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Cylinder Condition

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 and starting air distributor.

Open the indicator valves.
Engage the turning gear.

Remove the inspection covers on the camshaft side of the cylinder frame, and clean the openings.
Remove the cover(s) on the scavenge air receiver.

Note: Do not enter the scavenge air receiver before it has been thoroughly ventilated.

Begin the inspection at the cylinder whose piston is nearest BDC.

- Inspect the piston, rings, and cylinder wall.

  Wipe the running surfaces clean with a rag to ensure correct assessment of the piston ring condition.

  Use a powerful lamp to obtain a true impression of the details.

  Regarding the sequence, see Plate 70701. Regarding description of the conditions, see Item 3.3, points A) to H).

  Record the results on *Plate 70702, 'Inspection through Scavenge Ports'.*

  Use the symbols shown on *Plate 70703* to ensure easy interpretation of the observations.

  Keep the records to form a "log book" of the cylinder condition.

- Measure the total clearance between the piston rings and the ring grooves, *see Vol. II Procedure 902-1. Maximum clearance, see Vol. II Data 102-1.*

Continue the inspection at the next cylinder whose piston is nearest BDC, and so on according to the firing order. Note down the order of inspection for use at later inspections.

Check the non-return valves (flap valves/butterfly valves) in the auxiliary blower system for easy movement and possible damage.

Remove any oil sludge and carbon deposits in the scavenge air boxes and receiver.
Record the observations on *Plate 70702.*

3.3 Observations

A) <u>Piston Rings: In good Condition</u>
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.

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 point 4.12, and the separate 'Cyl. Lubrication' section in this Chapter).*

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 point 5.5 covering 'Abrasive Wear').*

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 breakdown, 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.

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.

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 Chapter 704 ('Putting Cylinders out of Operation' Case A) and Chapter 706 'Evaluation of Records', Item 2.2, Fault Diagnosing Table.*

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.

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 point 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 point 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 point 5.4 and separate section 'Cylinder Lubrication' in this Chapter).*

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

NB: 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 Programme'.*

Base the actual intervals between piston overhauls on the previous wear measurements and observations from scavenge port inspections, supplemented with the pressures read from indicator cards.

Regarding procedures for the dismantling and mounting of pistons, *see Vol. II, Chapter 902.*

Note: 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.

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.

Note: Use only KAWASAKI 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 also Plates 70711 and 70712.

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 also Plates 70711 and 70712.

Cylinder Wear Measurements:

Note: 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, Chapter 903.*

Record the measurements on *Plate 70711.*

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

Example (S/K/L90MC):
Measured value: 901.3 mm
Δt measured : 30°C
(corrected value: 901.3 × 0.99964 = 900.98
(i.e. a reduction of 901.3-900.98 = 0.32 mm)

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.

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 points 3.3E, 3.3H and 5.4.*

4.6 Piston Skirt, Crown and Cooling Space

Plates 70711, 70712

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, Chapter 902.*

Inspect the crown for cracks.

Pressure-test the piston assembly to check for possible oil leakages, *see Vol. II, Chapter 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 also Plates 70711 and 70712.

Check the piston ring grooves as described in Vol. II, Chapter 902.

If the ring groove wear exceeds the values stated in Chapter 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, Chapter 902.*

4.10 Fitting of Piston Rings

Fit the piston rings. *See also Item 3.4.*

Note: Use only KAWASAKI standard piston ring opener. *See also point 4.2.*

Push the ring back and forth in the groove to make sure that it moves freely.

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, Chapter 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:

Pump the lubricators by hand 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 lubricators as described in the lubricator instruction book.
For calculation of the lubricator's pump stroke, *see the 'Cylinder Lubrication' section further on in this Chapter.*

Coat the piston with clean oil.

Note: Before mounting the overhauled piston, remove any remaining deposits from the upper end of the liner.

Mount the piston.
See Vol. II, Chapter 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 Items 4.13.1 - 4.13.4.*

- **Notes:** Refer to Chapter 703, 'Checks during Loading', Check 9, 'Feel-over Sequence', regarding feeling-over during running-in.

- If only one or two cylinders have been overhauled, *see Item 4.13.2*
- *See also Item 4.13.2 regarding manoeuvring and low-load running.*
- Refer to the maker's special instructions on how to adjust the lubricator's stroke.

4.13.1 Running-in of Liners and Rings (Fixed pitch propeller plants)

Plates 70714,70715

---Loading-up program shown in Plate 70714 is to be followed at breaking-in operation.

---Cylinder oil feed rete while breaking-in and runnning-in period is to be adjusted according to Plate 70715.

---After the cylinder oil feed rate reaches down to the upper side of Normal Feed Rate Range shown in Plate 70715, the feed rate can be further reduced provided that the cylinder condition is proved to be stabilised and satisfactory by scavenging port inspections.

- Make repeated scavenge port inspections.
- If the cylinder condition proves satisfactory, reduce the feed rate by **maximum** 0.05 g/bhph, at intervals of **minimum** 600 hours, *see Plates 70710A, 70710B.*

Increase or decrease the feed rate during the continued service, based on the regular:

scavenge port inspections, *see Vol. II, Chapter 900*, and
piston/liner overhauls, *see Section 'Cylinder Condition', Item 4.1, 'Intervals between Piston Pulling'.*

- piston/liner overhauls, *see Section 'Cylinder Condition', Item 4.1, 'Intervals between Piston Pulling'.*

See also section 'Cylinder Condition', Item 4.8, 'Special Conditions'.

4.13.2 Special Remarks

See also Item 4.13.1.

Breaking-in one or two cylinders:

If only one or two cylinders have been renewed or have undergone reconditioning, the fuel pump index for the cylinders in question can be decreased in proportion to the required load reduction. Before starting the engine, fix the fuel rack for the pertaining cylinder(s) at 16% of MCR index. Increase the index stepwise in accordance with the breaking-in schedule, *see Plate 70714.*

Regarding the pressure rise p_{comp} - p_{max}, see Chapter 703 'Running Difficulties, Supplementary Comments', point 7.

Note: If the engine is fitted with the Turbo Compound System (TCS), the TCS must be out of operation if running-in with reduced index is chosen in order to safeguard the gear.

Regarding cylinder lubrication, see Item 4.13.1.

Manoeuvring and low load:

In practice, of course, the engine must be able to operate freely in the whole manoeuvring range.

Also the situation where low load has to be maintained for an extended period, e.g. in connection with river/canal passage, has to be coped with in the breaking-in program.

As an example, when the first breaking-in has to take place during a long river passage, we suggest the following program, *(See also Plate 70714):*

	%rpm	%Load	Duration (h)
Increase to :	55	16	0.5
River passage:	55	16	5.5
Sea passage :	70	34	2.0
-	80	51	2.0
-	85	61	2.0
-	87.5	67	2.0
-	90	73	2.0
-	92.5	79	2.0
-	95	86	2.0
-	97.5	93	2.0
-	100	100	2.0
Total Breaking-in time:			24.0

Note: Do not run for less than two hours at 55% rpm (16% load).

Regarding cylinder lubrication, see Item 4.13.1.

4.13.3 Running-in of Rings after a Piston Overhaul (Fixed pitch propeller plants)

When running-in piston rings in already run-in liners, the breaking-in time can be reduced to some 10 - 14 hours, e.g. following the dotted line in *Plate 70714, 'Running-in Load'.*

The extra lubrication should follow the same pattern as when running-in new liners; however, the duration of the 150% and 125% steps can be reduced to the time intervals between scavenge port inspections, *see Plates 70710A and 70710B.*

4.13.4 Running-in of Liners and Rings (Controllable pitch propeller plants)

Regarding running-in when only one or two cylinders have been overhauled, *see the procedure described in Item 4.13.2.*

Regarding the cylinder oil dosage during breaking-in and running-in, *see the procedure described in Item 4.13.1.*

About half an hour before harbour manoeuvres are expected, start the engine and increase to rated speed, with the propeller in Zero-pitch.

Connect the shaft generator (if installed) to the grid, and let the generator take over the electrical power supply.

This is in order to raise the engine temperature towards the normal service value prior to the harbour manoeuvres.

When manoeuvring is finished, gradually increase the propeller pitch corresponding to about 50% of MCR-load.

The increase to 100% of MCR-load should be effected gradually during the next 20 hours. *See also Plate 70714.*.

When running-in piston rings in already run-in liners, the breaking-in period can be reduced to abt. 10 hours.

5. Factors Influencing Cylinder Wear

5.1 General

Plate 70706 gives a summary of the most common causes of cylinder wear.
The following gives a brief explanation of the most important aspects, and of the precautions to be taken to counteract them.

5.2 Materials

Check that the combination of piston ring and cylinder liner materials complies with the engine builder's recommendations.

5.3 Cylinder Oil

Check that the quality and feed rate are in accordance with the recommendations under 'Cylinder Lubrication' further on in this Chapter.
See also Item 4.13 regarding running-in.

