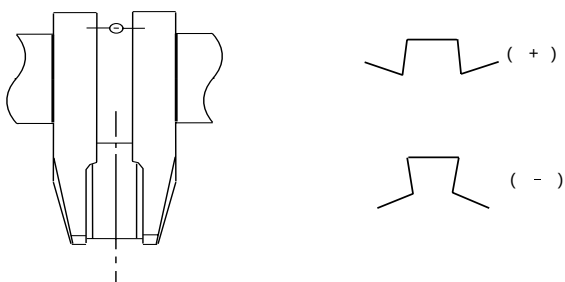


Fig. 1

For deflection readings, a dial micrometer is to be placed in the punch marks.
Closing of the crankthrow is regarded as negative deflection

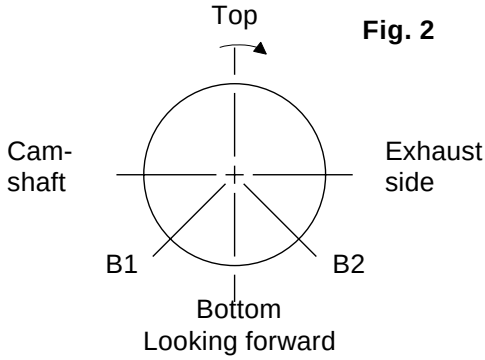


Fig. 2

Top
Cam-shaft
Exhaust side
B1
B2
Bottom
Looking forward

(Unit for measuring and calculating: 1/100 mm)

Fig. 3

Crankpin position		Cyl. No. & deflections						
		1	2	3	4	5	6	7
Near bottom, camshaft side	B ₁							
Camshaft side *)	C							
Top	T							
Exhaust side *)	E							
Near bottom, exhaust side	B ₂							

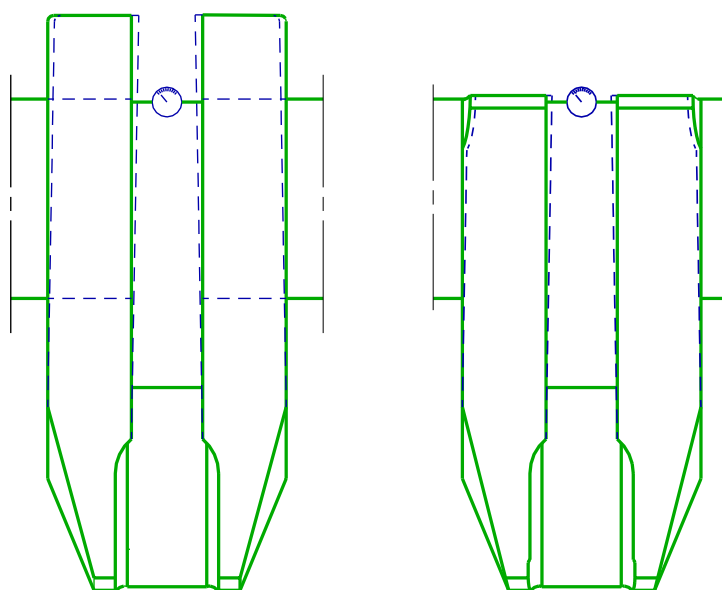
*) Positions C and E are included for reference purposes.

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.								

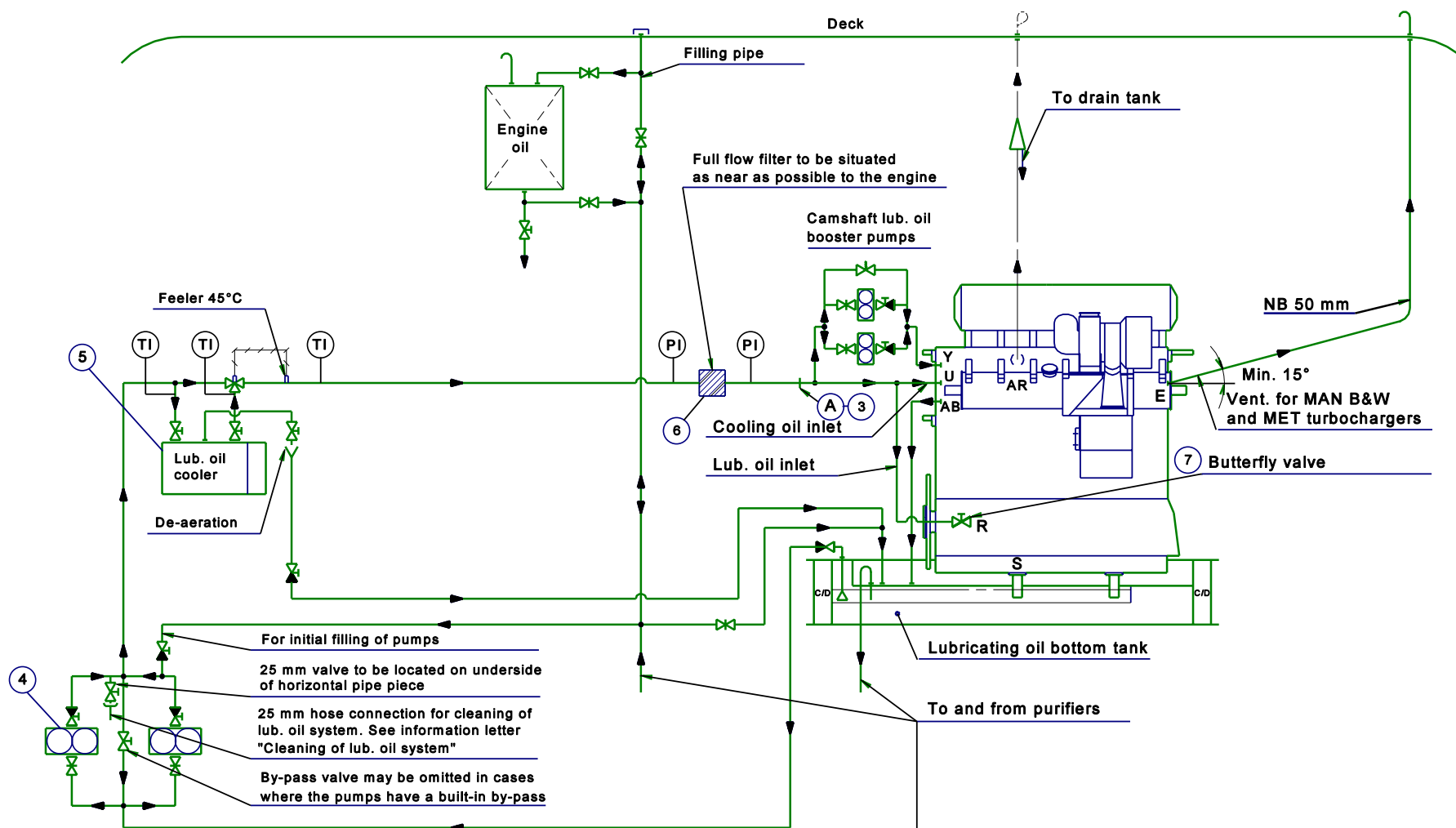


Type	Normally obtainable for a new or recently overhauled engine mm		Realignment recommended mm		Absolute maximum permissible mm	
	1	2	1	2	1	2
S46MC-C	0.23	0.46	0.62	0.69	0.93	0.93
K50MC	0.12	0.25	0.34	0.38	0.51	0.51
L50MC	0.17	0.34	0.45	0.51	0.68	0.68
S50MC	0.23	0.46	0.61	0.69	0.92	0.92
S50MC-C	0.23	0.47	0.62	0.70	0.94	0.94
K60MC	0.15	0.31	0.41	0.46	0.62	0.62
L60MC	0.20	0.40	0.54	0.61	0.81	0.81
S60MC	0.27	0.55	0.73	0.82	1.10	1.10
S60MC-C	0.28	0.56	0.75	0.84	1.13	1.13
K70MC	0.18	0.37	0.49	0.55	0.74	0.74
L70MC	0.24	0.48	0.63	0.71	0.95	0.95
S70MC	0.32	0.64	0.85	0.96	1.28	1.28
S70MC-C	0.33	0.66	0.88	0.99	1.32	1.32
L80MC	0.27	0.54	0.72	0.81	1.08	1.08
S80MC	0.36	0.73	0.97	1.10	1.46	1.46
K80MC-C	0.22	0.44	0.58	0.66	0.88	0.88
L90MC	0.30	0.60	0.81	0.92	1.22	1.22
K90MC	0.25	0.50	0.67	0.75	1.00	1.00
K90MC-C	0.20	0.41	0.54	0.61	0.82	0.82
S90MC-T	0.36	0.72	0.96	1.08	1.45	1.45
K98MC-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 aft end is provided with a flexible coupling.

