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Bearings

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 KAWASAKI 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)

There is a case that the coating of tin flash is applied to all over and functions primarily to prevent corrosion (oxidation) of the bearing.
A flash layer is a 100% tin (Sn) layer which is applied galvanically; the thickness of this layer is only a few µm.

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:

a) To enhance the oil distribution over the load carrying surfaces. (The tapered areas give improved oil inlet conditions).

b) Especially in the case of *crosshead bearings (Plate 70803)* - to assist the formation of a hydrodynamic oil film between the load carrying surfaces.

c) 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

a) To ensure against distortion of the sliding surface geometry, and

b) 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 KAWASAKI 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 KAWASAKI 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 KAWASAKI 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 KAWASAKI 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 ($D_{nominal}$ - 0.15 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 KAWASAKI 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 substandard bonding. The damage is not confined to specific areas of the bearing surface. The bearing metal/intermediate layer in the damaged area is seen clearly with a sharply defined overlayer border. 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 KAWASAKI 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 KAWASAKI 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 KAWASAKI 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 recommended 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 KAWASAKI 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 KAWASAKI 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 bimetal shell, as it does not have the overlayer coating; both the upper and lower shells are protected against corrosion with tin flash *(see Item 4).*

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 ensured 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 5.4) or
``Thin shell bearings" (Item 5.5).

The bearing type, i.e.``thick shell" or ``thin shell" determines the main bearing housing assembly described below *(see table of installed bearing types, 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:

a) 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.*

b) the bearing bore is furnished with a *bore relief* (Item 5.2) at the mating faces of the upper and lower shell, *see Plate 70801.*

9.2 The Thin Shell (Insert Bearing) Bearing Assembly
(Plate 70805, Fig. 2)

This is a rigid assembly (Fig. 2). The bearing cap (pos. 1) which has an inclined vertical and horizontal mating face, is wedged into a similar female geometry in the bedplate (pos. 2), which, when the assembly is pretensioned, will ensure a 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.

Alignment of Main Bearings

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).

<u>Procedure</u>

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.

Circulating Oil and Oil System

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).*

Maintenance of the Circulating Oil

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 <u>with</u> Uni-Lube system, *see 'Camshaft lubrication for engines with Uni-Lube system', Item 3.*
- Engines <u>without</u> 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 by-passing 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)

It is possible for dirt to enter the crosshead bearings due to the design of the open bearing cap. It is therefore essential to cover the bearing cap with rubber shielding throughout the flushing sequence.

As the circulating oil cannot by-pass the bottom tank, the whole oil content should partake in the flushing.

During the flushing, the oil should be heated to 60–65°C and circulated using the *full* capacity of the pump to ensure that all protective agents inside the pipes and components are removed.

It is essential to obtain an oil velocity which causes a turbulent flow in the pipes that are being flushed.

Turbulent flow is obtained with a Reynold number of 3000 and above.

$$R_e = \frac{V \times D}{v} \times 1000, \text{ where}$$

R_e = Reynold number
V = Average flow velocity (m/s)
v = Kinematic viscosity (cSt)
D = Pipe inner diameter (mm)

The preheating can be carried out, for instance, by filling the waterside of the circulating oil cooler (between the valves before and after the cooler) with fresh water and then leading steam into this space. During the process the deaerating pipe must be open, and the amount of steam held at such a level that the pressure in the cooler is kept low.

In order to obtain a representative control of the cleanliness of the oil system during flushing, "control bags" are used (e.g. 100 mm wide by 400 mm long, but with an area of not less than 1000 cm^2, and made from 0.050 mm filter gauze).

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 ≤ 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.

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 bypass filter, if installed, as illustrated on *Plate 70818*.

The engine as such consumes about 0.1 g/BHPh 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 flowrate, it is very important that this is optimised.

The above considerations are further explained in the following.

3.3 The System Volume, in Relation to the Centrifuging Process

As mentioned above, a centrifuge working on a charge of oil will, in principle, after a certain time, remove an amount of contamination material per hour which is equal to the amount of contamination material produced by the engine in the same span of time.

This means that the system (engine, oil and centrifuges) is in equilibrium at a certain level of oil contamination (Peq) which is usually measured as pentane insolubles %.

In a small oil system (small volume), the equilibrium level will be reached sooner than in a large system (Fig. 1) – but the final contamination level will be the same for both systems – because in this respect the system oil acts only as a carrier of contamination material.

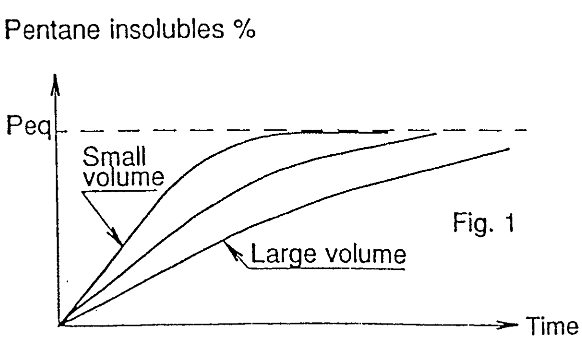


Fig. 1

A centrifuge can be operated at greatly varying flow rates (Q).

Practical experience has revealed that the content of pentane insolubles, before and after the centrifuge, is related to the flow rate as shown in Fig. 2.

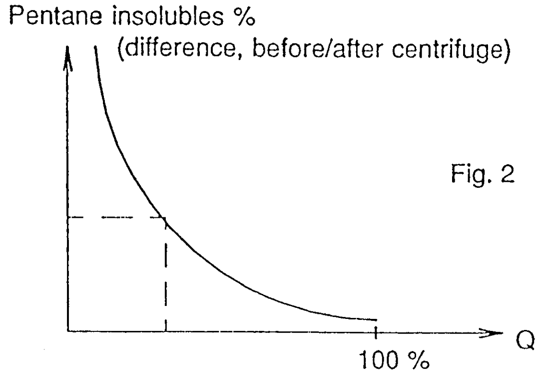


Fig. 2

Fig. 2 illustrates that the amount of pentane insolubles removed will decrease with rising Q.

It can be seen that:

a) At low Q, only a small portion of the oil is passing the centrifuge/hour, but is being cleaned effectively.

b) At high Q, a large quantity of oil is passing the centrifuge/hour, but the cleaning is less effective.

Thus, by correctly adjusting the flow rate, an optimal equilibrium cleaning level can be obtained (Fig. 3).

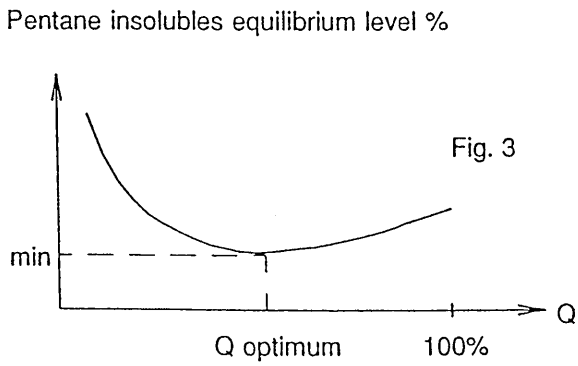


Fig. 3

41

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.

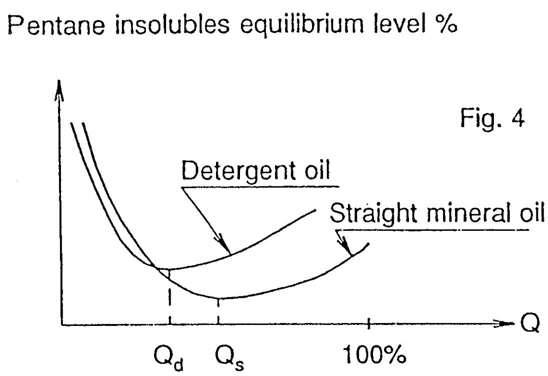


Fig. 4

As can be seen, the equilibrium level in a detergent oil will be higher than in a straight oil, and the optimum flow rate will be lower.

However, since the most important factor is the particle size (risk of scratching and wear of the bearing journals), the above-mentioned difference in equilibrium levels is of relatively minor importance, and the following guidance figures can be used:

In general,

a) the optimum centrifuge flow rate for a *detergent oil* is about 20-25% of the maximum centrifuge capacity,

b) whereas, for a *straight oil*, it is about 50-60%.

c) This means that for most system oils of today, which incorporate a certain detergency, the optimum will be at about 30-40% of the maximum centrifuge capacity.

The *preheating* temperature should be about *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 (acrid or pungent).
- Machined surfaces in crankcase become coffee-brown (thin layer of lacquer).
- Paint in crankcase peels off, or blisters.
- Excessive carbon deposits (coke) are formed in piston cooling chambers.

In serious cases of oil deterioration, the system should be cleaned and flushed thoroughly, before fresh oil is filled into it.

4.4 Water in the Oil

Water contamination of the circulating oil should always be avoided.

The presence of water, especially salt water, will:

- accelerate oil oxidation (tend to form organic and inorganic acids)
- tend to corrode machined surfaces and thereby increase the roughness of bearing journals and 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.	± 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. *See also Service Letter SL02-408/KEA.*	max. TBN 25 min. –30% (of initial value)
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
Conradsen Carbon	Residue from incomplete combustion, or cracked lubricating and cylinder oil.	max. + 3%
Ash	Some additives leave ash, which may thereby be used to indicate the amount of additives in the oil. The ash can also consist of wear particles, sand and rust. The ash content of a used oil can only be evaluated by comparison with the ash content of the unused oil.	max. + 2%
Insolubles	Usually stated as pentane/heptane and benzene insolubles. The amount of *insoluble ingredients* in the oil is checked as follows: Equal parts of the oil sample are diluted with benzene (C_6H_6) and normal pentane (C_5H_{12}) or heptane (C_7H_{14}). As oxidized oil (lacquer and varnish-like components) is only soluble in benzene, and not in pentane or heptane, the difference in the amount of insolubles is indicative of the degree of oil oxidation. The benzene insolubles are the solid contaminants.	Non-coagulated pentane insolubles max. 2% Non-coagulated benzene insolubles max. 1%

The above limiting values are given for reference / guidance purposes only.

The assessment of oil condition can seldom be based on the value of a single parameter, i.e. it is usually important, and necessary, to base the evaluation on the overall analysis specification.

For qualified advice, we recommend consultation with the oil company or engine builder.

6. Cleaning of Drain Oil from Piston Rod Stuffing Boxes

Plate 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.

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.

Separate Camshaft Lub. Oil System (Option)

(Engines without Uni-Lube System)

1. System Details

Plate 70824B

To prevent the circulating oil in the crankcase 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.*

Camshaft Lubrication for Engines with Uni-Lube System

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.

4. When the engine is running, it may become necessary to readjust the pressure control valve, to maintain the required pressure.

Turbocharger Lubrication

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.