5.4 Corrosive Wear

A) <u>The Influence of Sulphur in the Fuel</u>

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

In order to minimise condensation, the newest MC 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 Chapter 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 5.4D.*

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 *'Cylinder Lubrication', Item 4.8, 'Special Conditions'.*
- Check the alkalinity, *see Item 5.3.*
- Check the timing, *see Chapter 701, page 701.17, 'Adjustment Sheet'.*
- 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 5.4D.

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 3.3E and 5.4D, regarding 'clover-leafing'.*

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.

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.

Note: Cleaning of the air side of the air cooler **must only** be carried out during engine standstill.

See also Chapter 706 'Cleaning of Turbochargers and Air Coolers', and Maintenance book Chapter 910.

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 MC 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-leafing) on the liner surfaces between the cylinder lub. oil inlets.

It is very important that the water mist catcher drains function properly.

See Chapter 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

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 5.5C, '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 pump 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 Chapter 706, 'Cleaning of Turbochargers and Air Coolers', Item 1.3, regarding the use of a thin foam filter.*
  See also Chapter 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.

B) <u>Scuffing (micro-seizure)</u>

Abrasive wear may be the result of scuffing (micro-seizure).

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

- unsatisfactory running-in conditions (especially if a previous micro-seizure has not been successfully counteracted during a cylinder overhaul). As regards running-in, *see point 4.13.*
- misalignment, (including machining errors).

C) <u>Fuel Oil Treatment</u>

(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 *Chapter 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.

Cylinder Lubrication

1. Lubricators

Plate 70716

Each cylinder liner has a number of lubricating quills, through which oil is introduced from 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.*
For check of functioning, *see Chapter 702, Item C5.*

The lubricators are usually supplied with oil from a head tank, and are equipped with a built-in float which keeps the oil level constant. *See also Plate 70716, Fig. 1.*

The lubricators are equipped with alarm devices for low oil level and low oil flow.

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:

a. The cylinder lubricators must be correctly timed *(See Vol. II Maintenance'Chap ter 903).*

b. The cylinder oil type and TBN must be selected in accordance with the fuel being burned *(see point 3 below).*

c. New liners and piston rings must be carefully run-in, *see point 4.13 in the previous section.*

d. 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).

e. The feed-rate must be increased in the situations described in Item 4.8, 'Special Conditions'.

3. Cylinder Oils

We recommend the use of cylinder oils of the SAE 50 viscosity grade.

During shop trial and seatrial, we recommend using a cylinder oil with a high detergency level.
Use a ''total base number" (TBN) of 70 as a 70 TBN oil will normally give good results. Use higher TBN oils in the event of high sulphur content in the fuel oil.

Note: 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 engines (such as mean pressure, maximum pressure, lubricated liner area) as well as today's fuel qualities and operating conditions.

The cylinder condition is influenced by such factors as cylinder oil dosage, fuel oil quality, engine load and its fluctuation, atmospheric conditions in the operating route, and maintenance quality & frequency. And the cylinder oil dosage is related as trade-off with the wearing rate of cylinder liner & piston rings. Therefore the appropriate cylinder oil dosage for a particular main engine is to be decided by the shipping company as a company policy, taking into account the prevailing cylinder condition, the operating pattern of the vessel, and the planned maintenance cost.

The recommendations are valid for fixed pitch and controllable pitch propeller plants as well as stationary plants (generator application).

4.2 Feed Rate while and after Running-in

Regarding increased feed rate during breaking-in and running-in, and the step-wise reduction towards the Normal Feed Rate Range,see Section 'Cylinder Condition', Item 4.13, 'Running-in'.

In case of Alpha lubricatingsystem,the oil feeding control changes from RPM-depended to Pme-depended and vice versa when the feed rate setting on HMI panel passes the presetting of Menu "Ser.hi[%]".
The oil comsumption changes a bigger amount than the difference between settings before and after this passing due to the function of system.

4.7 Calculating the Feed Rate at Part Load

At part load the feed rate in kg/24hours may be reduced proportionally to the mean effective pressure (mep) .

In case of varying load pattern, use the **highest** m.e.p. for calculating the new feed rate.

Note: Remember to readjust the feed rate to the normal level, when low load running is finished.

Note: Contact KAWASAKI for the feed rate during prolonged low load running.

Special equipment may be installed, which automatically adjusts the feed rate corre-sponding to the actual mep.

4.8 Special Conditions (1)

We recommend to increase the actual feed rate in the following cases:

- During START, manoeuvring and sudden load changes;
  - increase by 50%.

(2)Low sulfur fuel oil

It is recommended to decrease the feed rate in proportion to sulfur content to the value calculated in the formula mentioned below when the sulfur in the fuel oil is less than 1.5 %.

$$P_L = P - (1.5 - S) \times 0.25$$

P_L : Recommended feed rate in g/PSh when using low sulfur fuel oil
P : Present feed rate in g/PSh
S : Sulfur content %

Please consult KAWASAKI when using cylinder LO with TBN other than 70.

Reduction should be effected by the step of 0.05 g/PSh with due attention to the cylinder condition.

Please inspect the cylinder condition (piston ring surface, deposits on piston top land, cylinder liner surface, etc) at the earliest opportunity. The dosage to be increased to 150 % of the original value " P" and continue careful observation for a while if the deteriorated condition is noticed in the inspection.

(3)Low TBN cylinder oil

It is considered effective and appropriate to use low TBN cylinder oil when using low sulfur fuel oil in order to prevent excessive depositing of remnant Ca.
However, low TBN cylinder oil could lack detergency and other characteristics to some extent compared with TBN 70 one. So please consult with KHI or the oil supplier in advance in such a case.

(4)Dubious fuel oil

The fuel oil with following characteristics could create abnormal combustion and give bad influence to the cylinder condition.

i) With strange order (stinking fuel oil)
ii) With higher Al+Si contents (possibility of abnormal combustion besides abrasiveness)
iii) With density unbalanced with carbon residue content
iv) Causing frequent clogging of filter or increased number of back-washing

Please increase the cylinder oil dosage by 20-30 % when using this kind of fuel oil and continue careful observation of the condition for a while.

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.

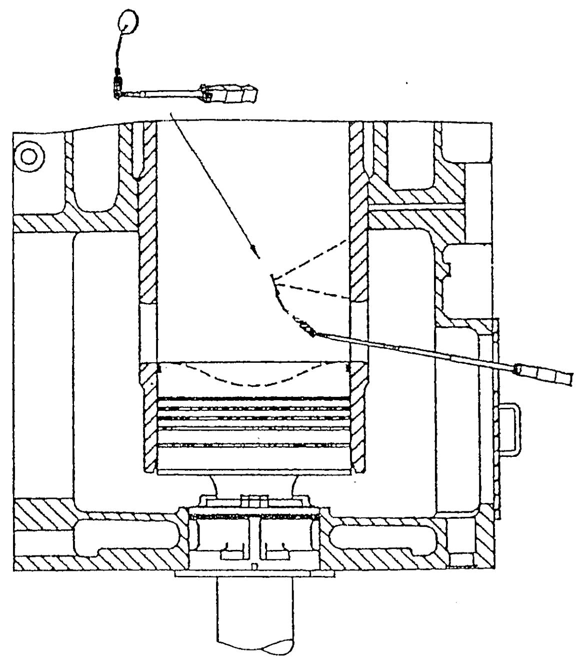
4) In order to inspect a larger area of the cylinder liner and piston, it is expedient to enter the scavenge air receiver and make observations from the "exhaust side". This should be done every time the sludge is cleaned out from the scavenge air receiver and box.

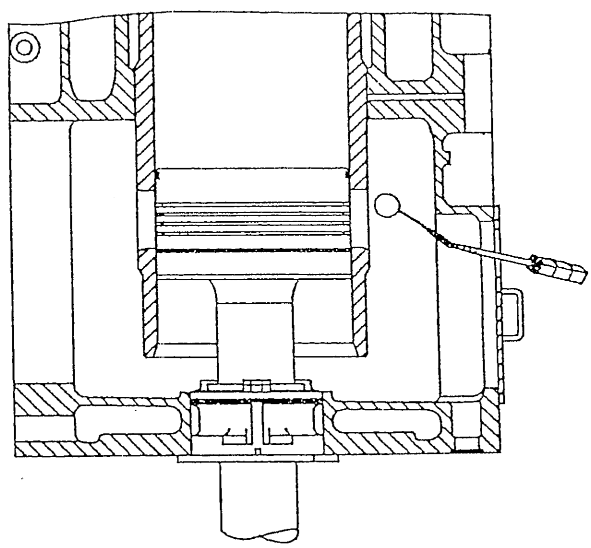
5) While the piston is passing the scavenge air port, examine the piston crown, the rings, and the skirt.
In order to be able to correctly observe the running surfaces of the piston rings, clean them with a rag.

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.