When judging the alignment on the above “limiting-value” basis, make sure that the crankshaft is actually supported in the adjacent bearings. (See ‘Alignment of Main Bearings’ point 2.3 ‘floating journals’).

(Engines with Uni-Lube System)

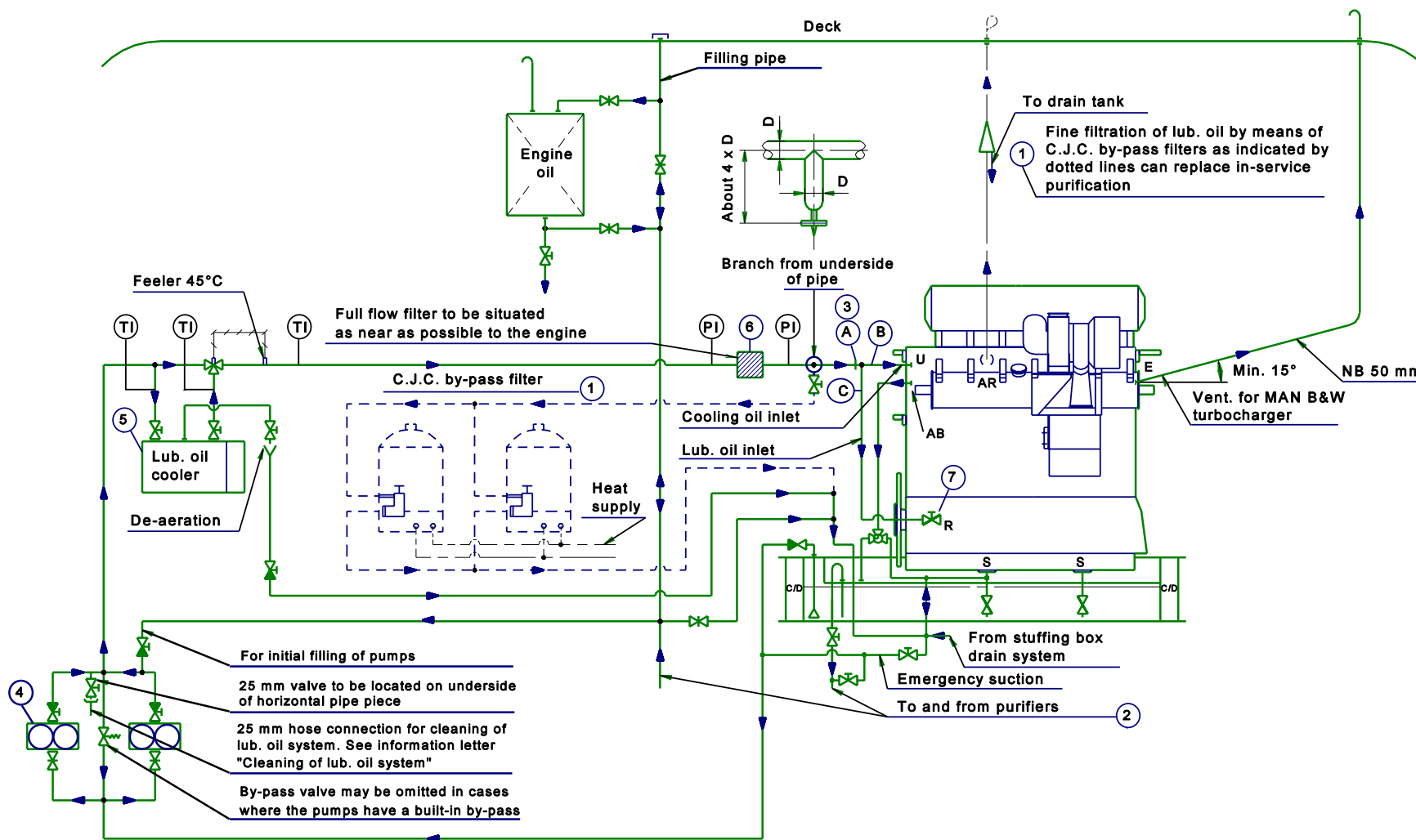


- 3 If using centrifugal pumps it is recommended to install a throttle valve at pos. A to prevent a too high oil level in the oil pan. A device preventing the valve from being closed has to be introduced so that the min. flow area gives the specified pressure at inlet to engine under normal service conditions. It ought to be possible to fully open the valve e.g. when starting the engine with cold oil.

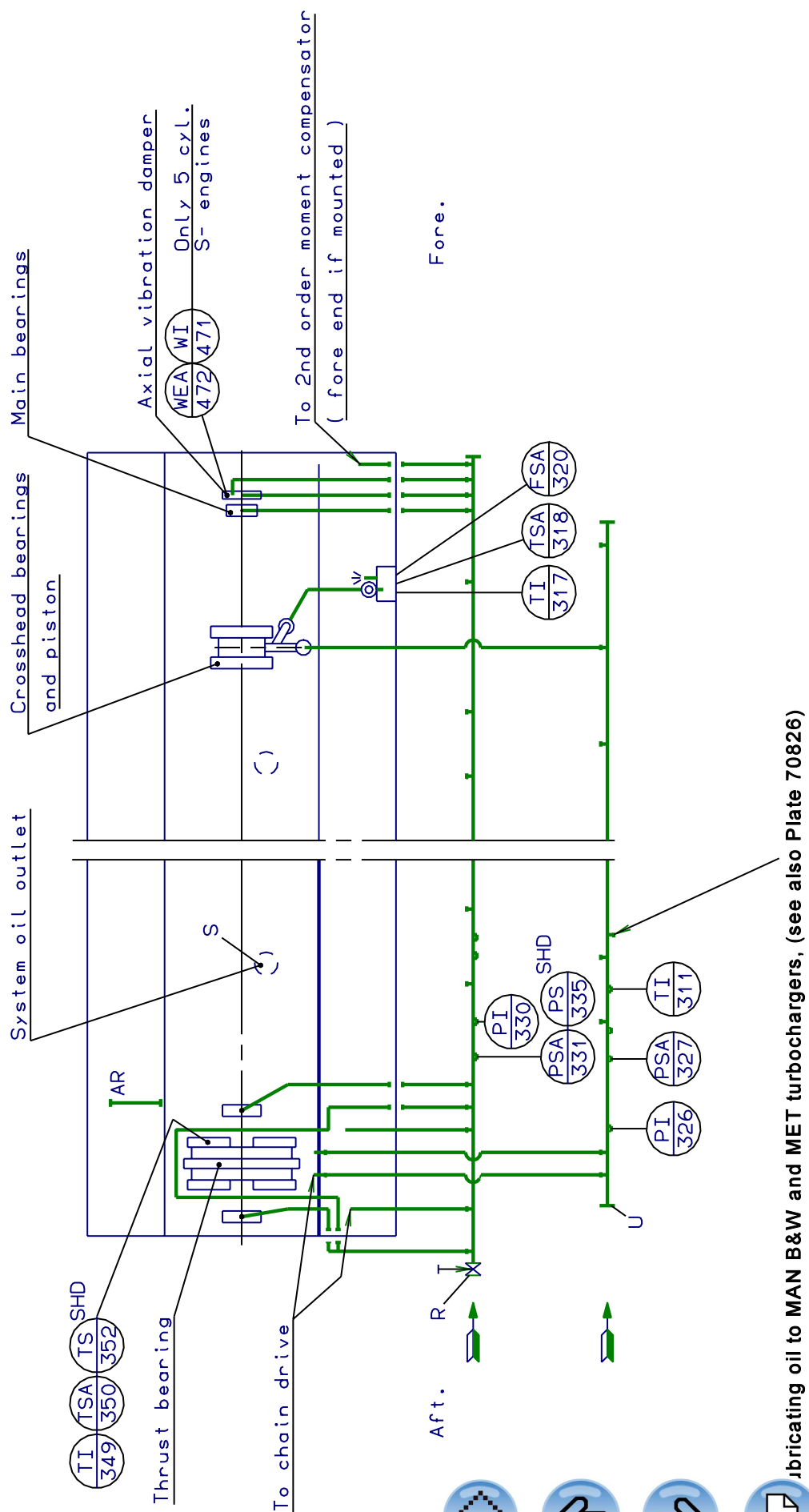
Approximately the following quantity of lub. oil should be treated in the purifiers 0.136 l/kwh. The capacity of purifiers to be according to manufacturer's recommendation.