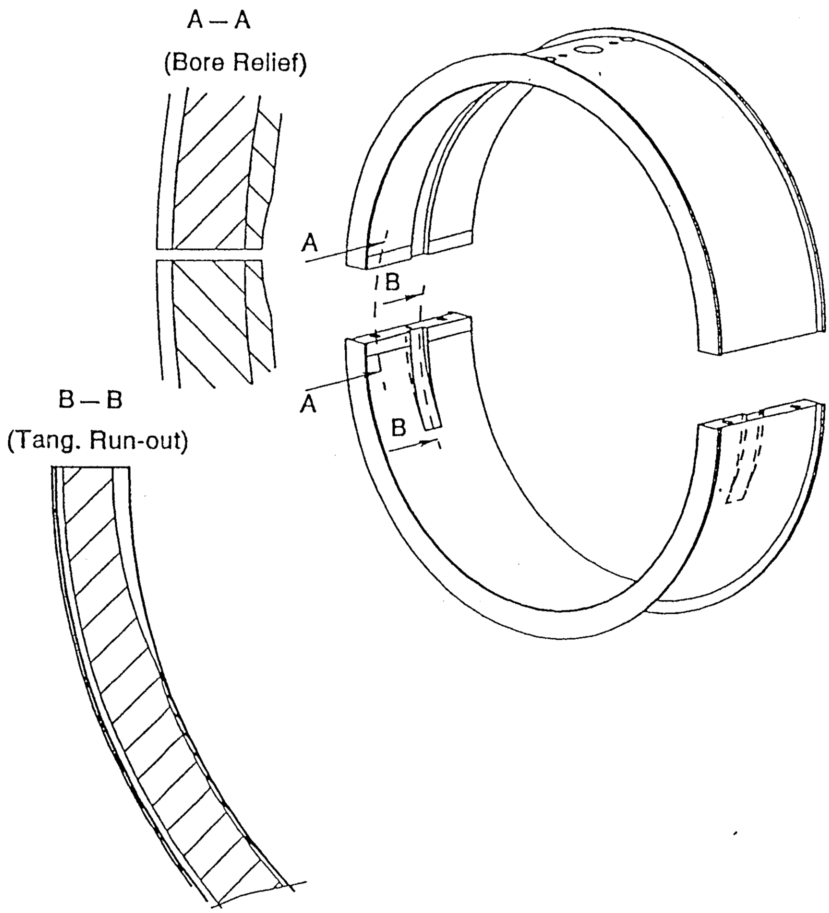
The tank is mounted on top of the turbocharger, and is able to supply lub. oil until the rotor is at a standstill, or until the lub.oil supply is re-established.

2. MET T/C, System Details

The MET turborchargers 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'.*

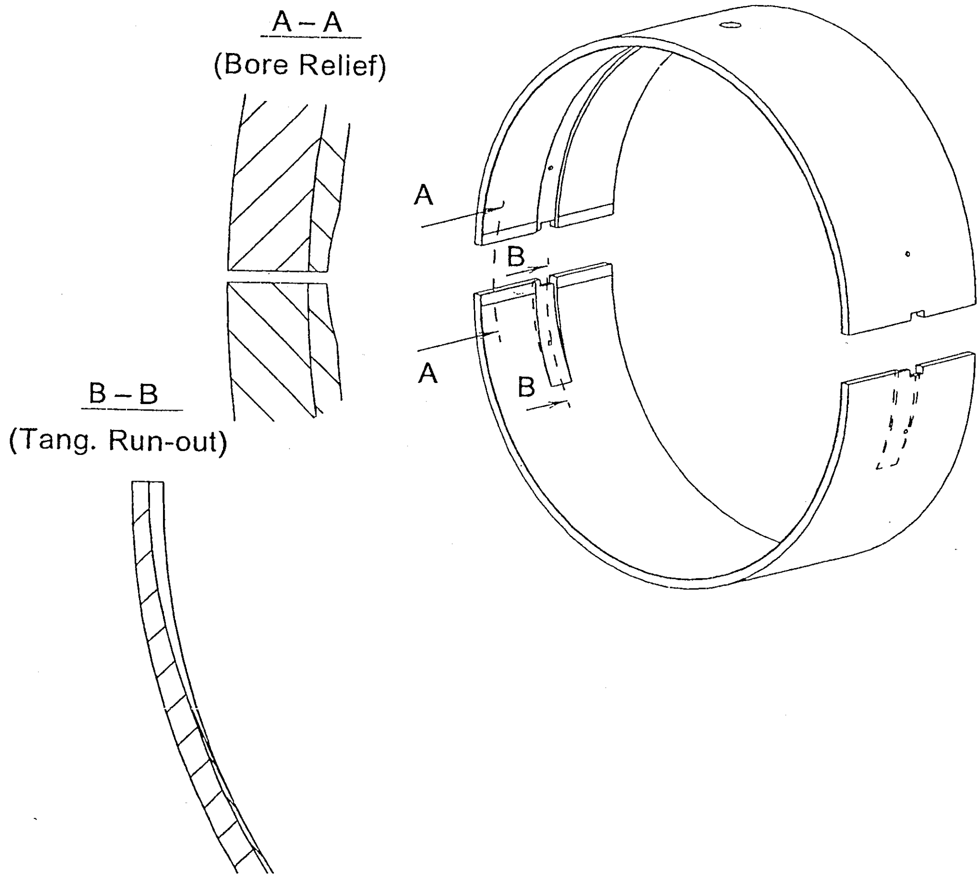
3. BBC T/C, System Details

The BBC/ABB turbochargers are designed with an integrated lub. oil system, please refer to the relevant BBC/ABB-instruction manual.



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

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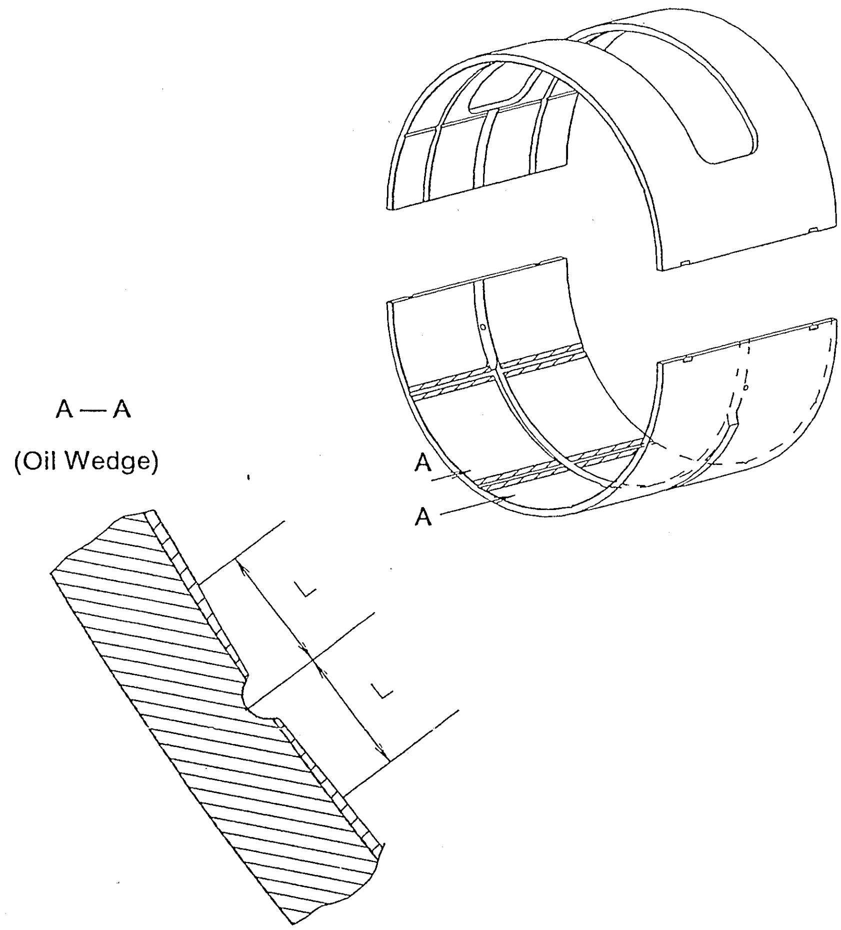


Extent of oil wedges in crosshead bearing lower shell

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.