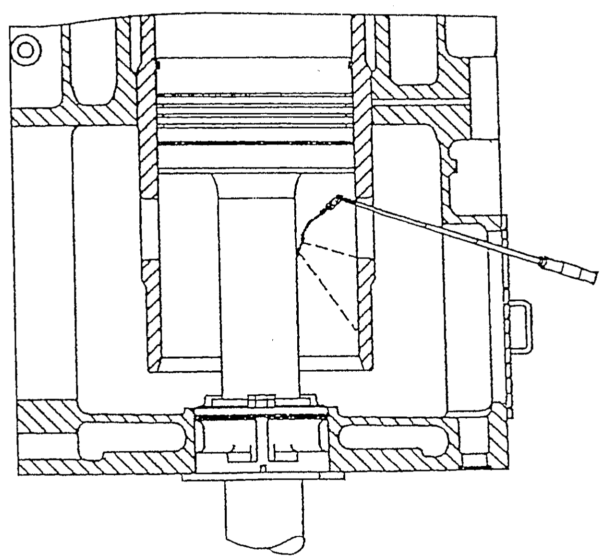


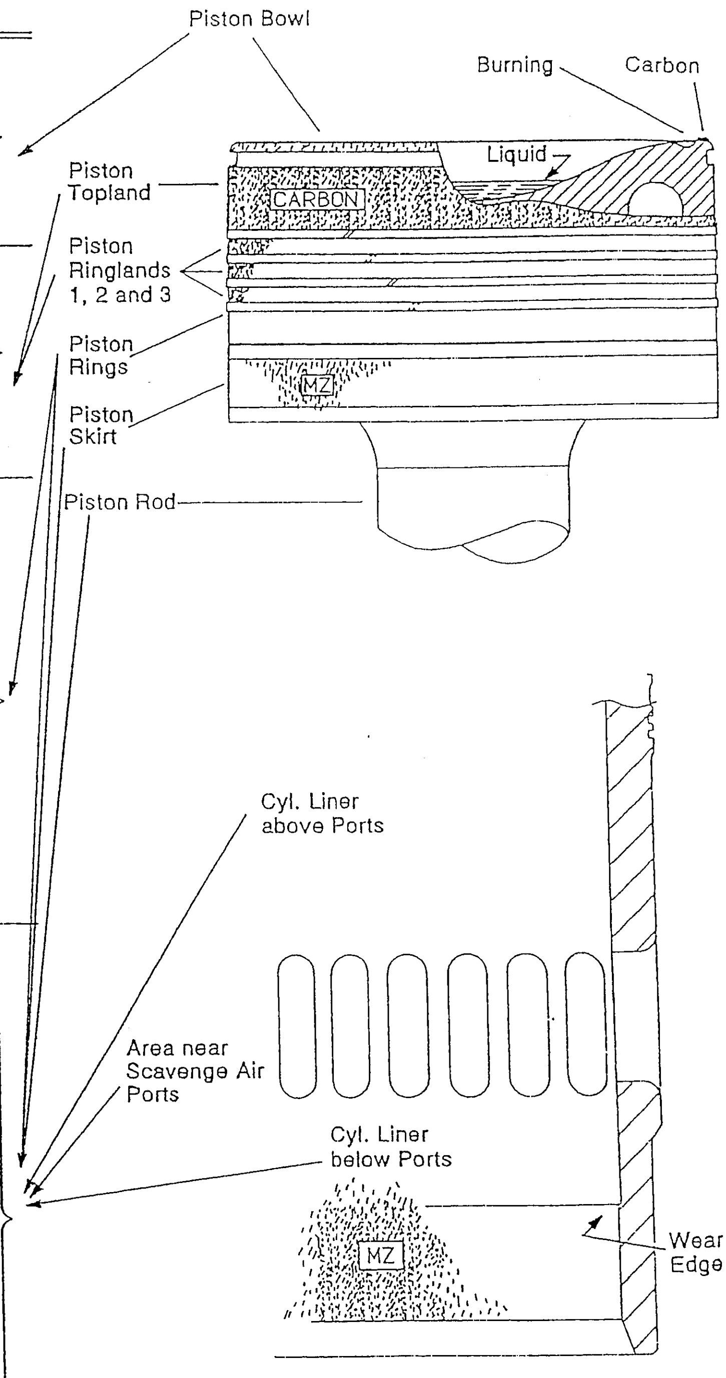
Plate 70702-40D Inspection through Scavenge Ports, Record

M/V	Engine Type:		Running hours Total:	Checked by:
Yard:	Builder:	Engine	Cylinder oil dosage:	
No.:	Built year:	No.:		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 . . . . • Light deposit . . . . LC Excessive deposit . . . . . . EC Polished deposit . . . . PC	Topland												
		Ringland 1												
		Ringland 2												
		Ringland 3												
Ring Breakage	Intact . . . . • Broken opposite ring gap BO Broken near gap . . . . BN Several pieces . . . . SP Entirely missing . . . . M Collapsed . . . . COL	Ring 1												
		Ring 2												
		Ring 3												
		Ring 4												
Ring Movement	Loose . . . . • Sluggish . . . . SL Sticking . . . . ST Running surface, – Black, overall . . . . B – Black, partly . . . . (B) Black ring ends > 100 mm BR	Ring 1												
		Ring 2												
		Ring 3												
		Ring 4												
Surface Condition	Clean, smooth . . . . • Scratches (vertical) . . . . . S Micro-seizures (local) . . . mz Micro-seizures (all over) . MZ Micro-seizures, still active MAZ Old MZ . . . . OZ Machining marks . . . . . . •• still visible Wear ridges near bottom . WR Scuffing . . . . SC Clover-leaf wear . . . . CL Corrosion . . . . CO Rings sharp-edged Top/Bot T/B	Ring 1												
		Ring 2												
		Ring 3												
		Ring 4												
		Piston skirt												
		Piston rod												
		Cylinder liner abv. scav.ports												
		Cylinder liner near scav.ports												
Lubrication Condition	Optimal . . . . • Too much oil . . . . O Slightly dry . . . . D Very dry . . . . DO Black oil . . . . BO	Ring 1												
		Ring 2												
		Ring 3												
		Ring 4												
		Piston skirt												
		Piston rod												
		Cylinder liner												
Deposits	Little sludge . . . . LS Much sludge . . . . MS	Scavenge box												
		Scav. receiver												
	Movable . . . . M	Flaps and non-return valves												
Running hours since last overhaul														

Inspection through Scavenge Ports, Symbols

Symbol	Condition of inspected part	
•	Satisfactory	Deposits, etc.
C	Carbon Deposit	
BU	Burning	
LO	Leakage Oil	
LW	Leakage Water	
•	Satisfactory (no deposits)	Deposits
LC	Light carbon deposit	
EC	Excessive carbon deposit	
PC	Thick carbon deposit worn bright by rubbing against cyl. liner	
•	Intact	Broken
BO	Broken, opposite ring gap	
BN	Broken, near ring gap	
SP	Broken in several pieces	
M	Entirely missing	
COL	Collapsed	
•	Loose	Sticking
SL	Sluggish in groove	
ST	Sticking	
B	Black running surface, overall	
(B)	Black running surface, partly	
•	Clean, smooth	Surface condition
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	Lubr. condition
O	Too much oil	
D	Too dry	
DD	Very dry	
BO	Black oil	



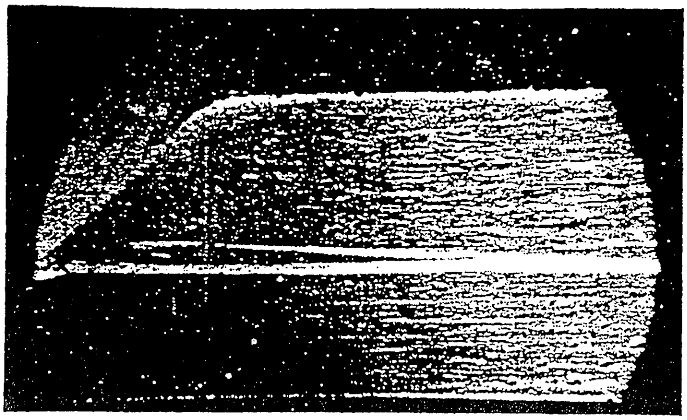
A dot (•) always means that the inspected condition is satisfactory, e.g. small deposits, no leakage, no breakages, no sticking, clean smooth surface, normal oil film, etc. However, this shall be recorded in order to show that the condition has been noted.