(Engines without Uni-Lube System)

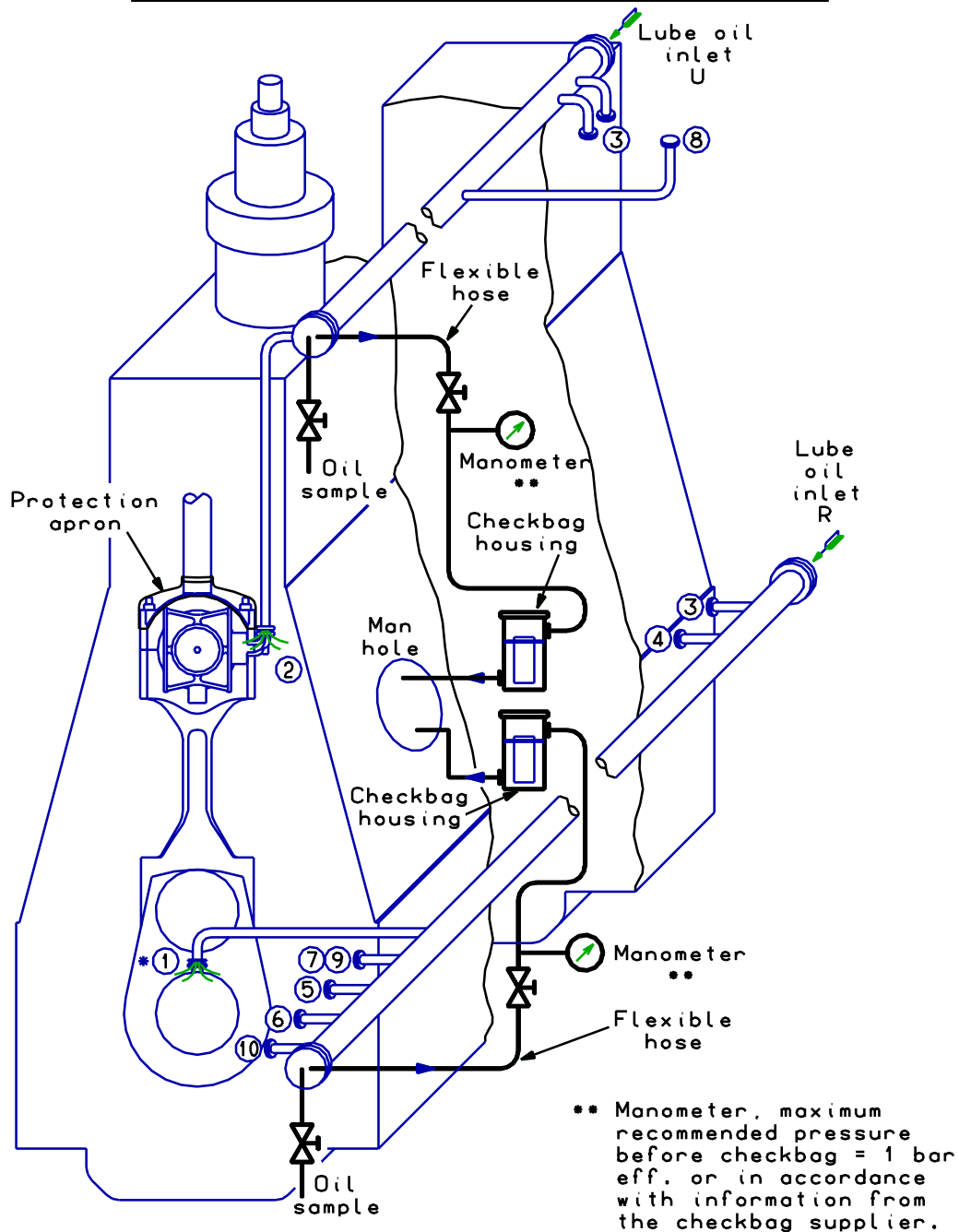


If using centrifugal pumps it is recommended to install a throttle valve at pos. A to prevent a too high oil level in the oil pan. A device preventing the valve from being closed has to be introduced so that the min. flow area gives the specified pressure at inlet to engine under normal service conditions. It ought to be possible to fully open the valve e.g. when starting the engine with cold oil.



lubricating oil to MAN B&W and MET turbochargers, (see also Plate 70826)

Location of checkbag and blank flanges.

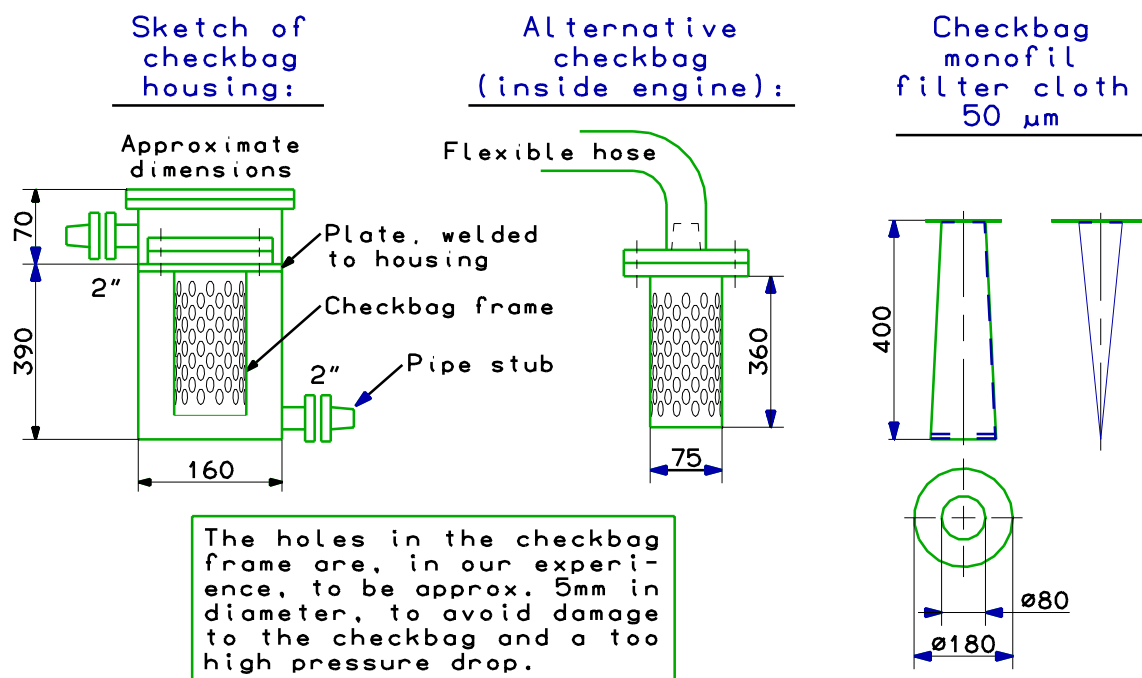


Blanking off pipes:

1. Main bearing by-pass blanks
2. Crosshead 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
8. Blank-off or by-pass turbocharger
9. Blank-off hydraulic chain tightener
10. Blank-off PTO-PTI power gear