Plate 70804-40 Crankpin Bearing

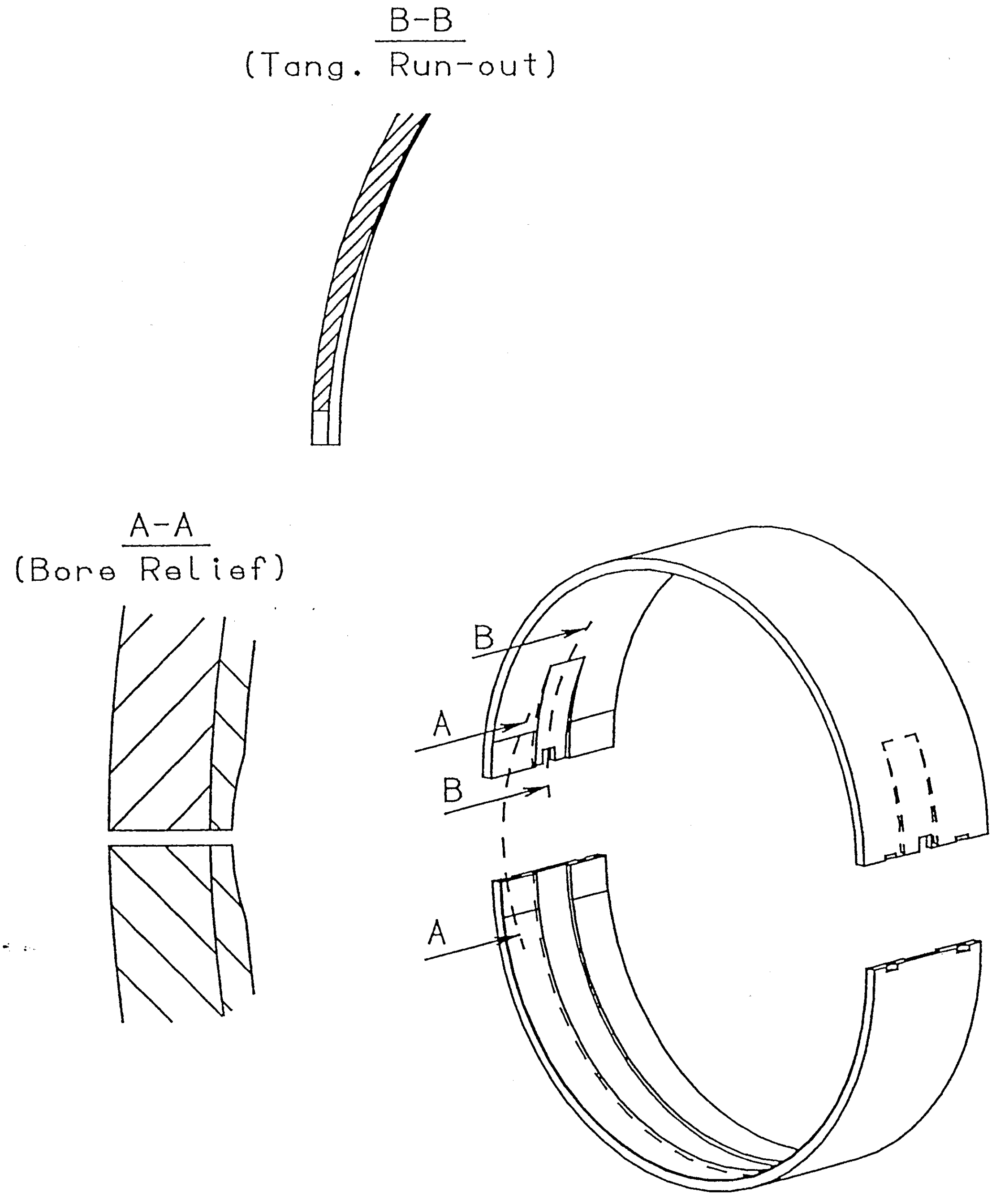


Fig. 1 Thick Shell

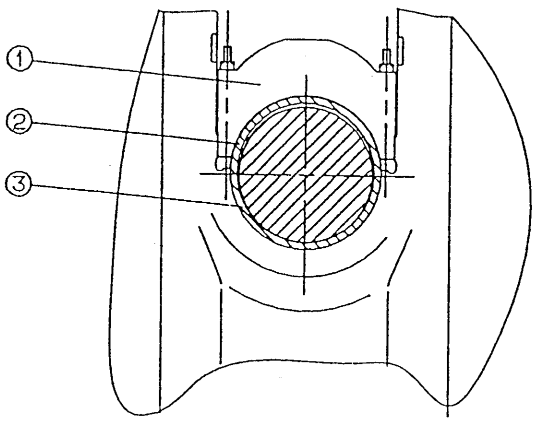


Fig. 2 Thin Shell

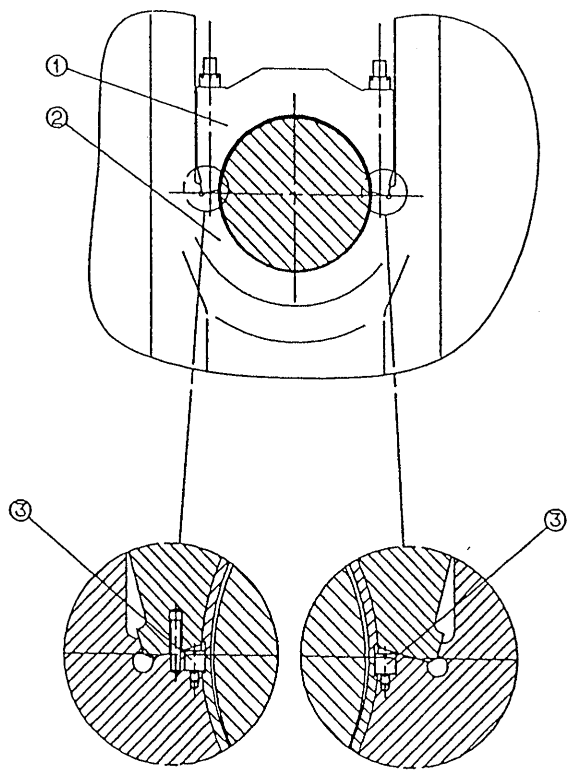
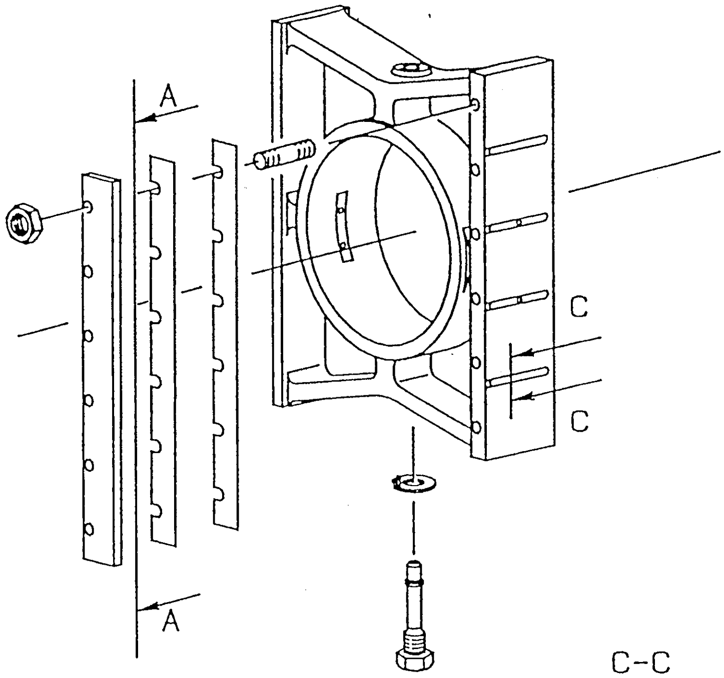
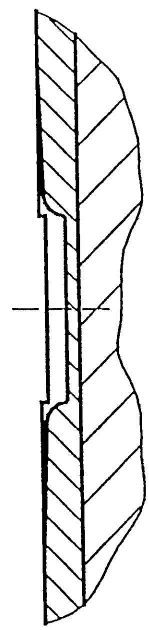


Plate 70806-40 Guide Shoes and Strips

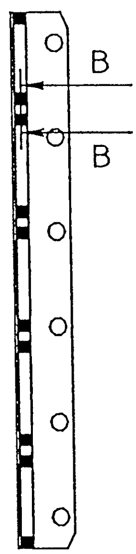


C–C



B–B

A–A



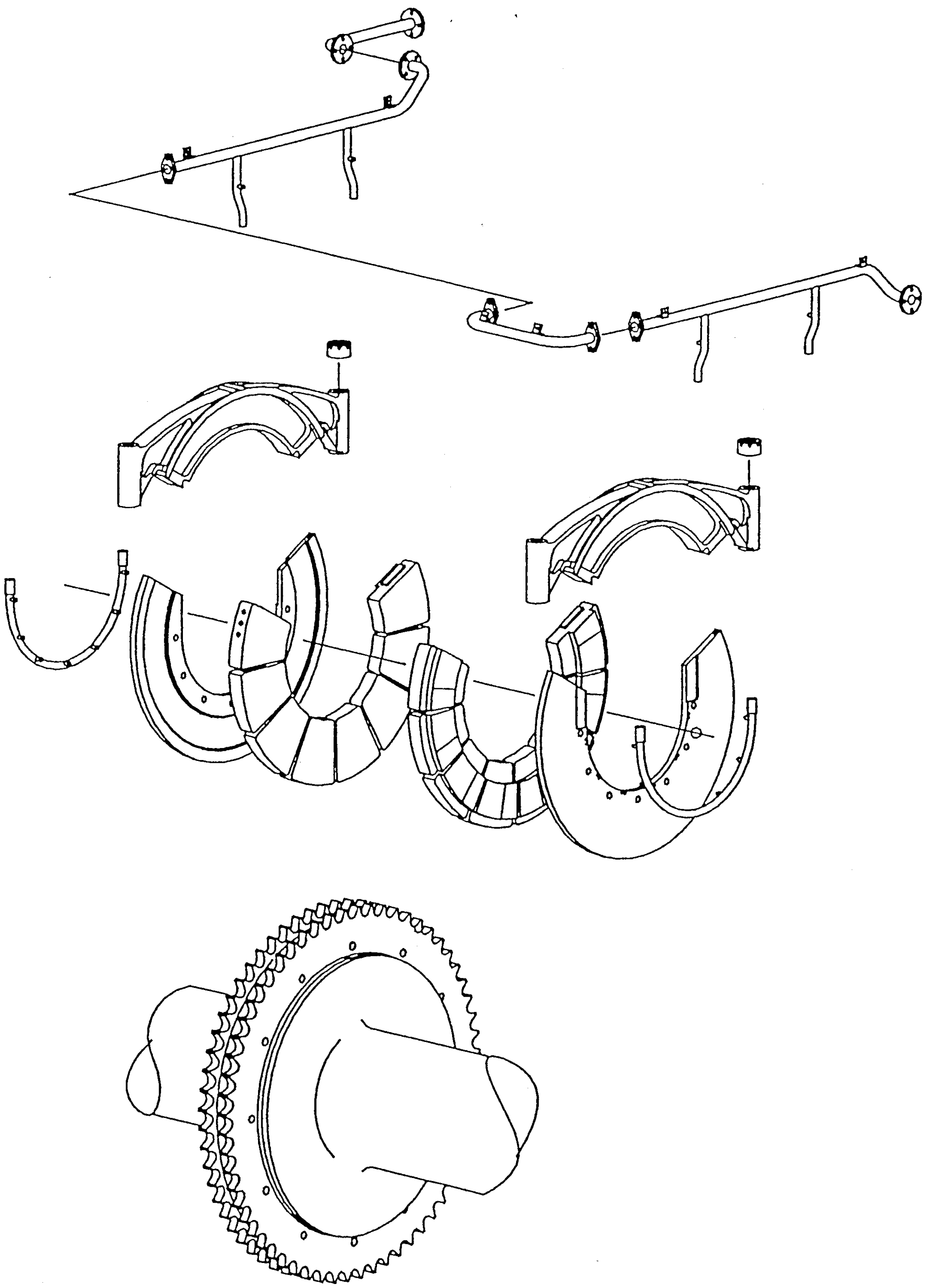


Plate 70808-40B Camshaft Bearing Assemblies

Fig. 1 Two-Shell Assembly

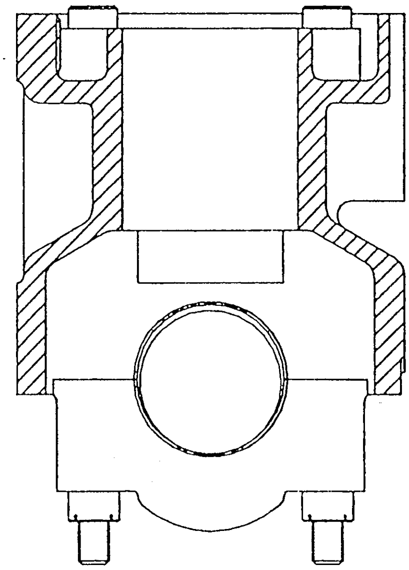
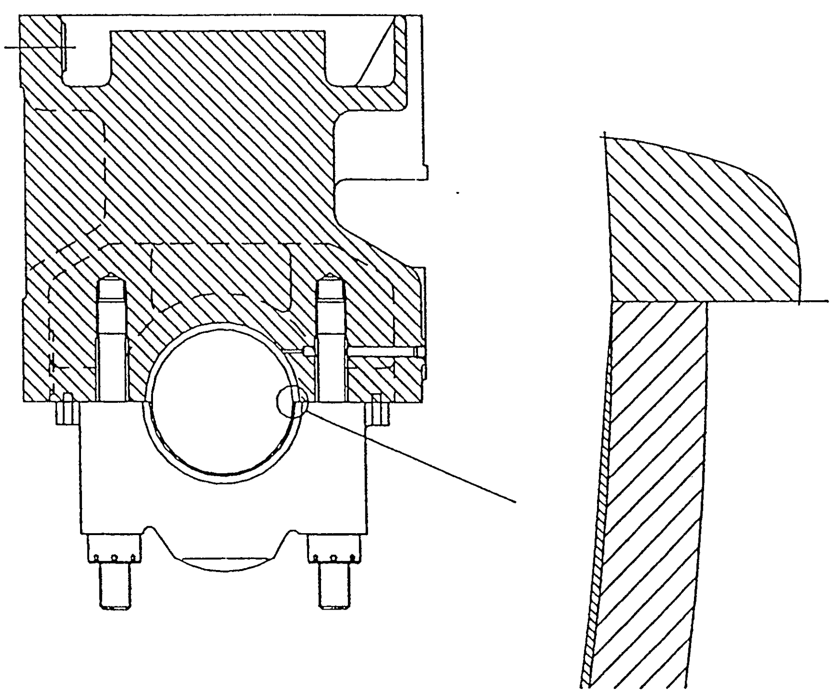


