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TRANSACTIONS (TM)

SOME MARINE MACHINERY FAILURES AND THEIR CAUSES

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Some Marine Machinery Failures and Their Causes

R. F. Munro and P. E. Haynes
Lloyd's Register of Shipping

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After a marine engineering apprenticeship, Ron Munro CEng, FIMarE served at sea from 1942 until 1952 and came ashore with the rank of Chief Engineer. As a Surveyor to Lloyd's Register of Shipping he has served in UK outports and at Bremen, Winterthur and Copenhagen where he was appointed Principal Engineer Surveyor for Denmark in 1969. From 1973 to 1981 he was Principal Surveyor in the Classification Machinery Reports Department in Headquarters and since 1981 has been Senior Principal Surveyor in charge of that department.

In 1967 Peter Haynes gained an honours degree in metallurgy from Nottingham University. He then joined Round Oak Steelworks, progressing to rolling mill management, and in 1970 joined the APV Co., Crawley, working in the technical department of the foundry division, specializing in high alloy cast steels. In 1981 he joined Lloyd's Register of Shipping as a metallurgist undertaking both marine and non-marine damage investigation studies.

1. INTRODUCTION

Many of the cases which have been used to illustrate this paper were investigated by specialist surveyors to Lloyd's Register of Shipping in order to establish beyond reasonable doubt the cause of failure. Recourse is frequently made to the Society's laboratory at Crawley, Sussex, where a full range of laboratory equipment is available to verify or establish the material properties, and in the case of metals the metallurgical structure, with reference to the original design requirements.

It is perhaps important to record that it is rare to find that material has been used that does not conform to the original design specification and that very few cases of metallurgical faults have been found responsible for failures investigated in the laboratory during the last 30 years.

For a variety of reasons it was not always possible for clinical analysis to be made of reported failures but where sufficient could be pieced together for useful lessons to be learned these cases have also been presented.

Since it has been shown that machinery failures are not generally due to metallurgical matters, the causes must lie mainly in one or other of the following categories:

1.1 Operational
1.2 Design

1.1 Operational failure

This can be subdivided into:

1. Crew negligence (carelessness);
2. Crew ignorance (insufficient training).

The quality, capability and training of the man are of the utmost importance and, provided they become consistently of a sufficiently high level, failures due to operational irregularities can be expected to reduce dramatically.

1.2. Design fault

The paper quotes cases of stress concentrations which were built into the design and, in the presence of fluctuating stresses, resulted in serious and costly failures. All engineers must be aware, or made aware, of this danger and understand that—in simplest terms—sharp corners are to be avoided.

Figure 1 shows a medieval chapel in the Val d'Anniviers high in the Swiss Alps south of the Rhône Valley. It is hoped that this picture will serve to remind us that the old priest of the chapel found so much damage arising on the sharp corner of his building due to the passage of bullock carts that he washed the corner smoothly away! By appreciating a fundamental principle and taking the appropriate action, this unknown man qualified, in the Middle Ages, for recognition among the engineers of our day.

We are often asked about the effect of the introduction of unmanned machinery operation. Marine engineers of the middle of this century employed all their senses while on watch in their engine rooms. It may be worth listing these faculties as follows.

Sight
Hearing
Smell
Touch
Taste

This list has been arranged, not as set out in a popular and widely used dictionary, but in accordance with personal recollections and so it will be understood why 'Taste' comes last!

There is no doubt that a major step was taken when machinery at sea was placed under the control and surveillance of instruments. An entirely new philosophy was introduced, based upon confidence in the reliability of the machines and in the instruments watching over them. The change was gradual and was accompanied by, and largely stimulated by, pressure to reduce manning scales.