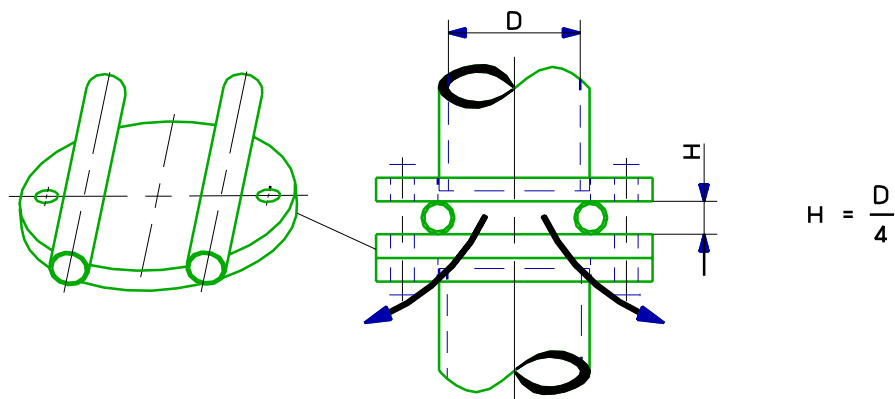
Dimension of Checkbag and Blank Flanges



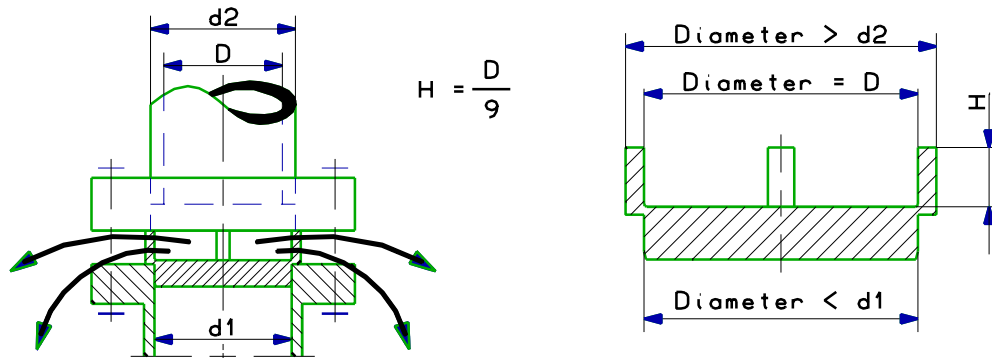
The above filter components can be delivered from MAN B&W Diesel

* Blank flanges for flushing:

A) Blank at main bearings.



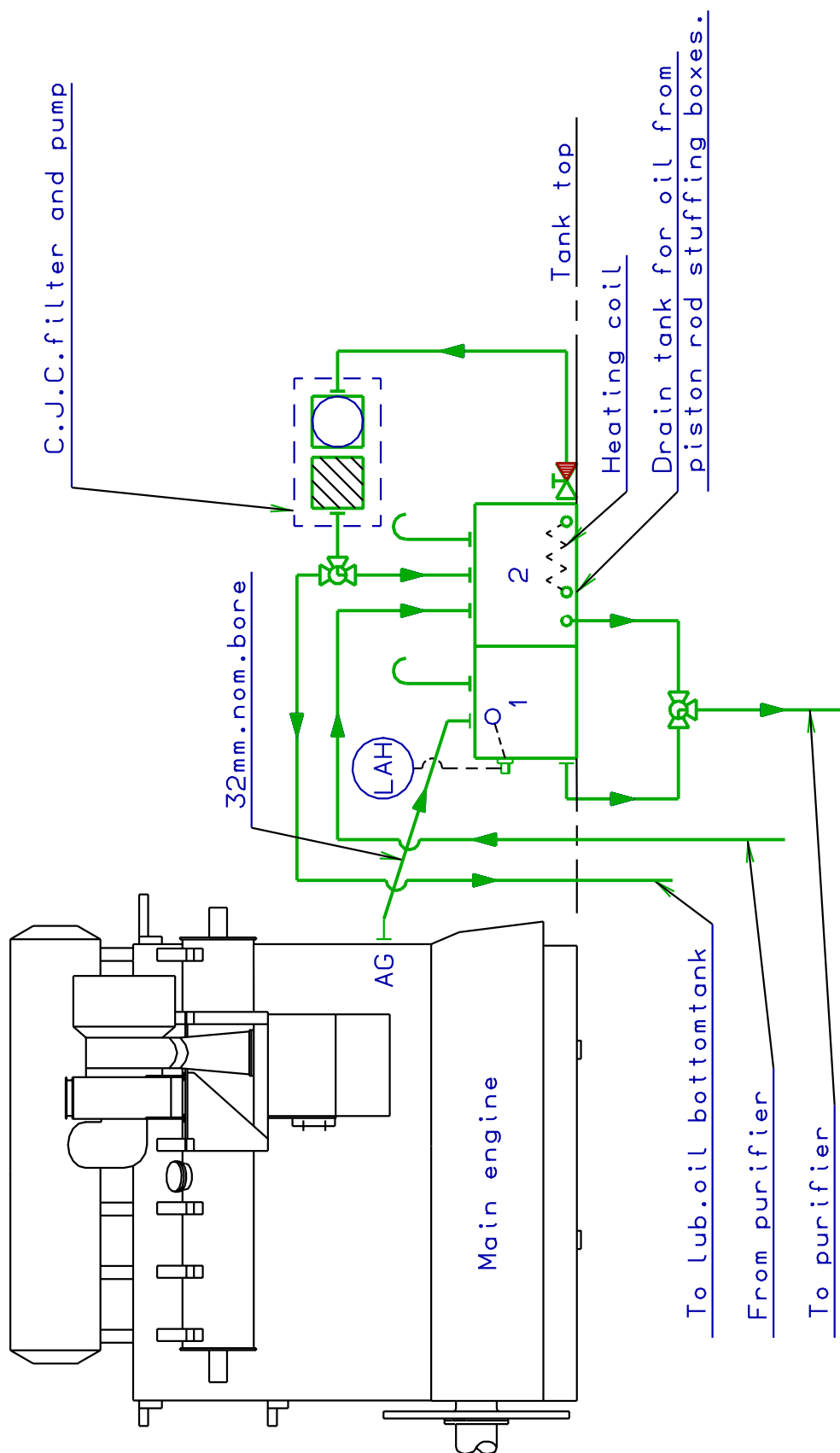
B) Blank between telescopic pipes and crossheads.