Fig. 2 One-Shell Assembly



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Inspection of Bearings
Recording of Observations

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
Transitions:	
Oil Wedge	OW
Bore Relief	BR
Tang. Run-out	TR
Back of Shell	BS

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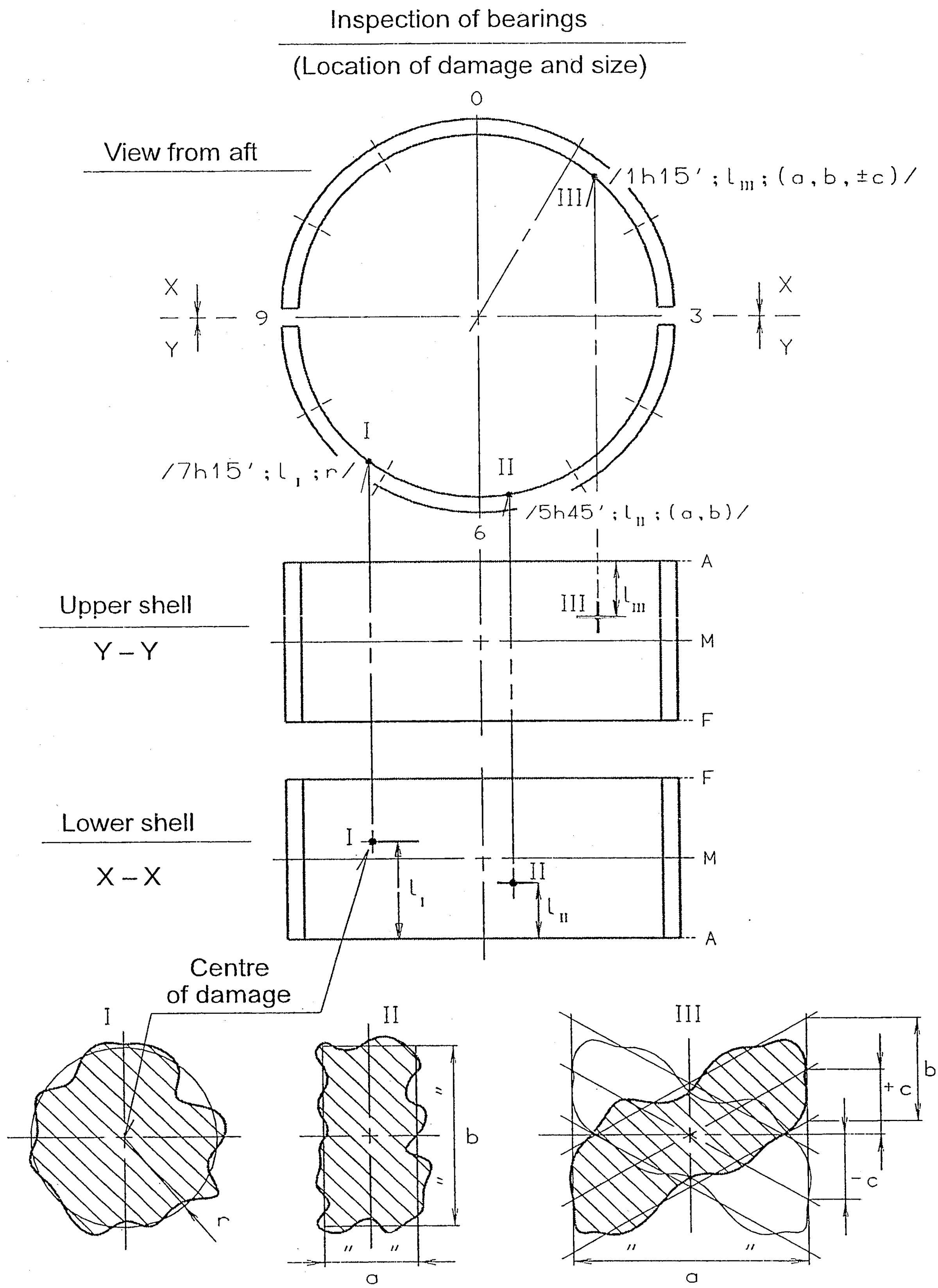
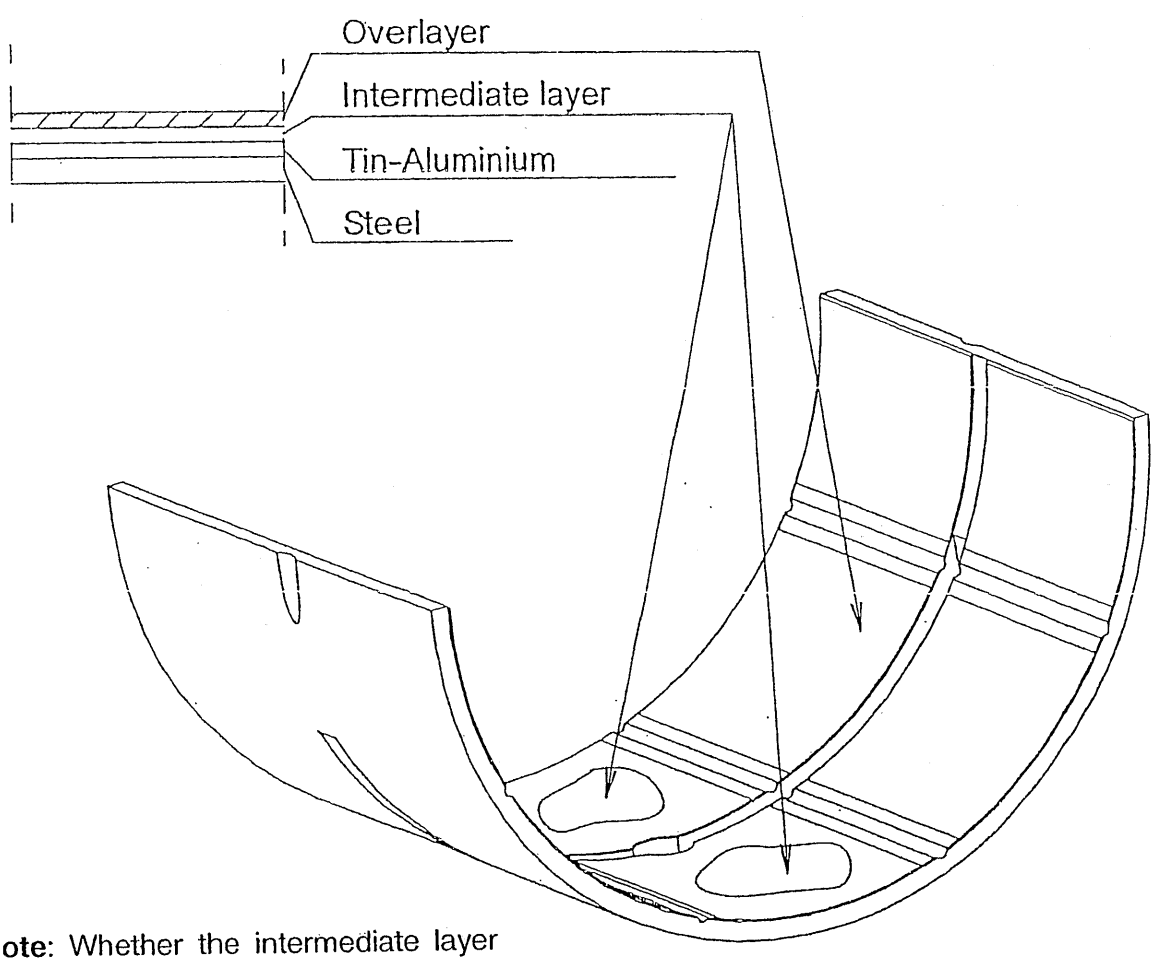

Inspection of bearings
(Location of damage and size)
View from aft
0
3
6
9
X
Y
/1h15'; l III; (a, b, ±c)/
/7h15'; l I; r/
/5h45'; l II; (a, b)/
I
II
III
Upper shell
Y – Y
Lower shell
X – X
A
M
F
Centre of damage
r
a
b
+c
–c

Plate 70810B-40F **Acceptance Criteria for Tin-Aluminium Bearings with Overlayer**
(Crosshead Bearing Lower Shells)



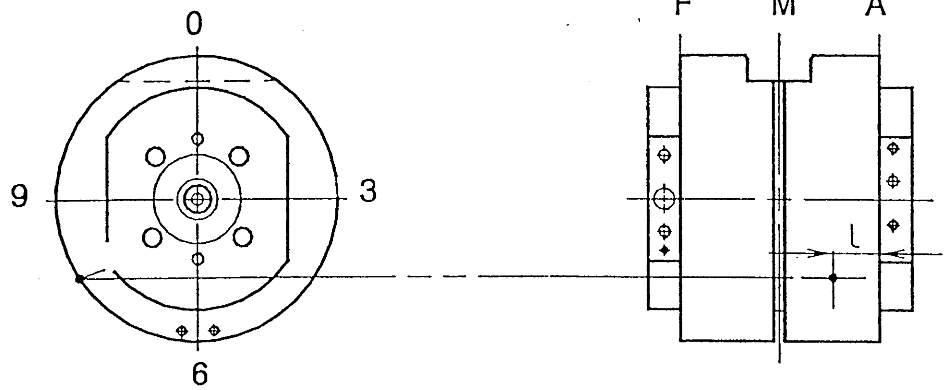
Note: Whether the intermediate layer is exposed can be determined with a knife test, as the knife will leave only a faint or no cut mark in the intermediate layer.