Inspection through Scavenge Ports

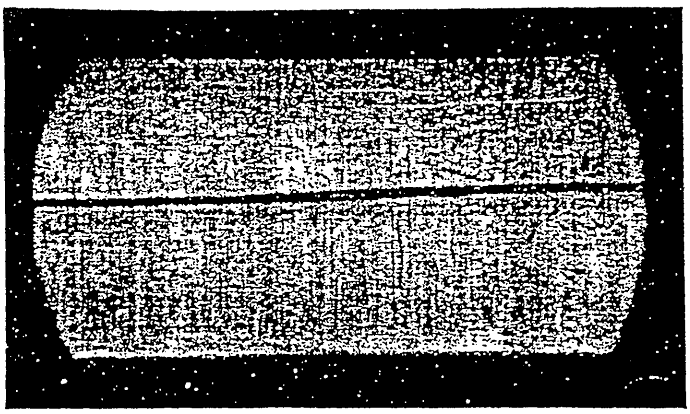
Running Surface of Piston Rings

(see also Plate 70705)

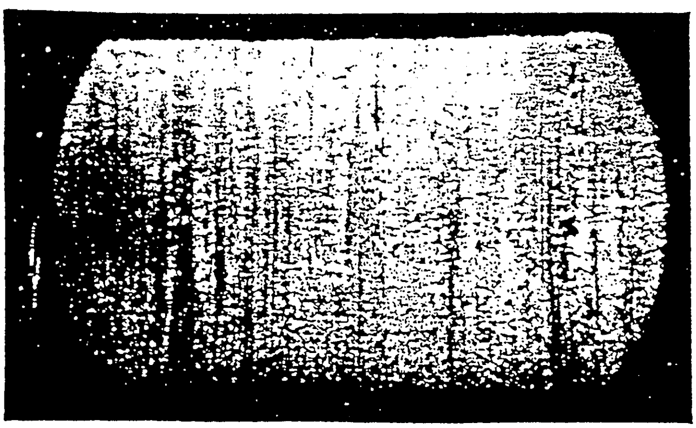
NB: In file tests, use a new very finely cut file



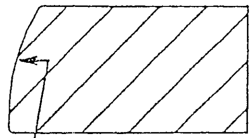
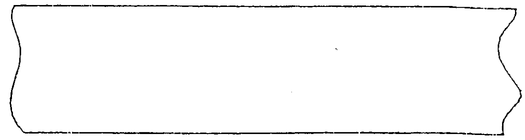
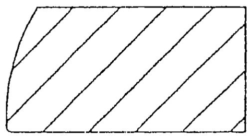
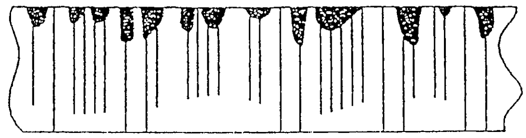
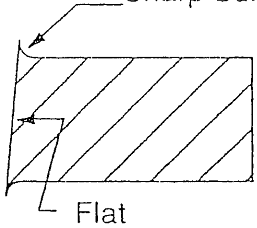
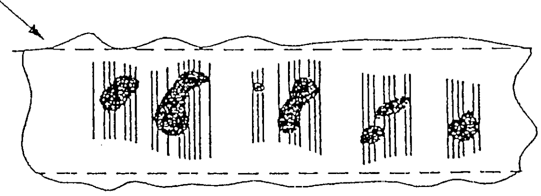
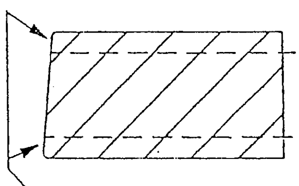
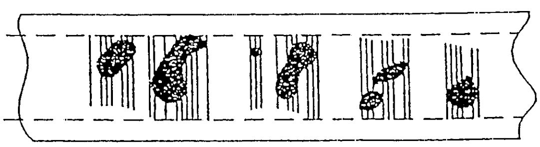
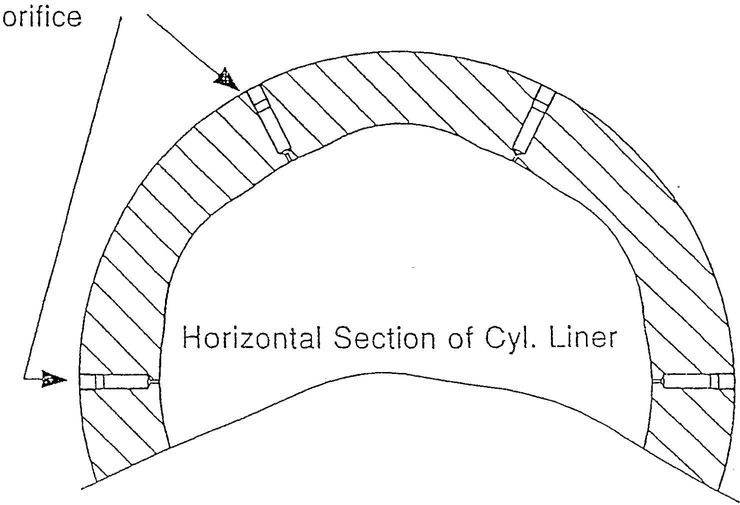
"Polished Mirror Surface"
Photo 1 (about X3)
A normal, good running surface is smooth, clean, and without scratches. The horizontal line is a scratch mark resulting from a file test, which indicates that the surface is not hardened.



"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.



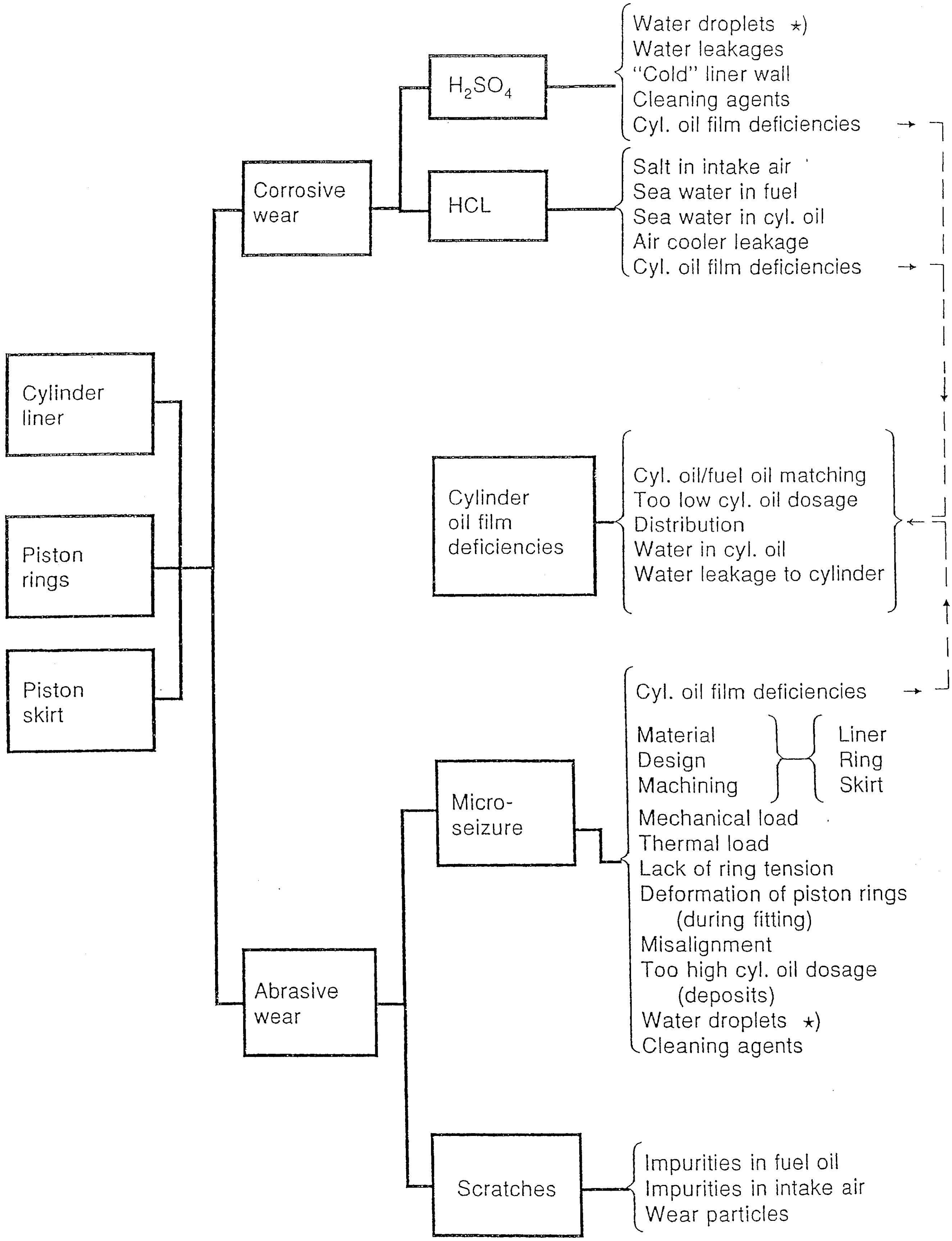
"Micro-Seizures"
Photo 3 (about X3)
A micro-seized running surface can appear as shown here.
The file test gives almost no horizontal scratch, which indicates that the surface is covered by a hard glaze, i.e. has been hardened due to micro-seizure.