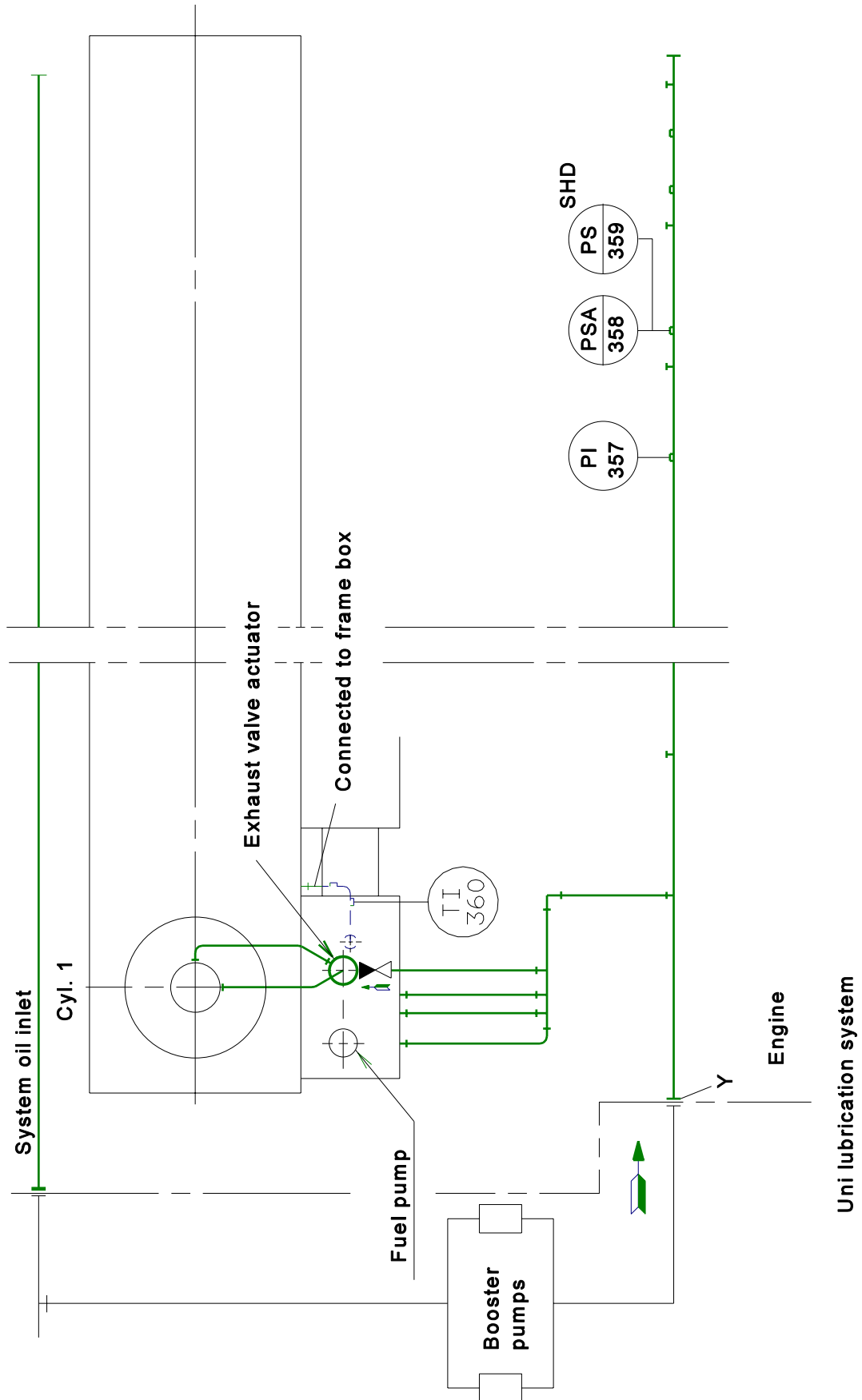
Flushing Log

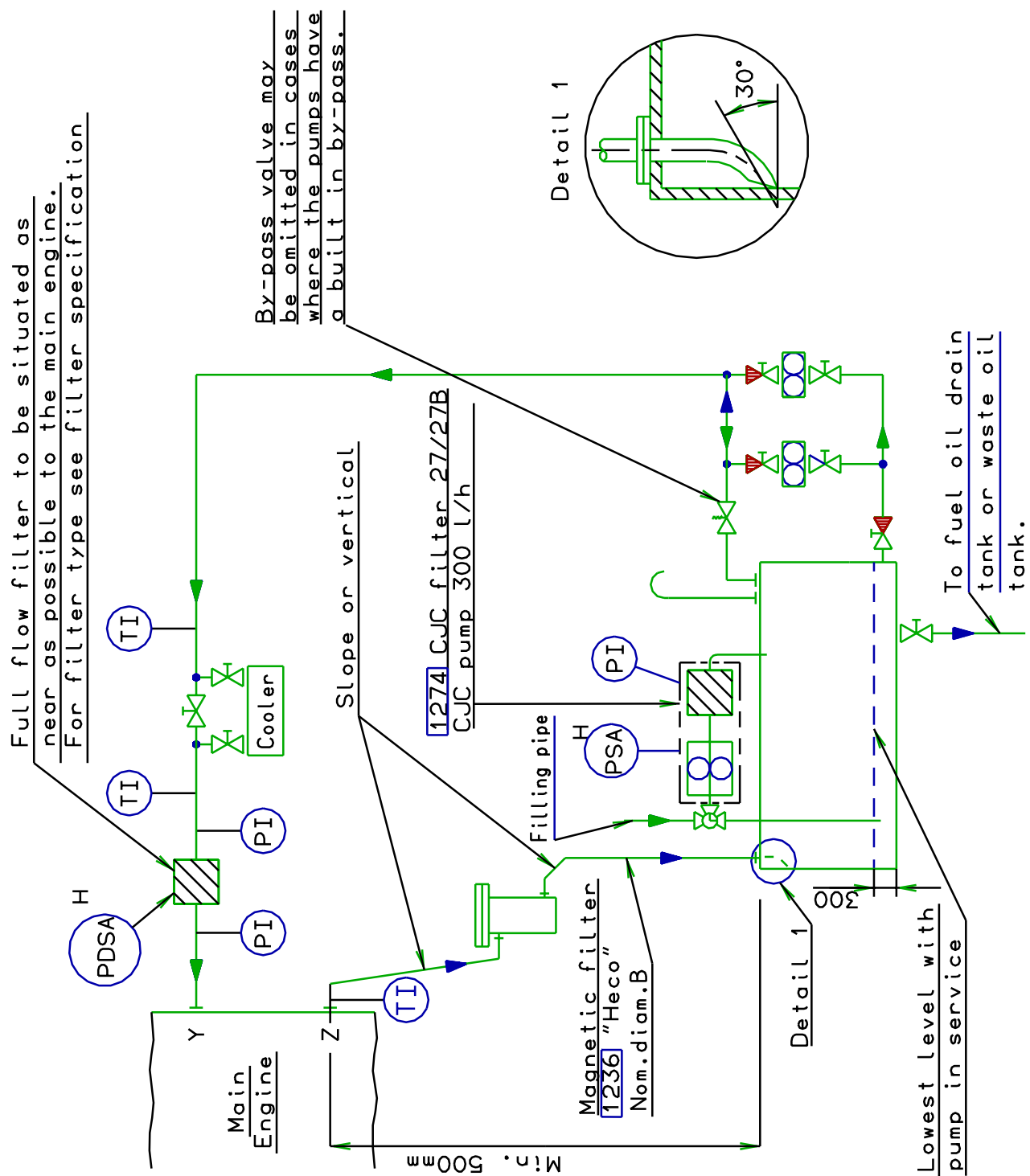
[illegible]

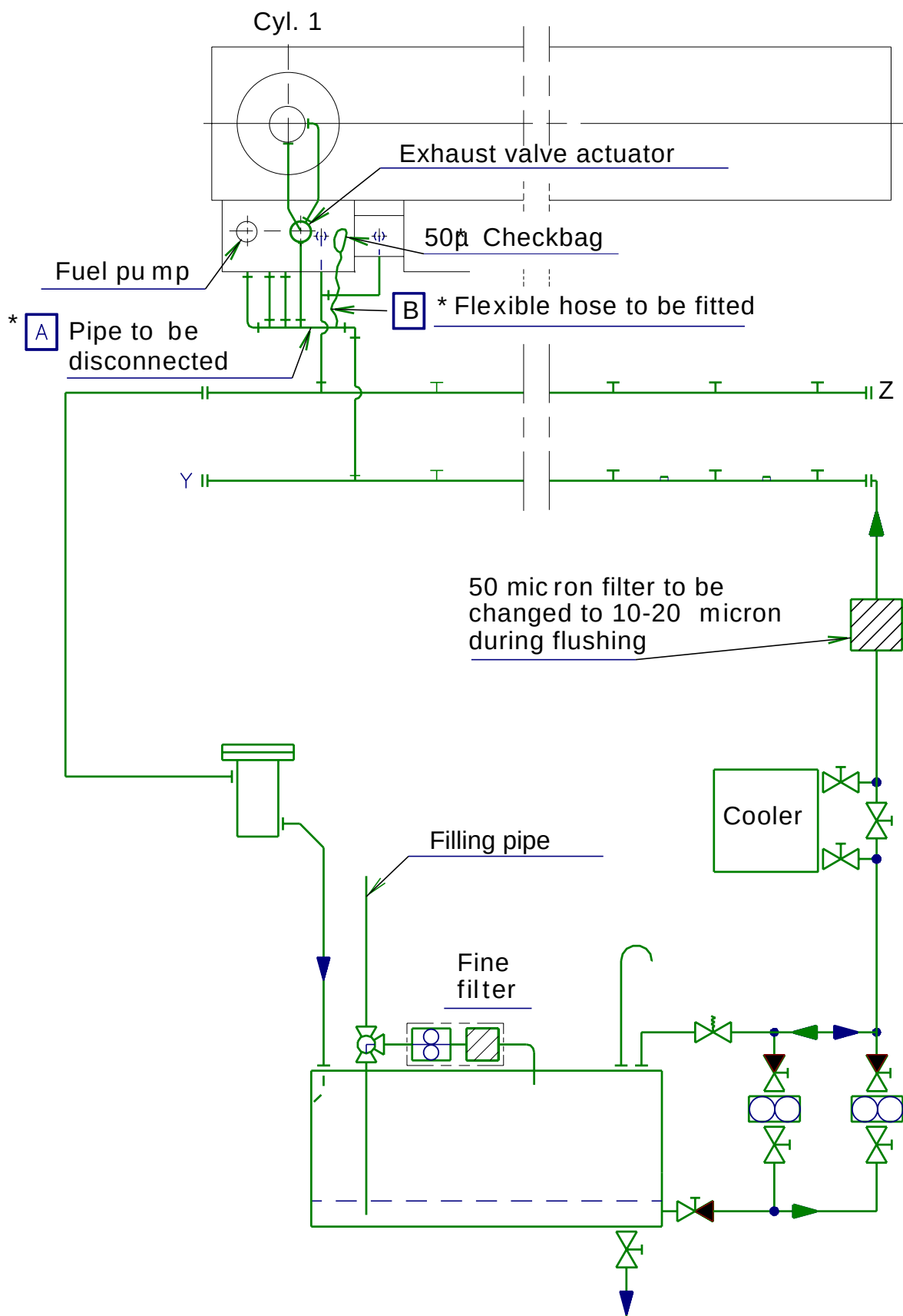
(Only engines without Uni-Lube System)