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

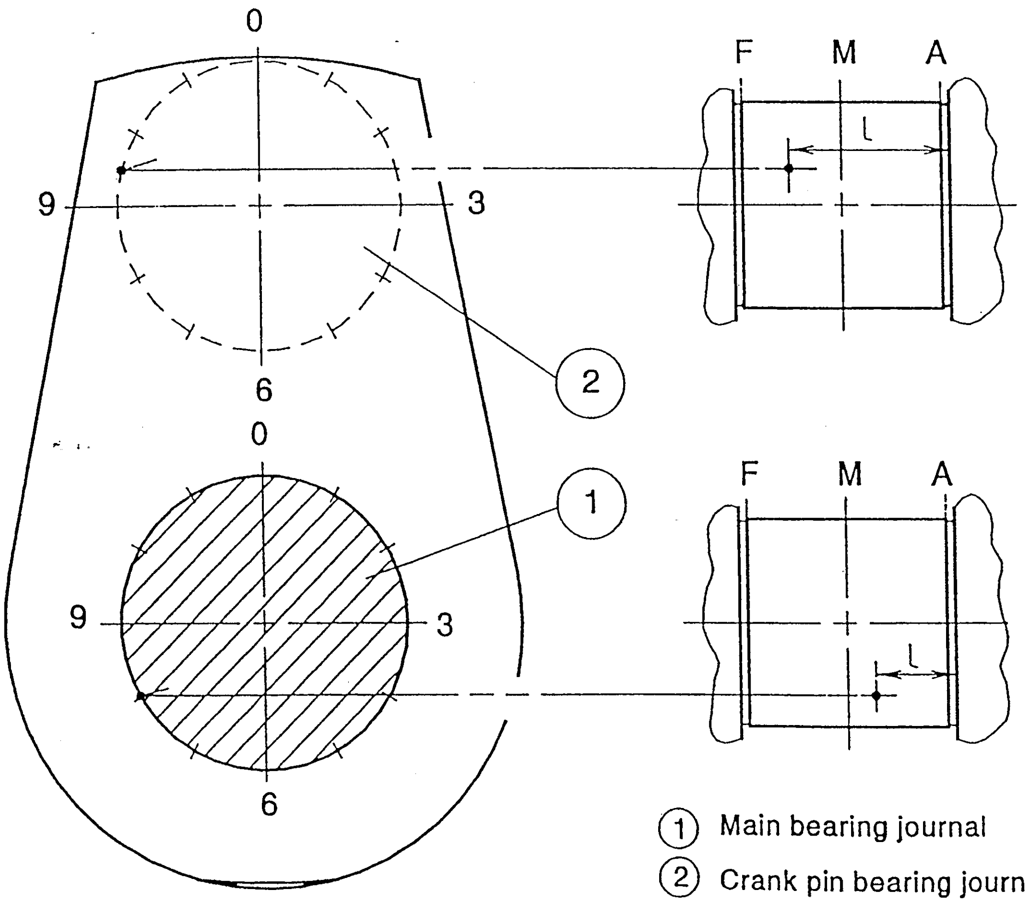
Crosshead pin

(View from aft)



Main and crank bearing journals

(View from aft)



(1) Main bearing journal

(2) Crank pin bearing journal

Plate 70812-40 **Inspection of Bearings**
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
Transitions: 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 Trapped Hard Particles	 7.4 7.4

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Inspection of Bearings

Inspection Records, Example

M/V	Engine type:	CW / CCW 1)	Running hours Total 4)	Checked by: 4)
Yard:	Builder:	Engine No.:		Date: 4)
No.:	Built year:			

Date	Checked by	Engine running hours	Type of inspection 2)	Description of condition	Clearance (mm) Top Fore	Clearance (mm) Top Aft	Hydr. open. pressure	Journal/pin Roughness 3)
8/3-93	N.N.	10000	7.2	MB/4 /MBD/WM /CR; L; M; HC/7h 15'; l_I; r//	0,5	0,5	880	N6 (M)
8/3-93	N.N	15000	7.2	CHB/5/MBD/WM; OW/W; RR/5h 45'; l_{II}; (a,b)//	0,4	0,4	900	N3 (E)
8/3-93	N.N.	8000	7.2	CRB/3/MBD/WM/M; W/ 1h 15'; l_{III}; (a,b,+½c)//	0,4	0,4	870	N6 (E)
8/3-93	N.N.	8000	7.1	CHB/6/OF; U/OJ; R; TW/WM; SQ//	0,45	0,45		

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.

Plate 70813-40

Plate 70814-40 Inspection of Bearings

Inspection Records, Blank

M/V	Engine type: CW / CCW 1)		Running hours Total 4)	Checked by: 4)
Yard:	Builder:	Engine		
No.:	Built year:	No.:		Date: 4)

Journal/pin Roughness 3)			
Hydr. open. pressure			
Clearance (mm)	Top	Aft	
		Fore	
Description of condition			
Type of inspection 2)			
Engine running hours			
Checked by			
Date			

1) Engine direction of rotation, seen from aft, must be underlined; CW: Clockwise, CCW: Counter Clockwise.
2) Inspection without opening-up: 7.1; Open-up inspection: 7.2.
3) It should be stated whether the roughness is measured: M, or evaluated: E.
4) Only to be filled in, if all observations are carried out at the same running hours.

M/V	Engine Type:		Total running hours	Checked by:
	Builder:	Engine No.:		
Yard No.:	Built year:			Date:
For comparison of measurements	Ships draught, aft measured (m)		Fully loaded (m)	Ballasted (m)
	Jacket cooling water temp. (°C)		Main lub. oil temp. (°C)	

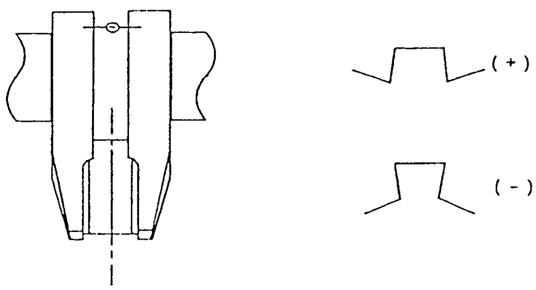


Fig. 1

For deflection readings, a dial micrometer is to be placed in the punch marks.
Closing of the crankthrow is regarded as negative deflection

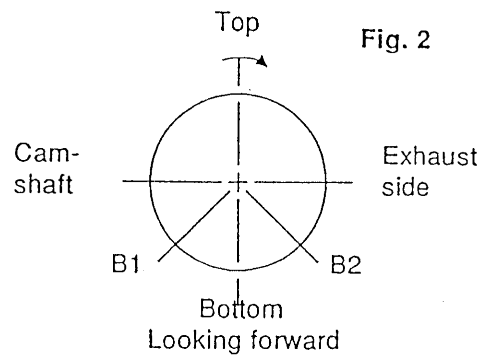


Fig. 2

(Unit for measuring and calculating: 1/100 mm)

Fig. 3

Crankpin position		Cyl. No. & 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.

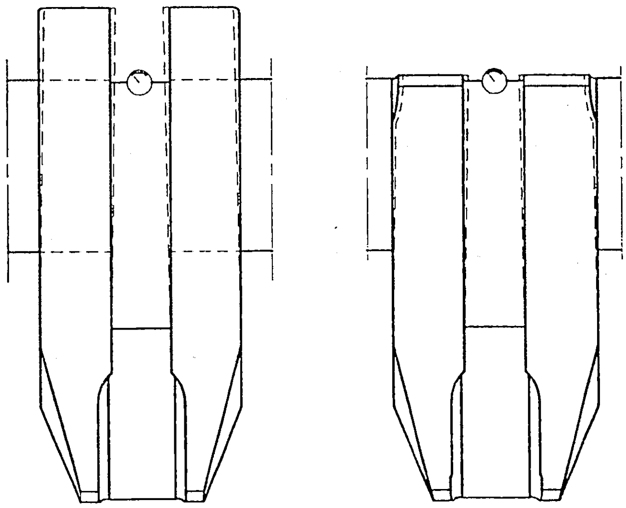
Fig. 4

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.							

Crankshaft Deflection, Limits

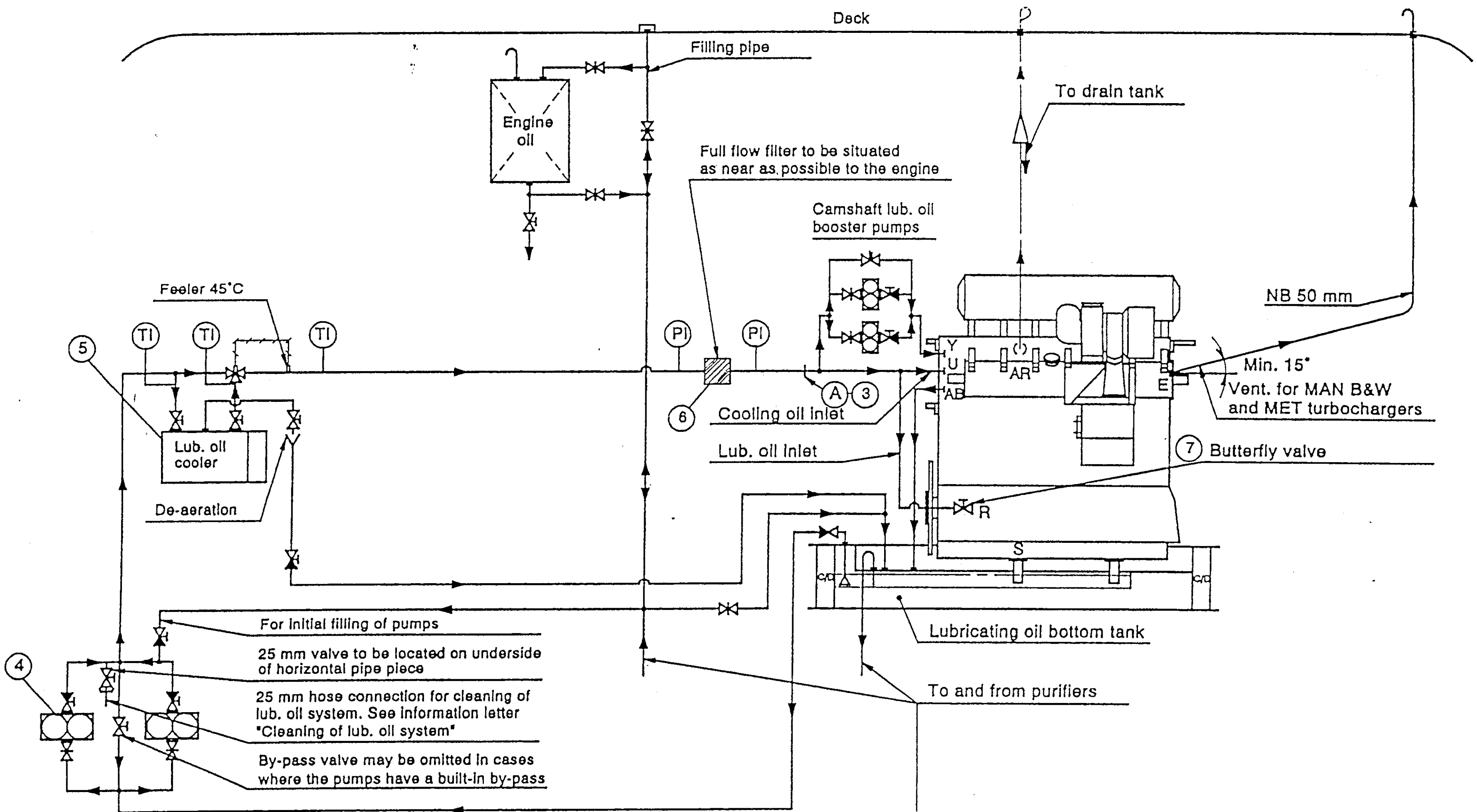


Type	Normally obtainable for a new or recently overhauled engine mm		Realignment recommended mm		Absolute maximum permissible mm	
	1	2	1	2	1	2
S46MC-C	0.23	0.46	0.62	0.69	0.93	0.93
K50MC	0.12	0.25	0.34	0.38	0.51	0.51
L50MC	0.17	0.34	0.45	0.51	0.68	0.68
S50MC	0.23	0.46	0.61	0.69	0.92	0.92
S50MC-C	0.23	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
L60MC-C	0.22	0.45	0.59	0.67	0.89	0.89
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
L70MC-C	0.25	0.49	0.65	0.74	0.98	0.98
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
S80MC-C	0.38	0.75	1.00	1.13	1.50	1.50
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
L90MC-C	0.27	0.54	0.72	0.81	1.08	1.08
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-C	0.36	0.72	0.96	1.08	1.45	1.45
K98MC	0.25	0.49	0.65	0.74	0.98	0.98
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').*