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  	

7

Plate 70706-40 **Factors influencing Cylinder Wear**

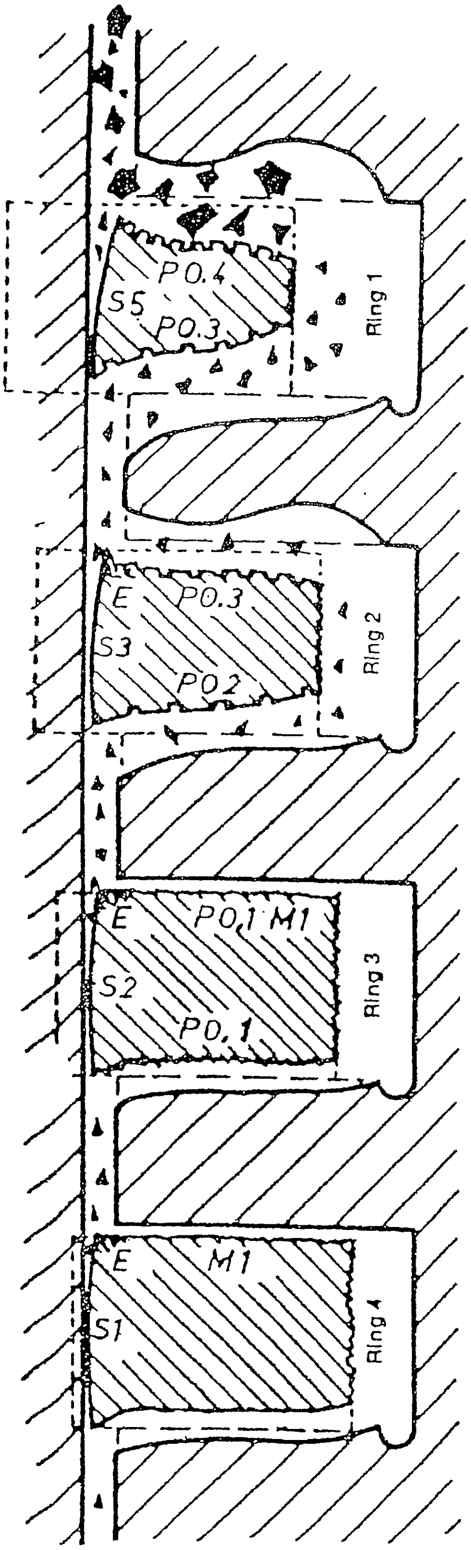
Schematic summary of the most widely recognized causes of "cylinder wear"



*) *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.*

Abrasive Particles - **Plate 70707-40**

Typical observations when particles penetrate from the combustion chamber into the piston ring zone



Exaggerated illustration of "worn and eroded" piston rings No. 1 to 4, in "worn" grooves. It is typical for particle wear that it excessively affects the upper ring (both the running face and the horizontal surfaces) as well as the groove. Some degree of micro-seizure sometimes occurs on the lower rings, decreasing upwards. This is contrary to the scratching intensity (or roughness) which decreases, from ring to ring, downwards.

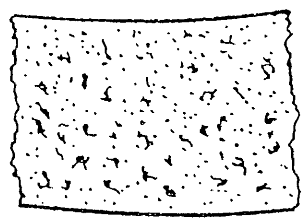
When particle-wear prevails, the cylinder liner wear rate usually rises to between 0.30 and 0.50 mm/1000 hours.

Running face ring No. 1

The "trumpet-shaped" scratches indicate that the hard particles have penetrated from above.

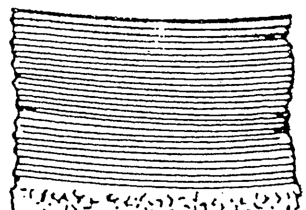
Upper side of the uppermost rings

The horizontal faces, especially the upper side, often become pock-marked due to hard grains being crushed when the rings are pressed upwards by the gas trapped between the rings. However, such an appearance can also be the result of mechanical impact due to ring collapse.



Upper side of the lower rings

The part sheltered in the groove still shows intact machining marks. The exposed part, protruding from the groove, becomes sand-blasted by the hard particles blown down through the ring gap above.



Designations

"S" - Scratched running face
"PO" - "pock-marked"

"E" - Erosion. Outer edge sand-blasted
"MI" - Machining marks intact.

Numbers 1 to 5 give degree of damage (5 being most).

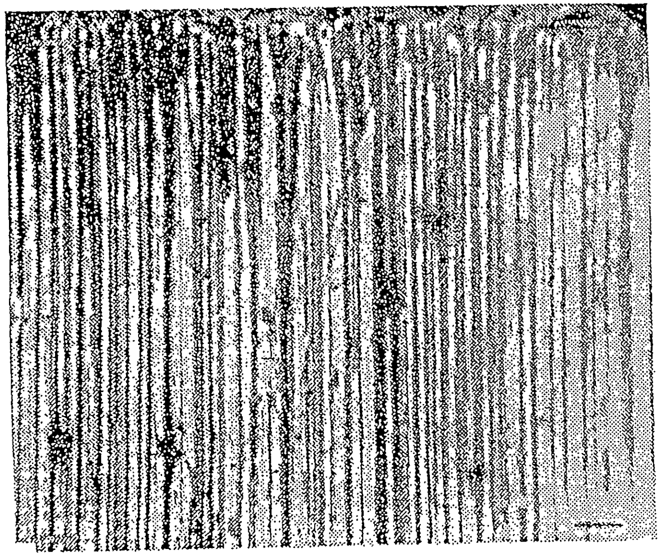


Photo 1 (X30)
Rough scratching (degree 5) of a top piston ring running face. The photo shows the upper edge, where the hard particles enter between ring and liner wall. This scratching is quite fresh, i.e. recovery or restoration has not yet commenced. Designation S5NEW.

Photo 2 (X30)
Typical "older" much finer scratching. That recovery or restoration is at work, can be seen from the fact that the graphite flakes are distinct. Designation S2OLD.

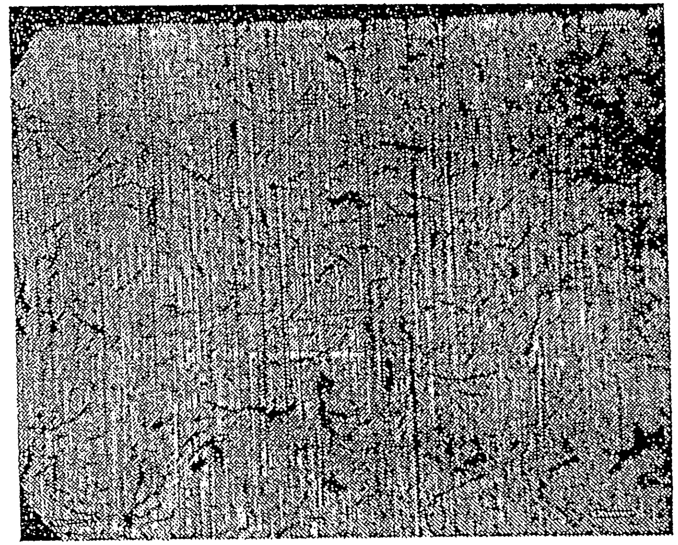
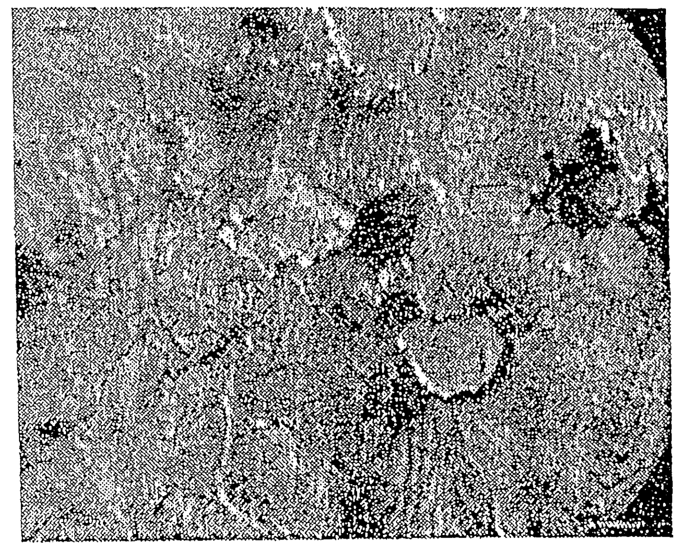


Photo 3 (X30)
Typical "pock-marking" of a ring upper side, caused by hard particles penetrating into the clearance above the ring and being crushed. This is most often seen on the two uppermost rings, which, during the last part of the expansion stroke, are pressed upwards, against the ceiling of the groove, by the gas trapped between the rings.

Photo 4 (X30)
This photo illustrates how small pieces of cast iron are "torn out" of the top surface, by the masticating effect of the hard particles. The pieces probably loosen due to shear stresses, which cause fractures in the material between the graphite flakes.
Also ring collapse can cause "torn out" material.