(Engines with Uni Lube System)

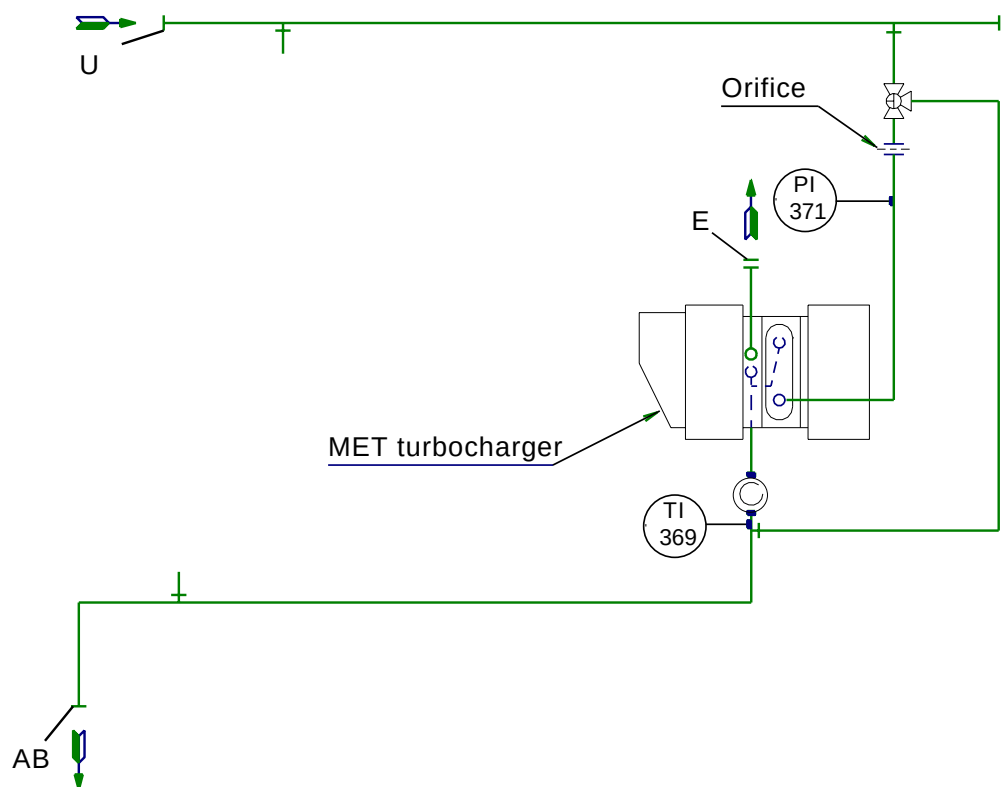
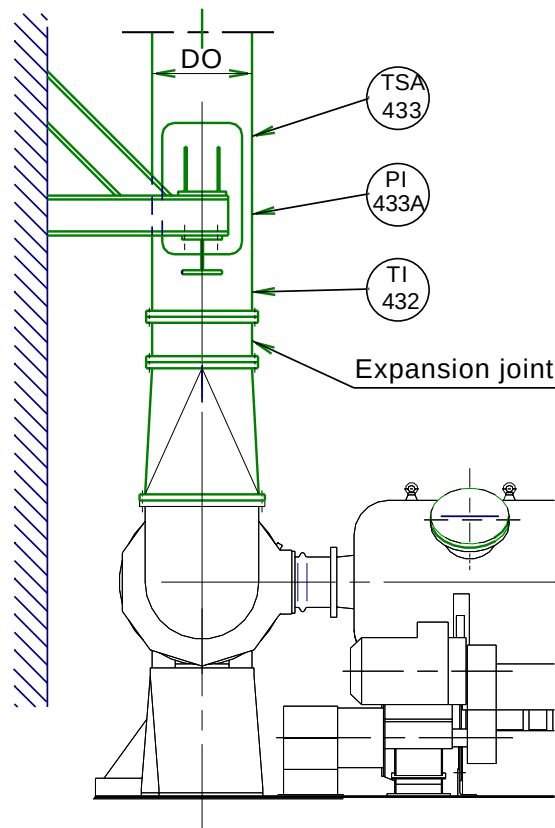
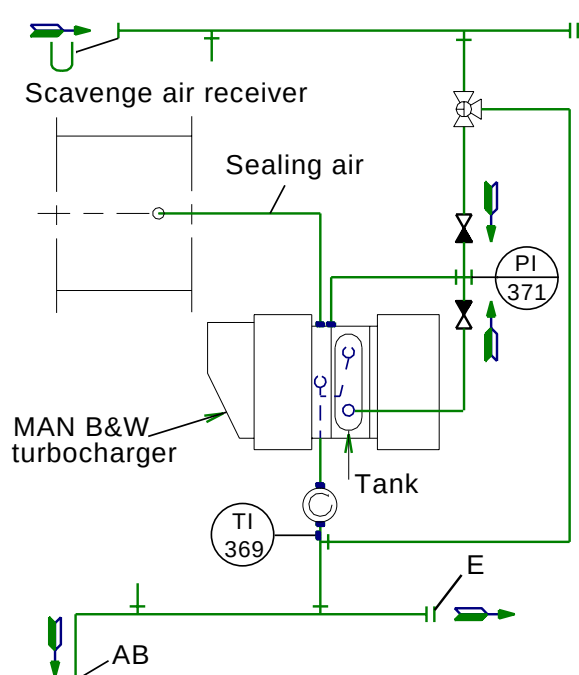






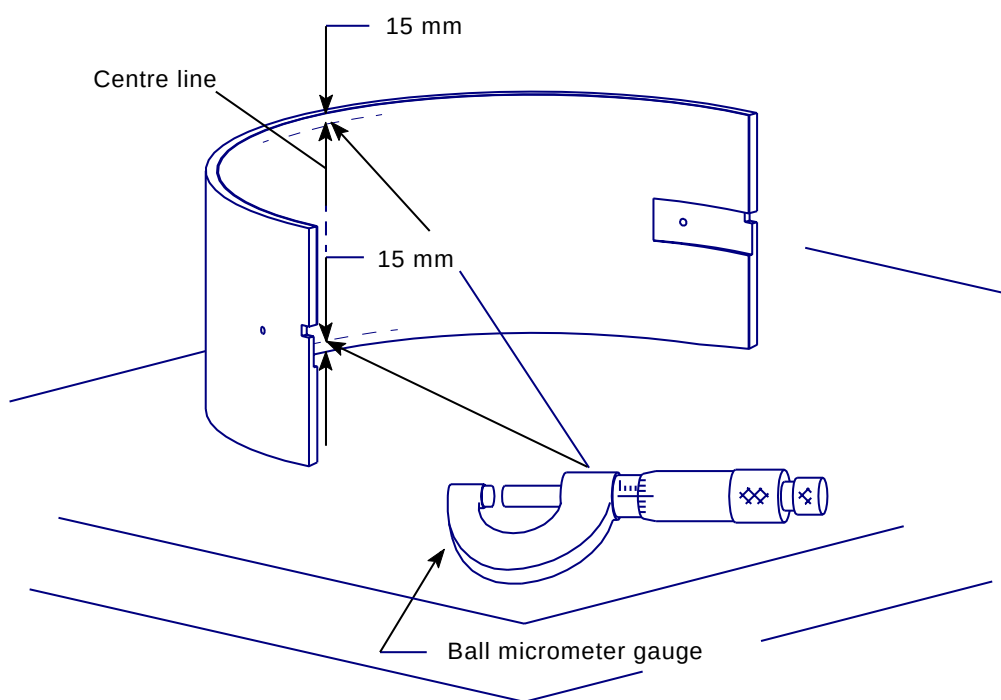
* Also valid for engines with Uni lube system





See also page 708.12, Item 14, 'Check of Bearings Before Installation'.