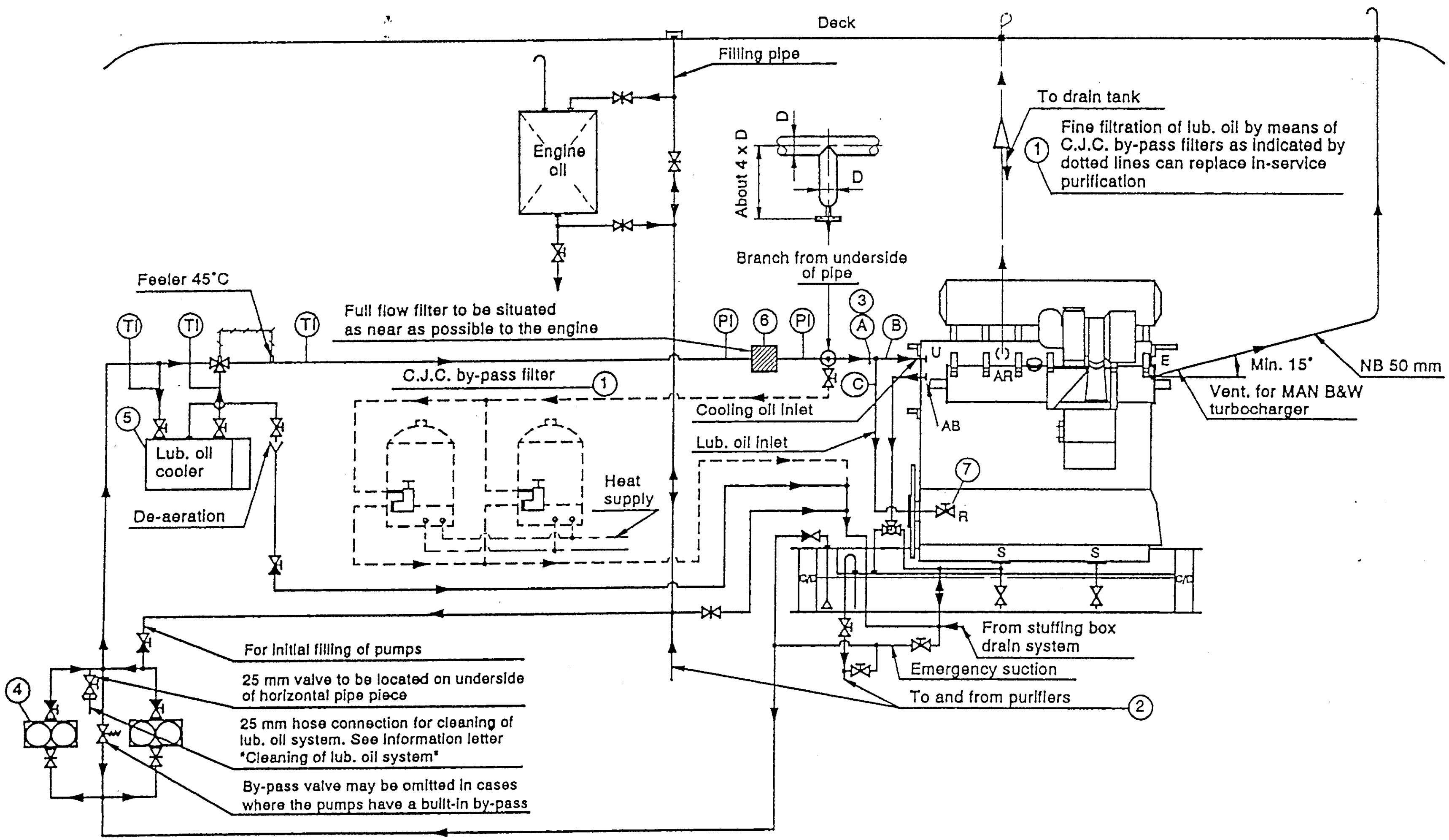
Plate 70818A-40D Circulating Oil System (Outside Engine)
(Engines with Uni-Lube System)



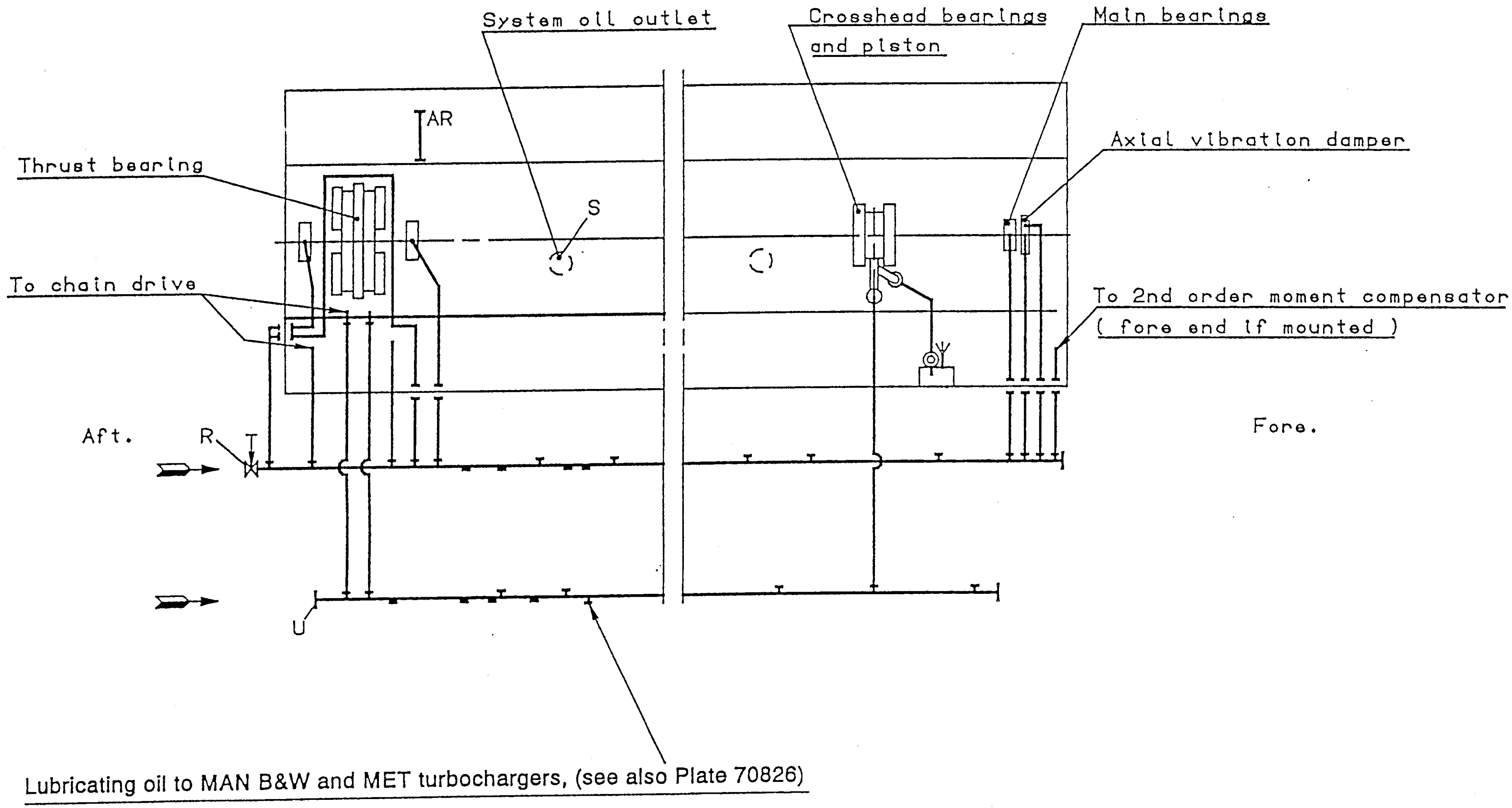
(3) If using centrifugal pumps it is recommended to install a throttle valve at pos. A to prevent a too high oil level in the oil pan. A device preventing the valve from being closed has to be introduced so that the min. flow area gives the specified pressure at inlet to engine under normal service conditions. It ought to be possible to fully open the valve e.g. when starting the engine with cold oil.

(2) 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.

Plate 70818B-40D Circulating Oil System (Outside Engine)
(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.

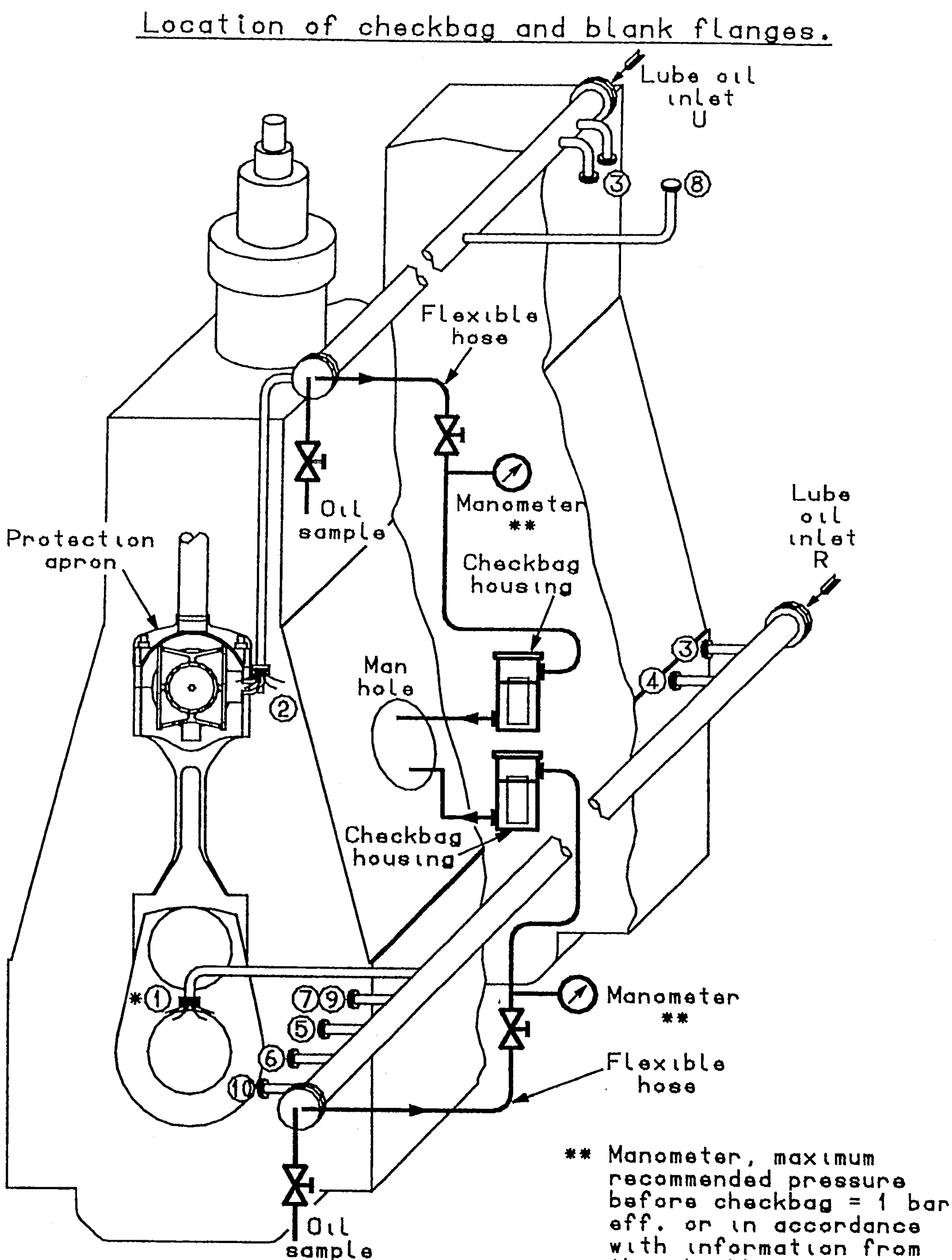


Circulating Oil System (Inside Engine)