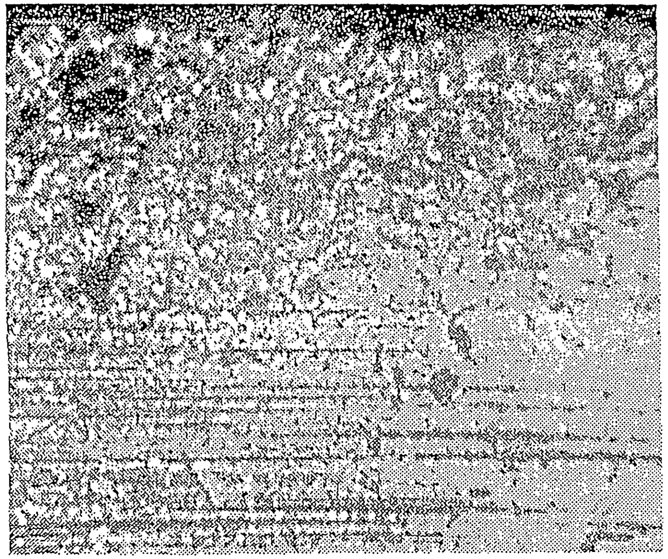


Photo 1 (X30)
Typical erosion or sand-blasting on the part of the ring topside which protrudes out of the groove. This is due to hard grains being blown down through the gap in the ring above (NB: The rings "turn" in the grooves). Such erosion is only seen on rings No. 2, 3 and 4.

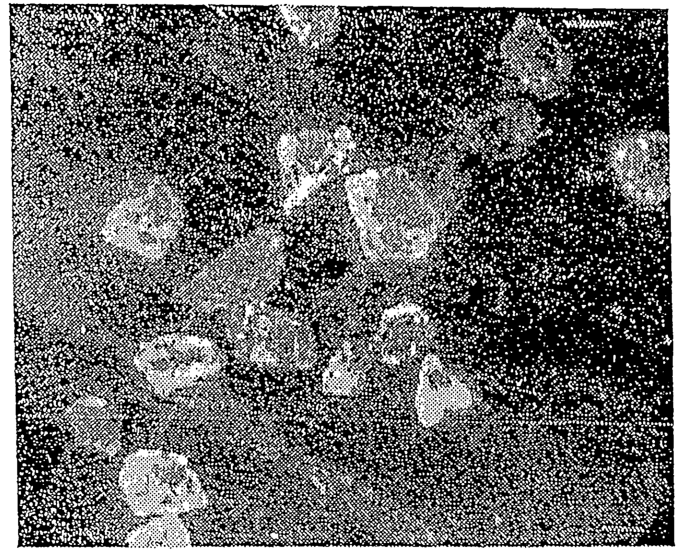


Photo 2 (X30)
Hard particles (sand) separated from a sample of piston crown deposit. Oil and carbon have been removed by incineration, other matter by acid, magnetic separation and filtration. Theoretically these particles could have come into the combustion chamber either with the air or with the fuel.

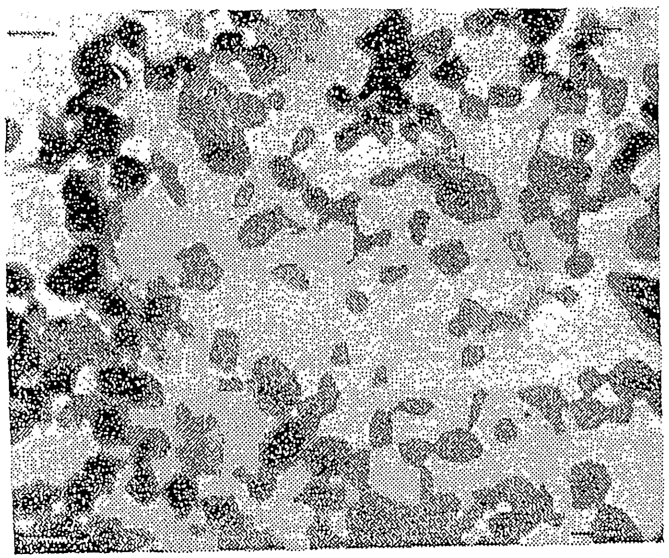


Photo 3 (X250)
Sand (or sand-like grains) separated from centrifuge sludge. In this case the centrifuge treated the fuel oil after the oil had passed a full flow (fabric) filter. The particles size is 10μ to 15μ.

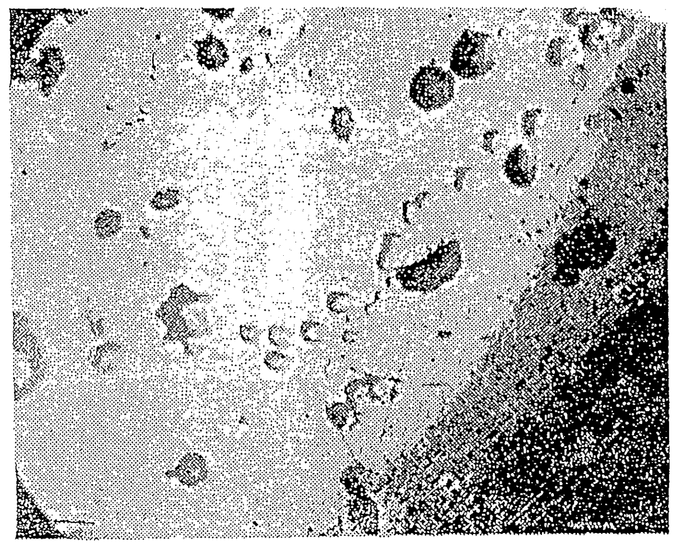
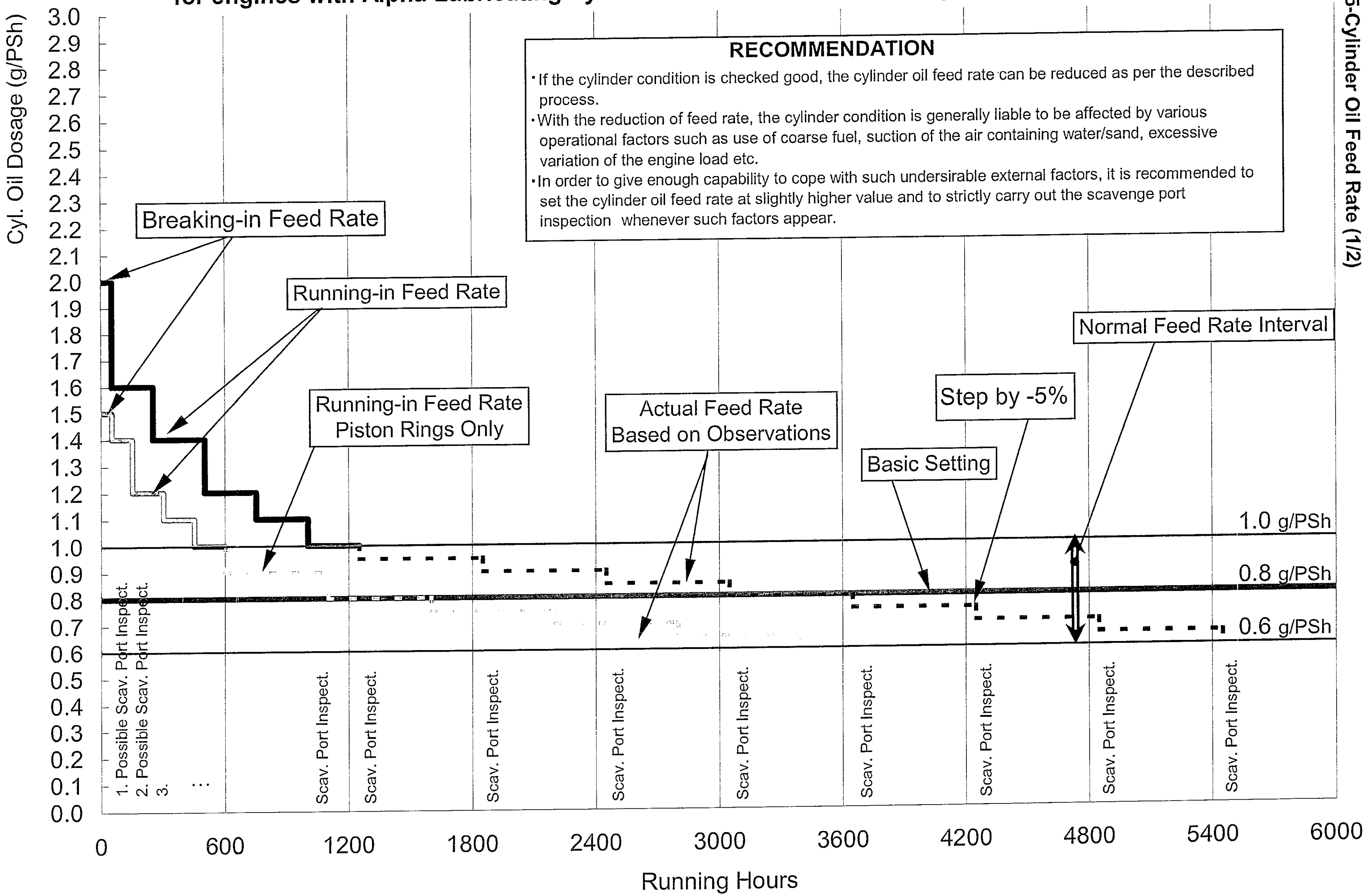


Photo 4 (X30)
Fuel pump suction valve <u>flap</u> after only a few service hours (the lapping marks are still visible. The depressions in the surface are in many cases made by one and the same particle (repeated and identical in shape and size). Usually the edge around the holes is raised, and often the original lapping marks are still visible in the bottom of the depressions.