Fig. 1 - Measuring of crown thickness.



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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:

- a) through the adjustable valve (3) direct to the main engine scavenge air cooler(s).
- b) through the non-return valve (5) to the auxiliary engines
- c) 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 c):

- Water supply to PTO/RCF lube oil cooler (if installed).
- Water supply to camshaft lube oil cooler (only engines without Uni-Lube system).

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', Chapter 701*).

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 Chapter 701, Pos. 387.*

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 forma-



tion in the system. *See Chapter 701, Pos. 395.*

Pressure gauges are installed to enable checking of the pressure difference across the engine. *See Chapter 701, Pos. 390.*

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'.*

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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 bypass 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 [Chapter 703](#), Item 7, 'Operations AFTER Arrival in Port'.

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, '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 water coming out?

YES

- Close the test cocks.
- Re-establish the cooling water supply at once, or stop the engine for trouble-shooting.

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 over heated 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 fresh water 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 Chapter 707, 'Cylinder Condition'](#).

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 709.10. The relevant dosages are also mentioned, and we recommend that these directions are strictly observed.

Cooling water treatment using inhibiting oils is not recommended, as such treatment involves the risk of uncontrolled deposits being formed on exposed surfaces, and furthermore represents an environmental problem.

Note: 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 de-ionized 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



Note: 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 'Jacket Water Cooling System', earlier in this Chapter.

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:

- Inhibitor concentration.
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.



Note: 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 the table on Page 709.10.

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.

Note: 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.

Note: 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

Note: 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

Note: Be careful. Use protective spectacles and gloves.

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.

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.

Circulate the solution

Circulate the agent for the period specified by the supplier.

Check and repair any leaks.

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

4.3 Descaling

On completing the degreasing procedure, see Item 4.2, apply this descaling procedure.

Note: Be careful. Use protective spectacles and gloves.

Note: To avoid polluting the sea 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 led overboard.

Prepare for descaling

Fill up with clean tap water.



Heat the water to a maximum of 70°C, and circulate it continuously.

Note: Some ready-mixed cleaning agents are specified to be used at a lower temperature. This maximum temperature must be adhered to.

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.

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.

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).

Note !

Check the acid content of the system oil directly after the descaling, and again 24 hours later.

See Chapter 708, 'Maintenance of the Circulating Oil', Items 4.5 and 5.



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 the table on Page 709.10.*

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', earlier in this Chapter.

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.



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	Powder	3 kg / 1000 l
	Castrol Solvex WT2	Liquid	20 l / 1000 l
Drew Ameriod Marine Boonton, N.J./USA	DEWT NC	Powder	3.2 kg / 1000 l
	Liquidewt	Liquid	8 l / 1000 l
	Maxiguard	Liquid	16 l / 1000 l
Nalfloc Ltd. Northwich, Cheshire, England	NALFLEET 9-121	Powder	2.5 kg / 1000 l
	NALFLEET 9-108	Liquid	2.25 l / 1000 l
Rohm & Haas (ex Duolite) Paris, France	RD11 DIA PROSIM	Powder	3 kg / 1000 l
	RD25 DIA PROSIM	Liquid	50 l / 1000 l
Unitor Rochem Marine Chemicals Oslo, Norway	Dieselguard NB	Powder	3 kg / 1000 l
	Rocor NB Liquid	Liquid	10 l / 1000 l
Vecom Maassluis, Holland	CWT Diesel QC2	Liquid	12 l / 1000 l

Generally we recommend 2000-2500 ppm Nitrite.

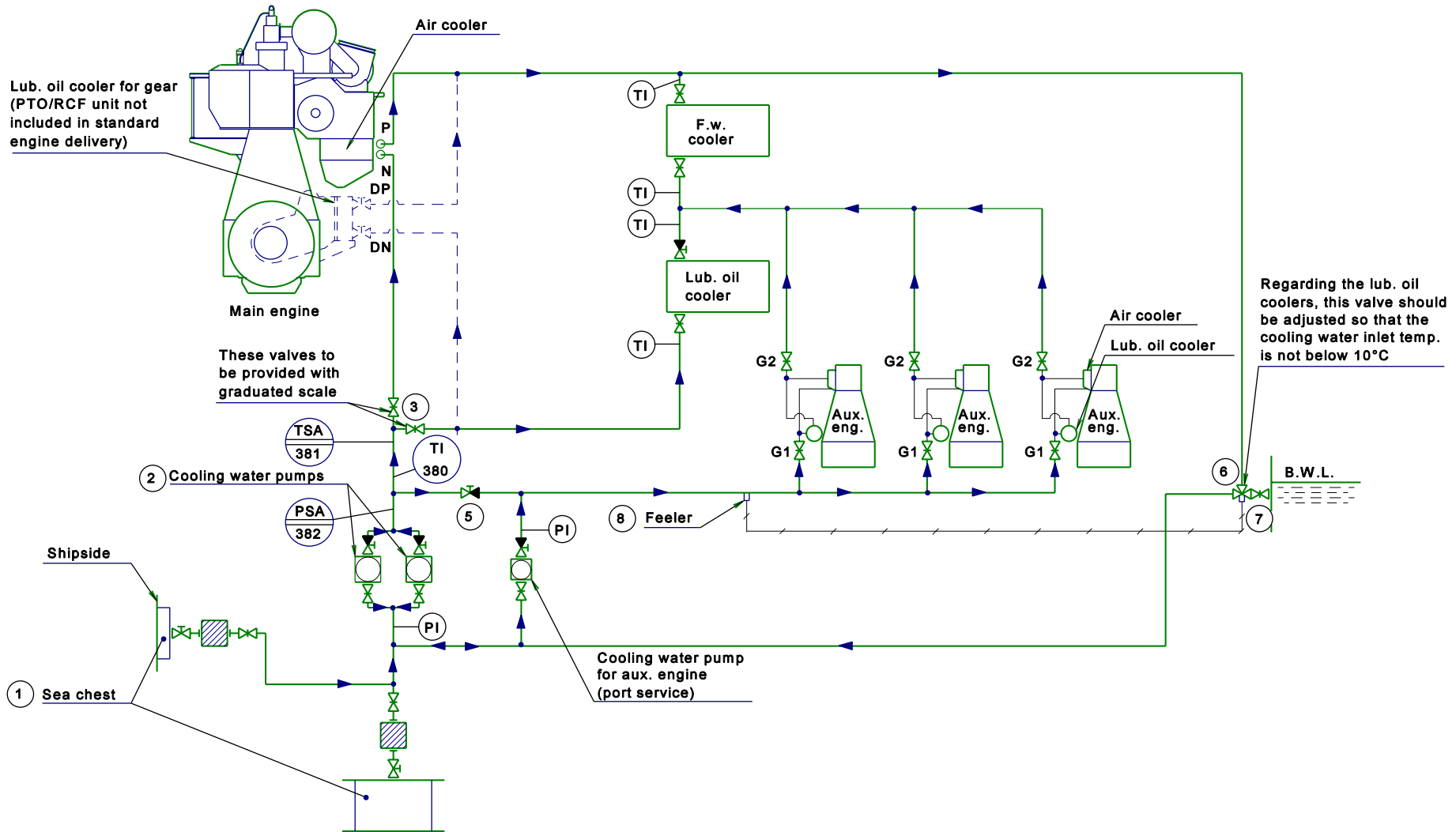
(*) Initial dosage may be larger.

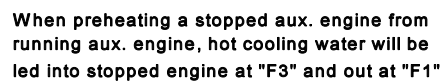
The list is for guidance only and must not be considered complete. We undertake no responsibility for difficulties that might be caused by these or other water inhibitors/chemicals.