Plate 70819-40D

Flushing of Main Lub. Oil System

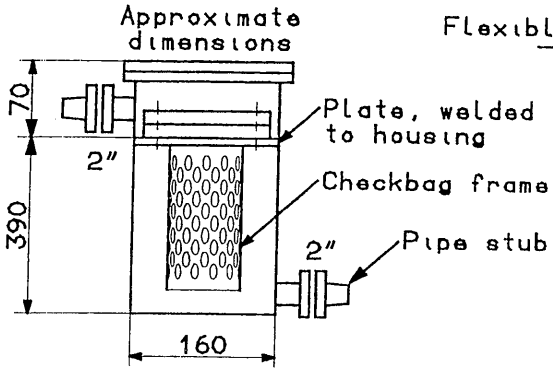
Location of Checkbag and Blank Flanges



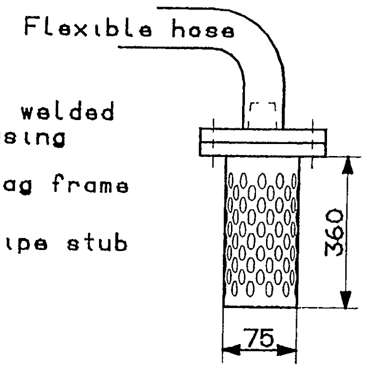
Blanking off pipes

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

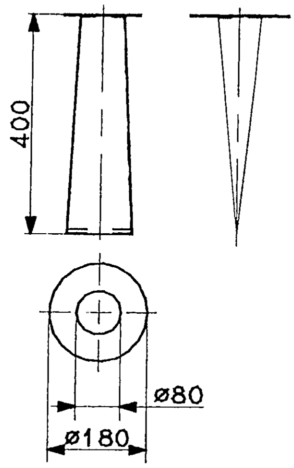
Sketch of checkbag housing:



Alternative checkbag (inside engine):



Checkbag monofil filter cloth 50 μm

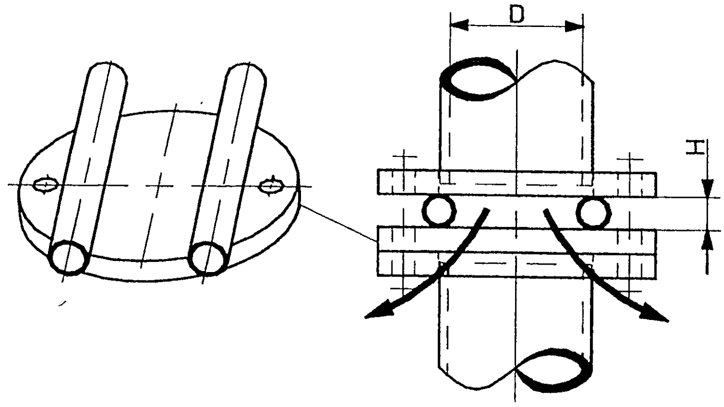


The holes in the checkbag frame are, in our experience, to be approx. 5mm in diameter, to avoid damage to the checkbag and a too high pressure drop.

The above filter components can be delivered from MAN B&W Diesel

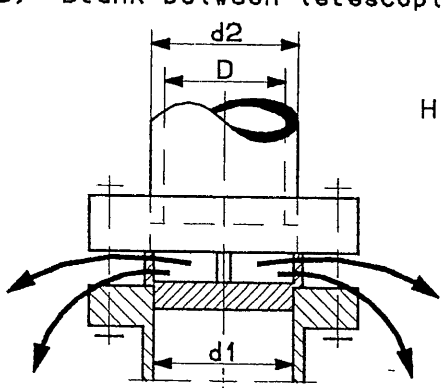
* Blank flanges for flushing:

A) Blank at main bearings.



$H = \frac{D}{4}$

B) Blank between telescopic pipes and crossheads.



$H = \frac{D}{9}$

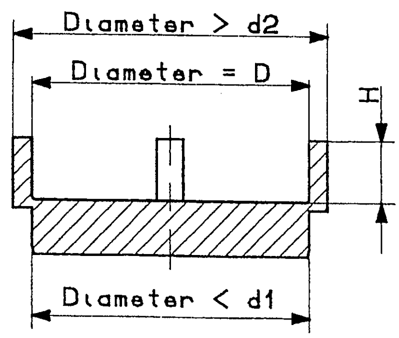


Plate 70822-40 **Flushing of Main Lubricating Oil System**

Flushing Log

MAN B&W

M/V	Engine Type:		System		Checked by:
	Builder:	Engine No.:	M.E. Lub. Oil		
Yard No.:	Built year:		Camshaft		Date:

Info	**Pumps**	**Filters** Absolute/fineness	**Centrifuge**	**Magnet Filter**
	Centrifugal ☐ Screw ☐ Maker : Type : Capacity :	Maker : Main : µm Type : By-pass : µm Type :	Maker: Type: Capacity:	Maker: Type: **Other Filters** Maker: Type:

Filter Unit (if used) µm
Type :
Maker :

Inspection of | Checked by | Date
Pipes :
Tanks :

Date:	Remarks	L.O. System: Temp. [C]	Press. [bar] at pump & M.E.	Pump 1-2: Time start & stop	Pump 1-2: Running hours per day	Pump 1-2: Running hours total	Purifier: Start/stop running hours	Filter Unit: Start/stop running hours	Check No. & ISO Code

Sign.	Inspector:	Yard/Engine builder	Total flushing hrs.:	Final cleanliness: Check bags ______ ISO 4406 Code ______

Recording of pump running hrs. within ½ hr.
Cleaning and replacement of filters to be recorded under remarks.
Accepted flushing cleanliness level: Clean check bags after 2 hrs. (ISO 4406 Code ≤ 19/15)

Cleaning System, Stuffing Box Drain Oil
(Only engines without Uni-Lube System)

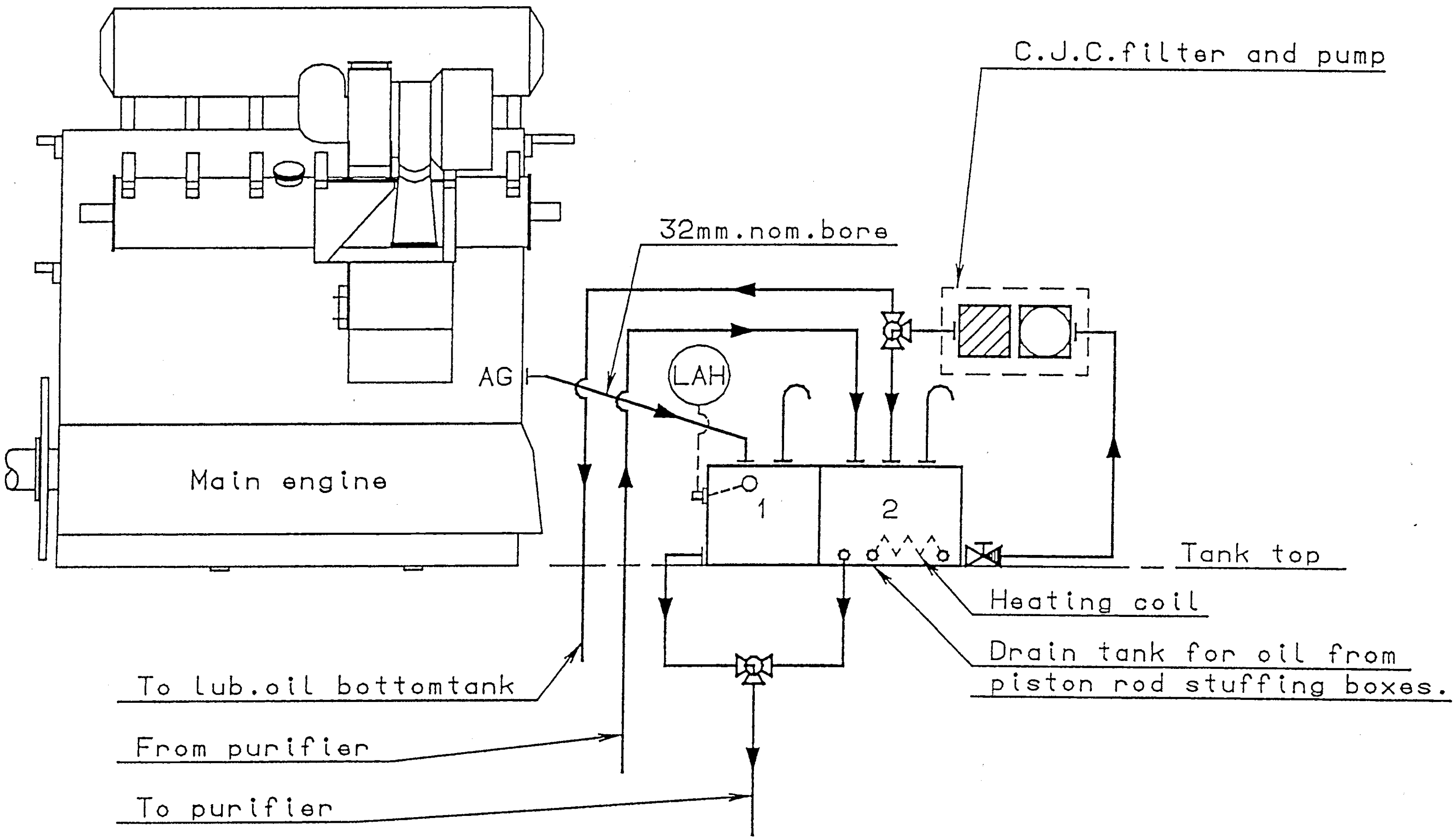


Plate 70823-40D

Plate 70824B-40D Camshaft Lubricating Oil Pipes
(Engines without Uni Lube System)