CYLINDER OIL FEED RATE

for engines with Alpha Lubricating System and Alu-coated 1st & 4th piston ring



707X70-40C-K

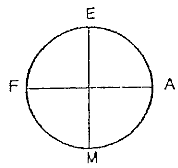
Cylinder Condition Report

Plate 70711-40D

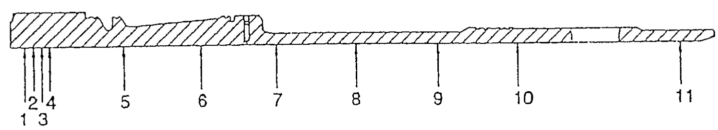
M/:	Engine Type:	No. of cyl.:	Cylinder No.:	Checked by:
Yard:	Builder:	Engine No.:		
No.:	Built year:		Engine hrs.:	Date:

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												



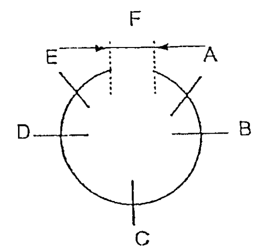
E: Exhaust
A: Aft
M: Manoeuvre
F : Fore



Cyl. cover tightened (Y/N):	Temp. betw. liner and measuring tool (°C):	Shims (mm):
Liner Remarks:		

Piston rings — Hours since last overhaul:

	Width of ring (mm)					Nom height (mm)	Height of ring (mm)				
	A	B	C	D	E		A	B	C	D	E
Degrees											
Ring 1											
Ring 2											
Ring 3											
Ring 4											



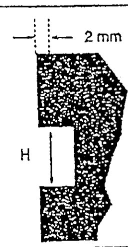
"F" to be measured before dismantling

	Piston ring type	Free ring gap "F" (mm)	Lock type (r/l/cpr)	Broken (Y/N)	Pist. skirt Guide ring (Y/N)
Ring 1					
Ring 2					
Ring 3					
Ring 4					

Reason for examination	(Y)
Routine overhaul:	Broken rings:
Routine check:	Collapsed rings:
Low p_{comp}:	Leaking piston:
Blow-by:	Change of piston:
Scavenge fire:	Pist. skirt scuffing:
Change of liner:	Other:

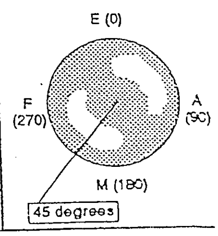
Ring grooves

	H (mm)			
	F	E	A	M
Ring 1				
Ring 2				
Ring 3				
Ring 4				



Piston top

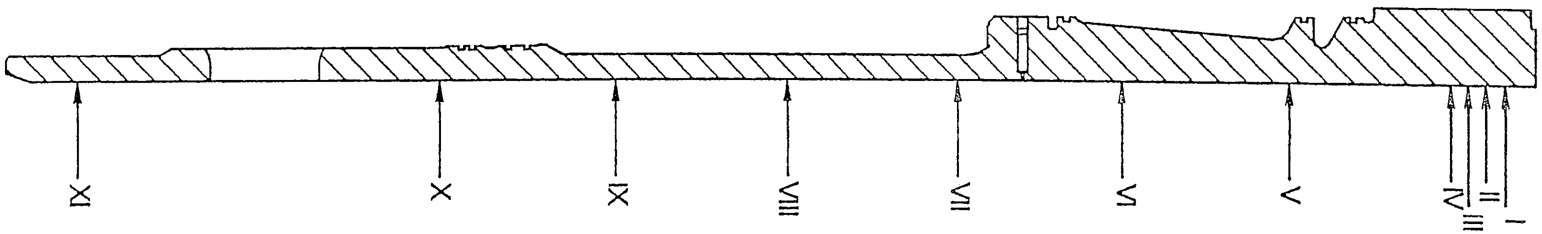
Piston no.:	
Crown (hrs.):	
Max. burning 1. (mm):	
Position 1. (degree):	
Max. burning 2. (mm):	
Position 2. (degree):	



Piston Remarks:	

PS. If a liner or piston crown is exchanged, two reports must be filled-in!

Plate 70712A-40D Cylinder Liner Wear Points



Cylinder Liner

Measuring points for wear

MC / MC-C MK V and MK VI Engines with 2 x 2 piston rings

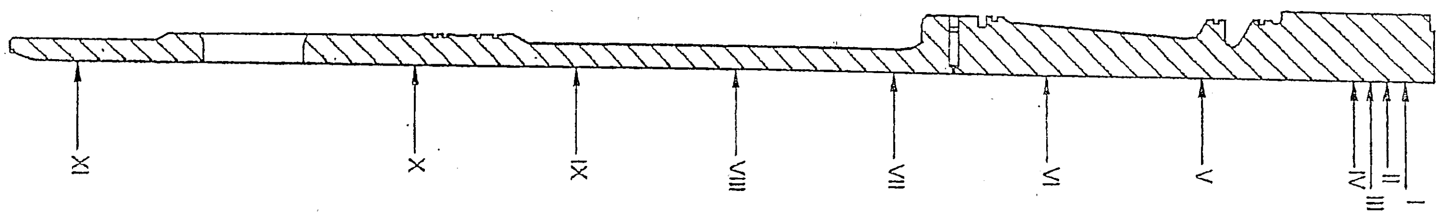
Unit: mm

Distance from I		L50	L60	L70	L80	L90	S50	S60	S70	S80	K50	K60	K90	K80-C	K90-C
	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.

Plate 70712B-40E Cylinder Liner Wear Points, High-Topland Piston



Cylinder Liner

Measuring points for wear

MC / MC-C MK V and MK VI Engines with high-topland piston

Unit: mm

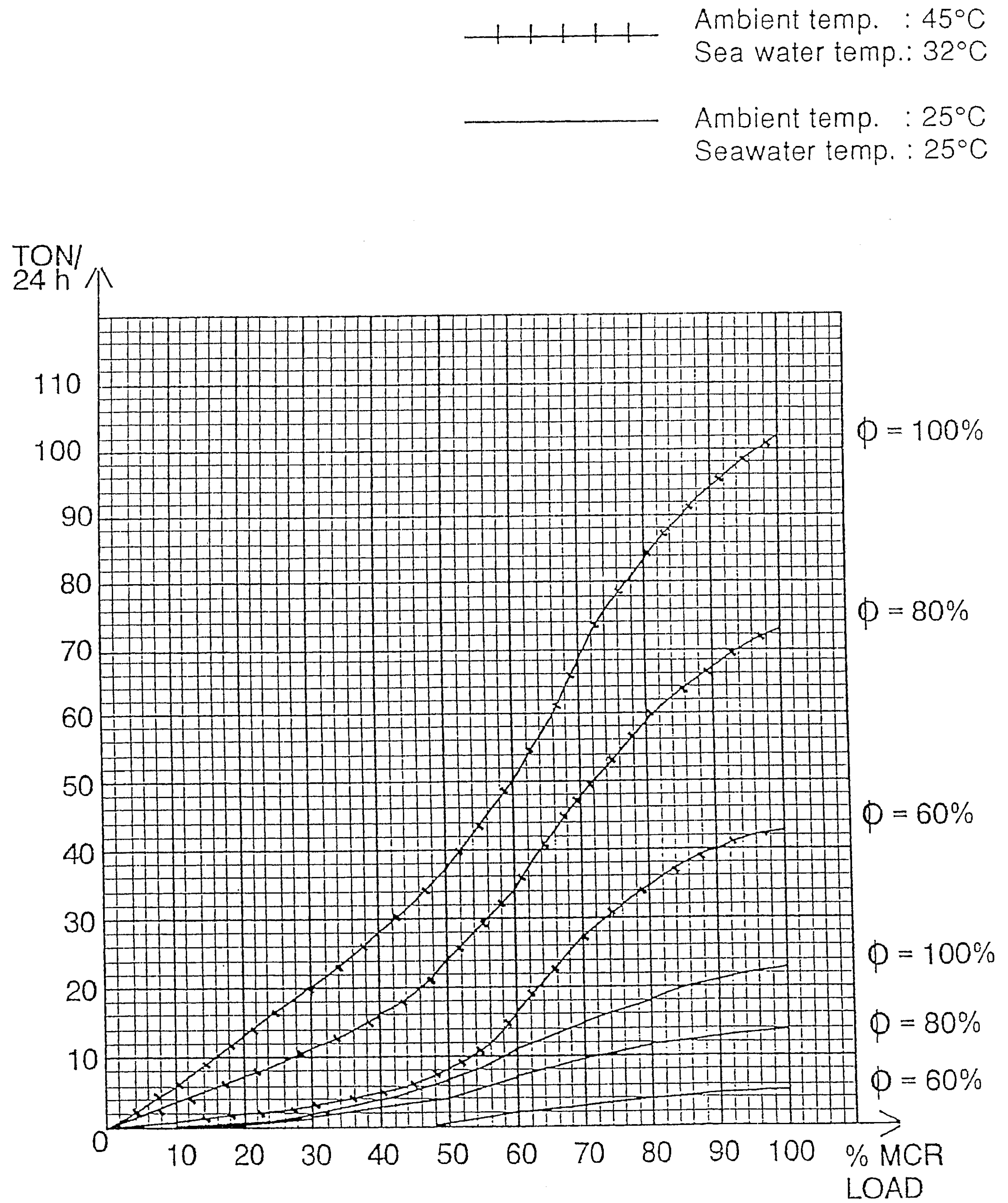
Distance from I		L50	L60	L70	L80	L90	S50	S60	S70	S80	S46-C	S50-C	S60-C	S70-C	S80-C	K50	K60	K90	K80-C	K90-C
	I			0	0			0	0	0	0	0	0	0	0				0	0
	II			40	45			30	40	45	25	28	35	40	45				45	45
	III			75	85			60	75	85	55	55	65	75	85				85	90
	IV			110	125			90	110	125	75	78	95	110	124				125	130
	V			225	265			300	350	380	320	330	370	425	490				310	285
	VI			345	405			512	600	635	560	580	645	735	857				500	440
	VII			460	545			725	850	895	800	830	915	1050	1224				690	600
	VIII			900	1050			1090	1300	1405	1050	1080	1255	1455	1690				1025	865
	IV			1400	1555			1450	1750	1915	1280	1330	1595	1885	2157				1380	1330
	X			1800	2065			1815	2200	2425	1530	1580	1930	2275	2624				1700	1700
	XI			2400	2800			2400	2800	3185	2020	2095	2510	2825	3334				2425	2500
	X			44	53			32	44	48	24	31	49	46	41				28	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.