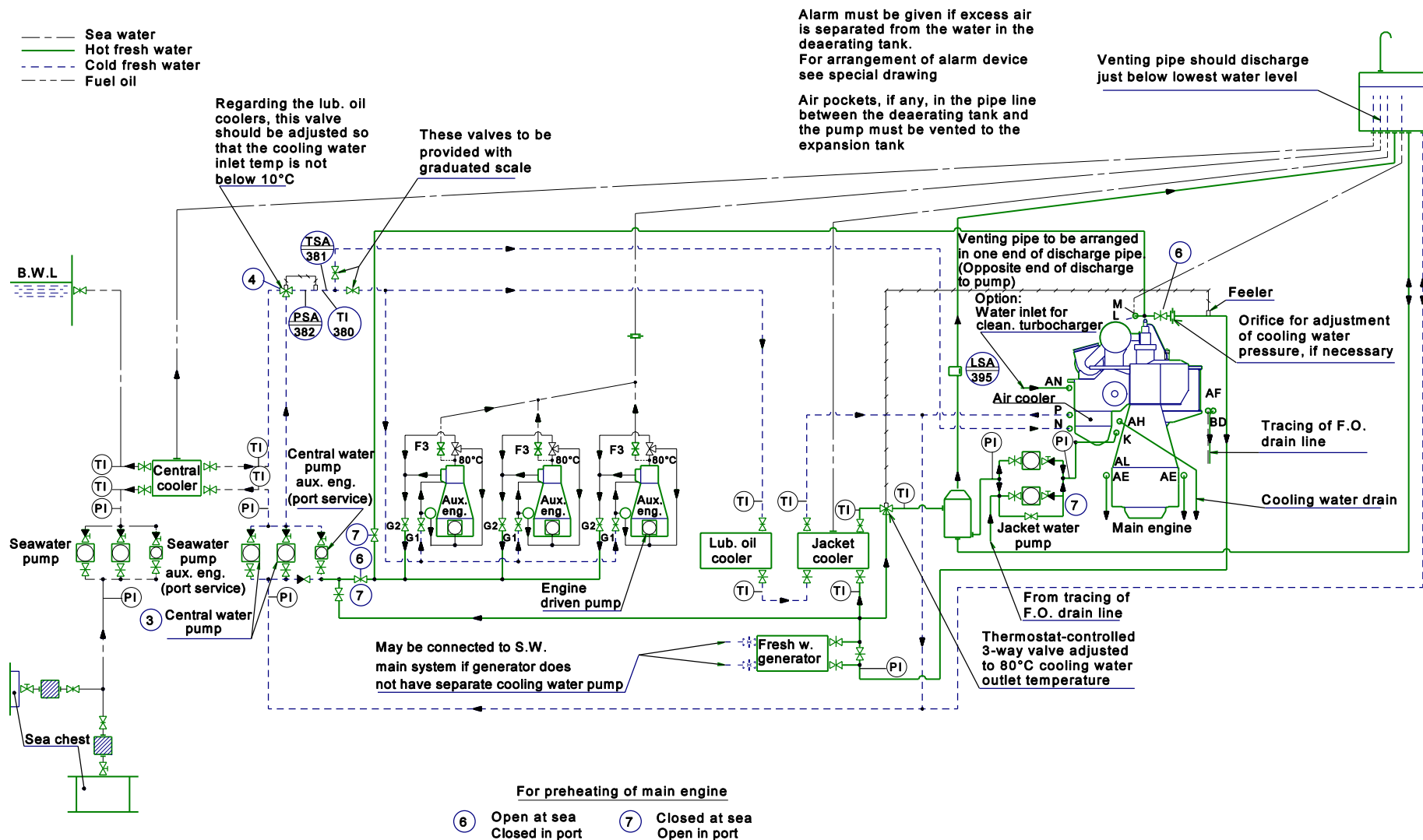
The suppliers are listed in alphabetical order.

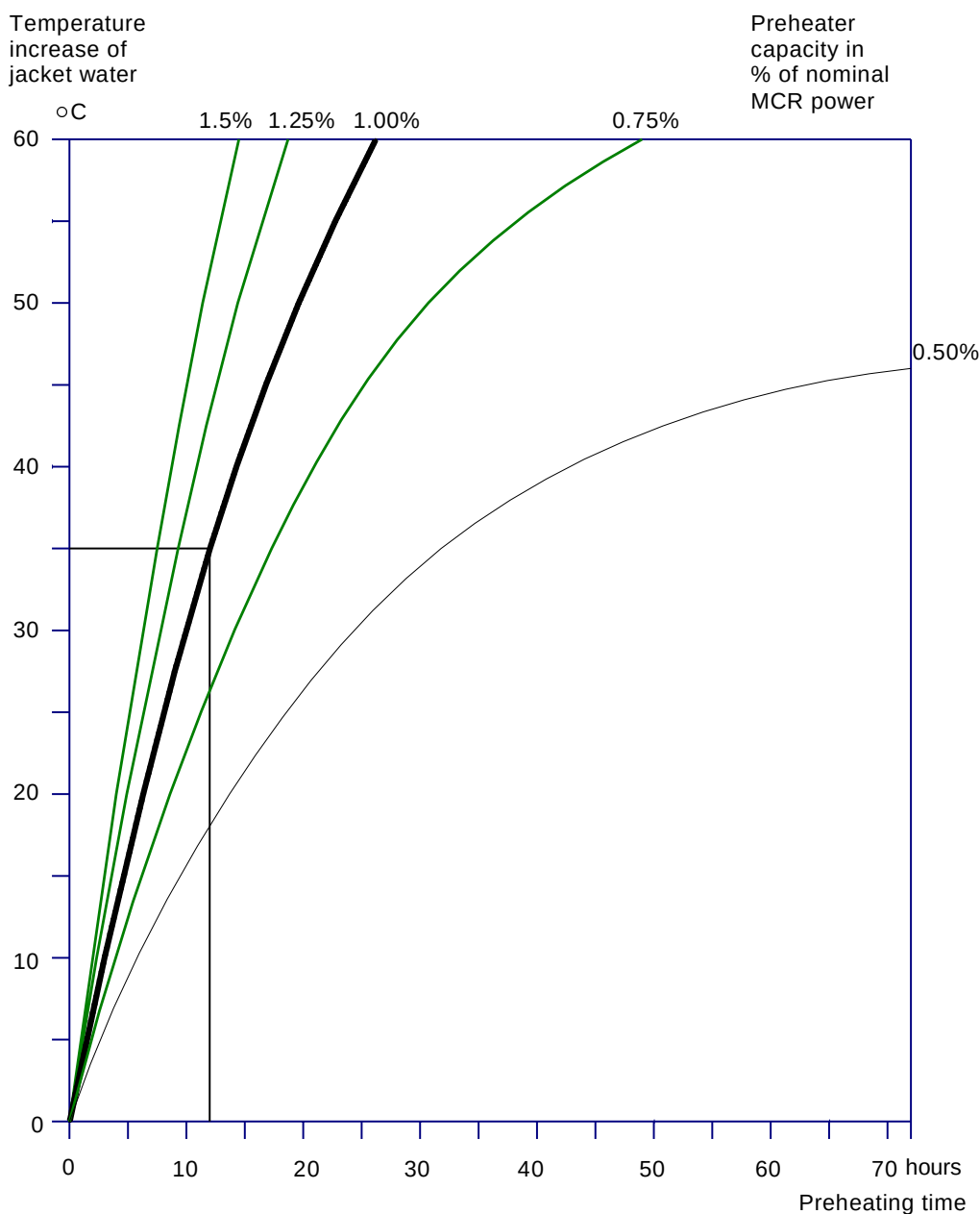
Suitable cleaners can normally also be supplied by these firms.

Main and Auxiliary Engines









Preheating of Jacket Cooling Water

If the cooling water is heated by means of a preheater installed in the freshwater system, the curves above can be used.

The curves are drawn on the basis that, at the start of preheating, the engine and engine-room temperatures are equal.

Example:

A freshwater preheater, with a heating capacity equal to 1% of nominal MCR engine shaft output, is able to heat the engine 35°C (from 15°C to 50°C) in the course of 12 hours.

Cooling water preheating during standstill is described in Chapter 703, Item 7, 'Operations AFTER Arrival in Port'.



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