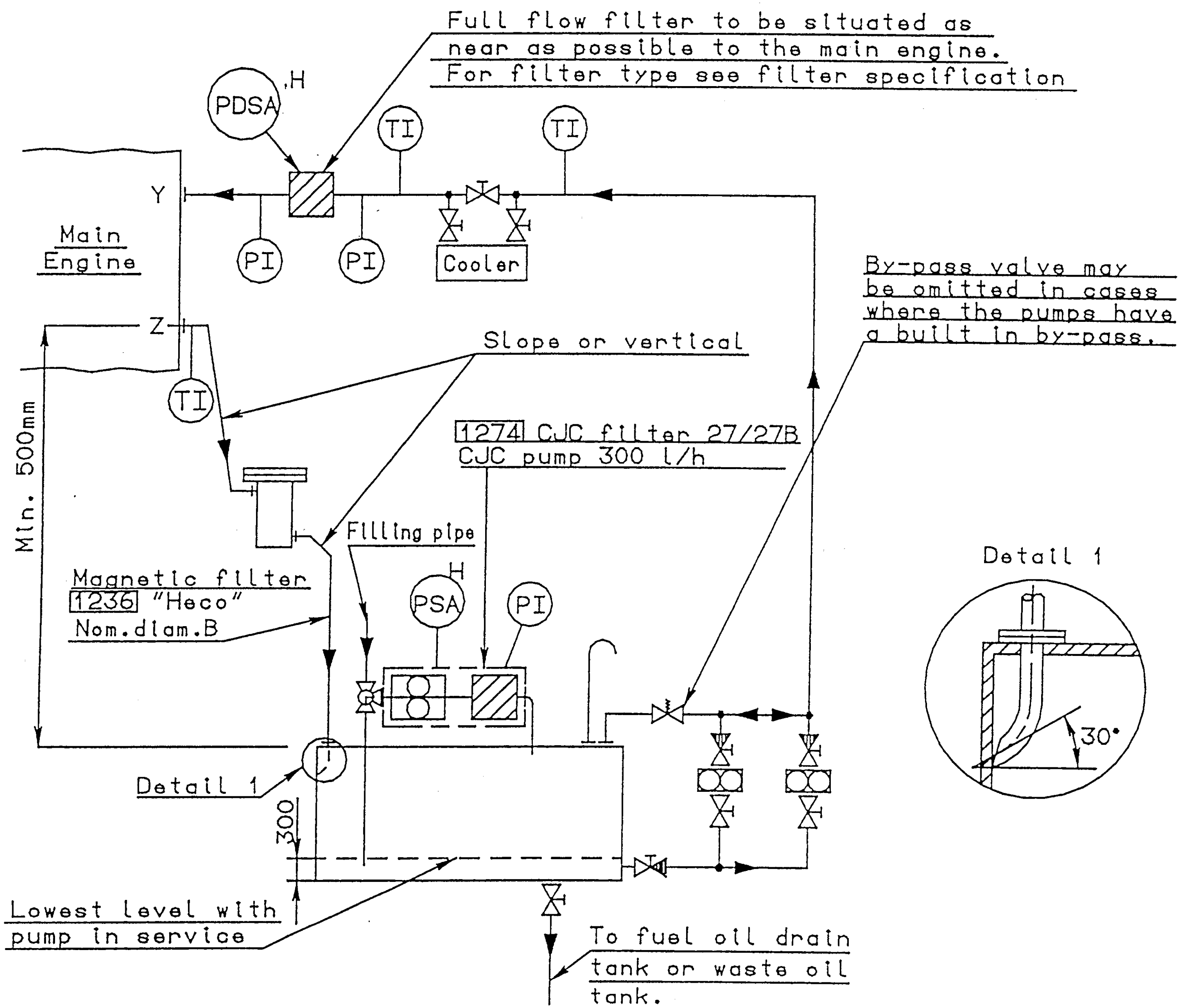


Plate 70824A-40D Camshaft Lubricating Oil Pipes

(Engines with Uni Lube System)

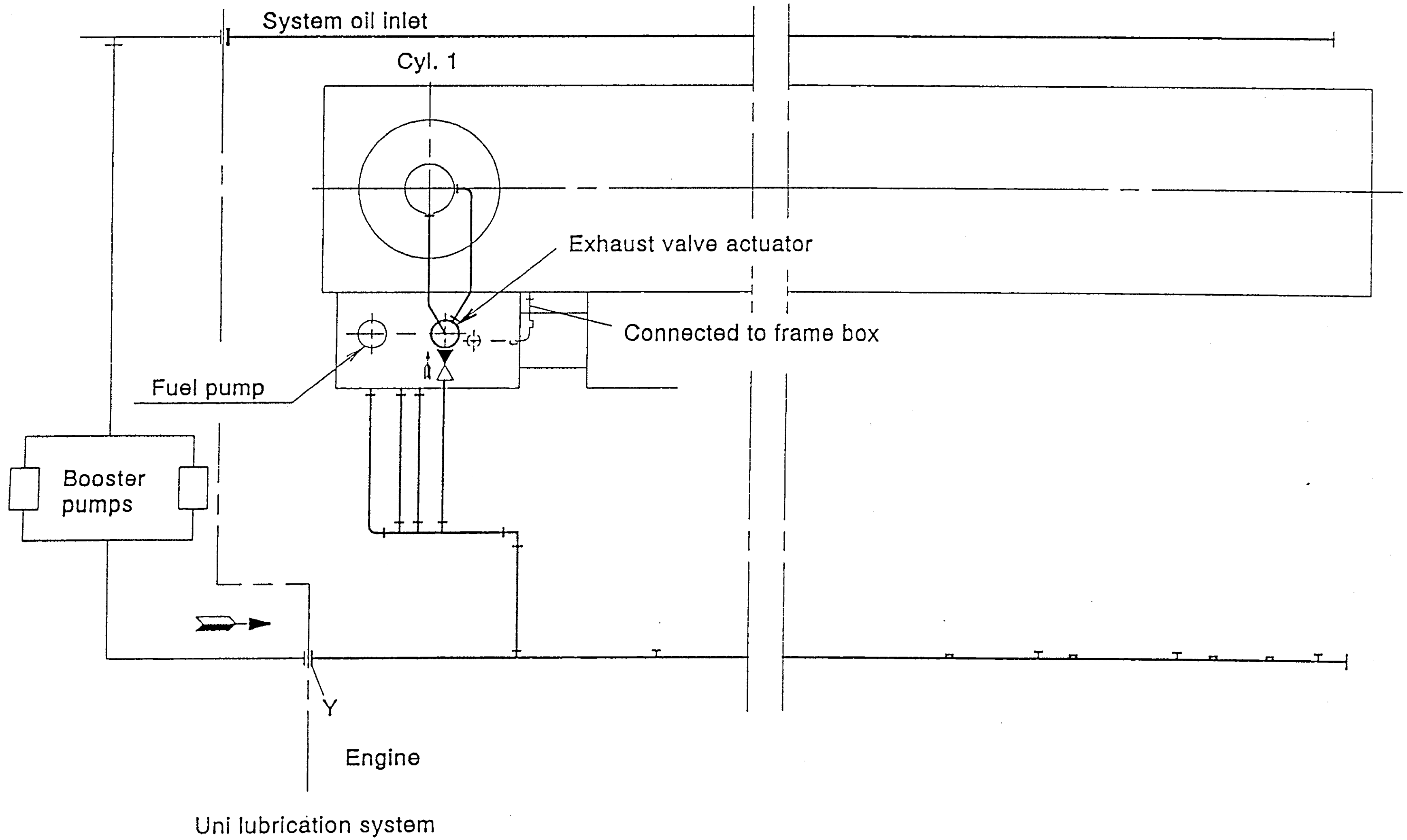
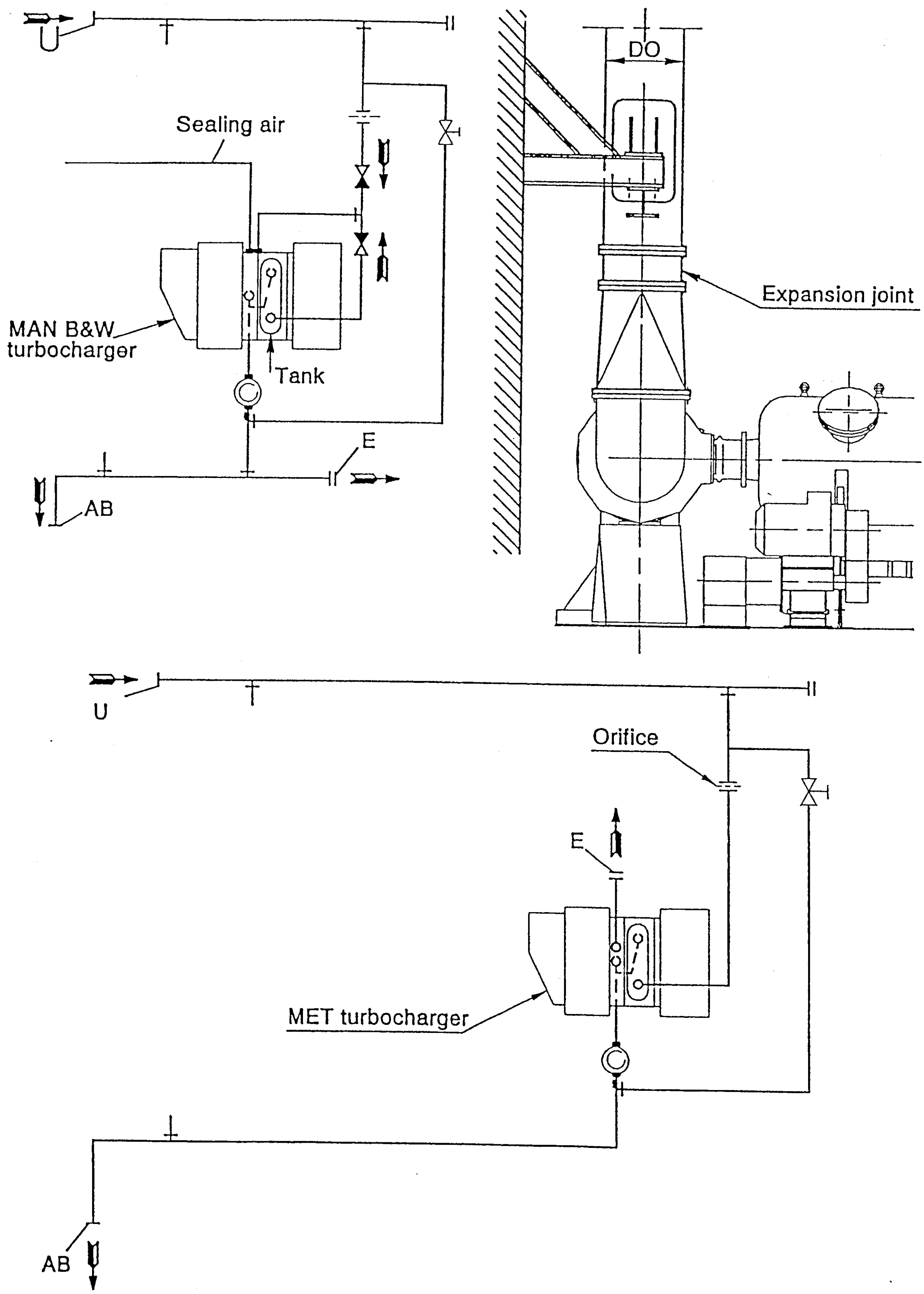


Plate 70826-40D Turbocharger Lubricating Oil Pipes



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See also page 708.12, Item 14, 'Check of Bearings Before Installation'.

Fig. 1 – Measuring of crown thickness.