Guiding values for condensation of water in the scavenge air cooler (drain from water mist catcher), with full, unregulated, cooling water flow.

Example: 6L60MC, nominal rated: 15600 bhp.



For other MC engines – nominal rated or derated with nominal mean effective pressure – the water condensation is approximately proportional to the MCR shaft power.

It is rare to see values above 60 T/24h in this example.

Running-in Cylinder Liners and Piston Rings

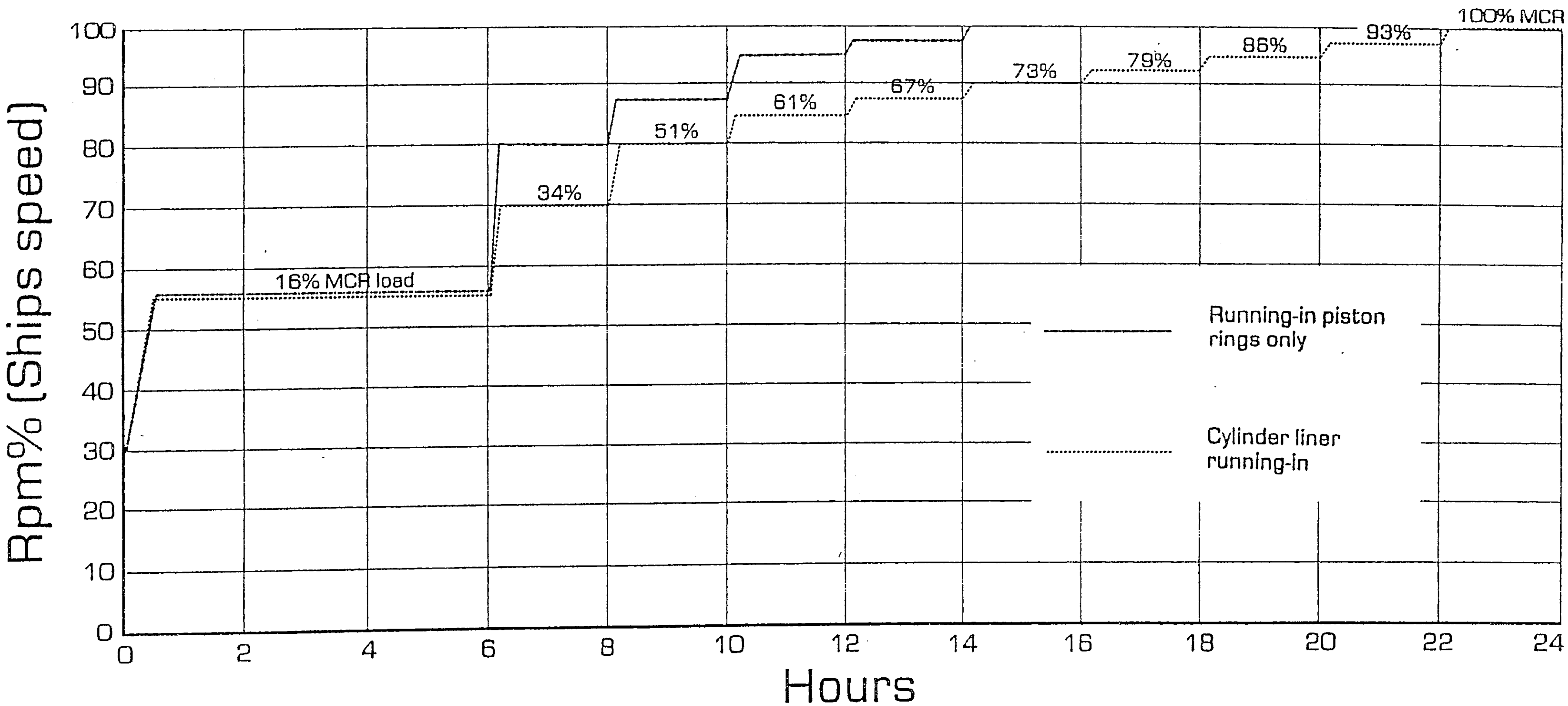


Fig. 1

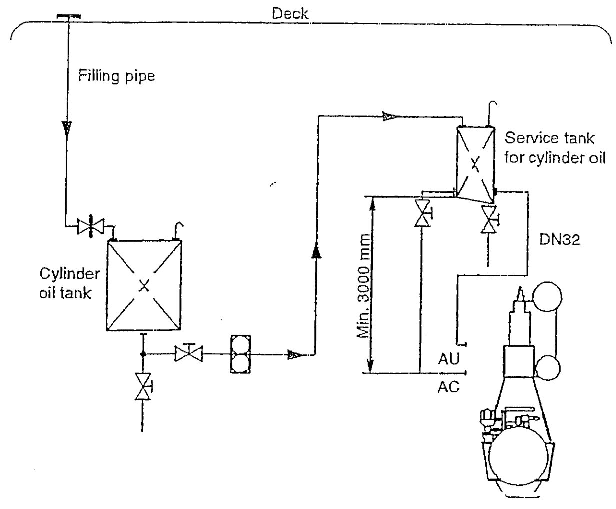


Fig. 2

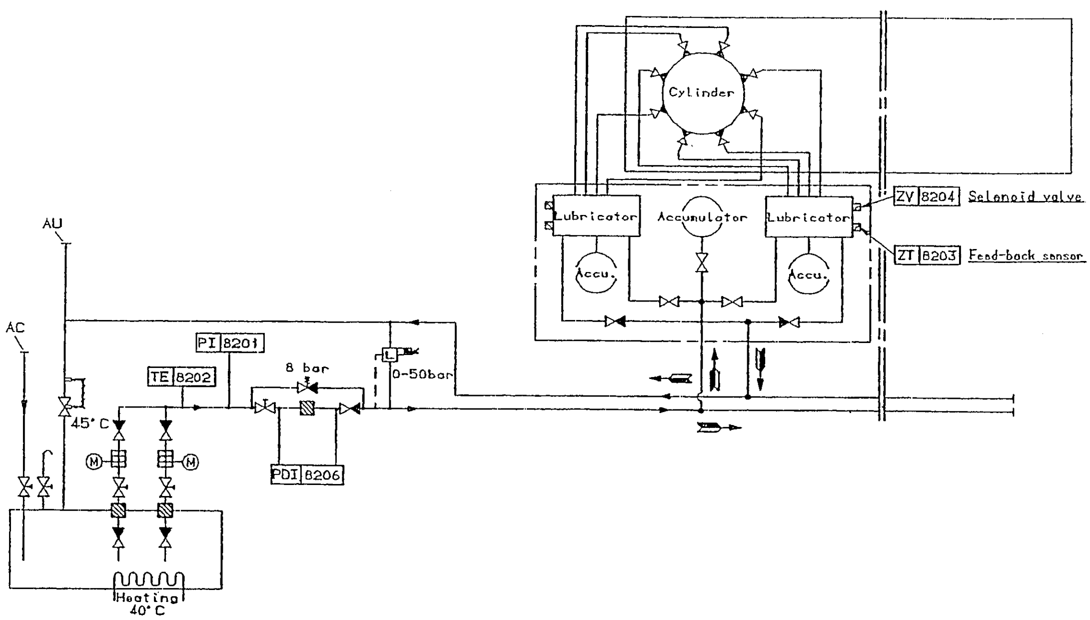


Fig. 3