FIG. 1

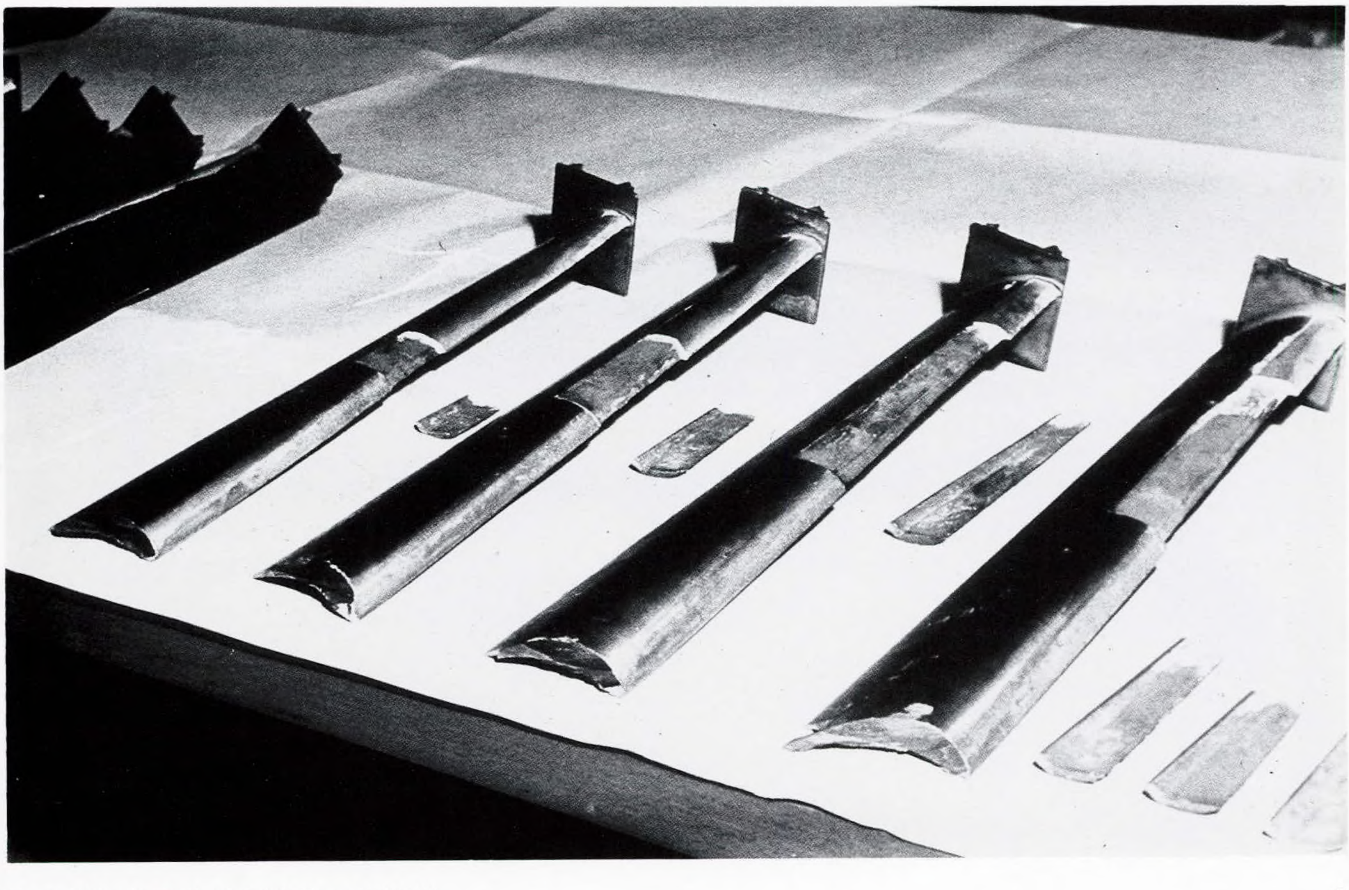
Experience has shown that marine machinery installations can and indeed are being operated efficiently in the unmanned mode and no human being sees, hears, smells, touches or tastes anything! There remains the feeling that we must not become complacent; and remember that there must be a time lag between the sounding of a fire alarm and the appearance of engineers in the engine room to take the effective action for which they have been adequately trained.

2. STEAM TURBINES

2.1. Blading—stellite detached

Figure 2 shows low pressure turbine blades from which the stellite protection has become detached. One case was a consequence of severe overspeeding. In the further three cases which are known to the designers, the cause was considered to

FIG. 2



be overheating during prolonged running astern. This resulted in the inner (radially) ends of the stellite pieces becoming loose, and separation taking place in the interface between the brazing filler metal and the blades, due to thermal expansion differences between the two materials.

In normal manoeuvring the temperature at the exit end of the LP turbine does not reach a level at which this damage can be suffered, but cases can arise where a shipmaster may require the highest possible astern power over a long period and high temperatures can be reached.

Cyclic stresses which are relatively harmless at design temperatures may be significantly above the endurance limit for the material at the elevated temperature pertaining during abnormal changes in duty.

In another case, significant transverse cracks were found in the mid-length of a number of turbine blades from the LP turbine (seventh row, inner section). The blades were made from a 13% chromium steel with a stellite shield on the leading edge. The cracks had formed at the transition between the inner (radially) edge of the stellite shield and the blade. The crack surfaces contained conchoidal (beach) markings and stepped ridges normally associated with fatigue failure.

The origin of the cracks was the braze metal–stellite shield junction near to the leading edges. The ground edge of the shield was clearly visible on the braze metal junction (see Fig. 3) and liquid penetrant and microscopic examination of an unaffected blade from the same stage showed lack of wetting by the braze metal between both the shield edges and blade faces (see Fig. 4).

The microstructure of the braze metal, blade and shield were normal. Vibration measurements on a similar engine under static excitation showed that the main cantilever mode of

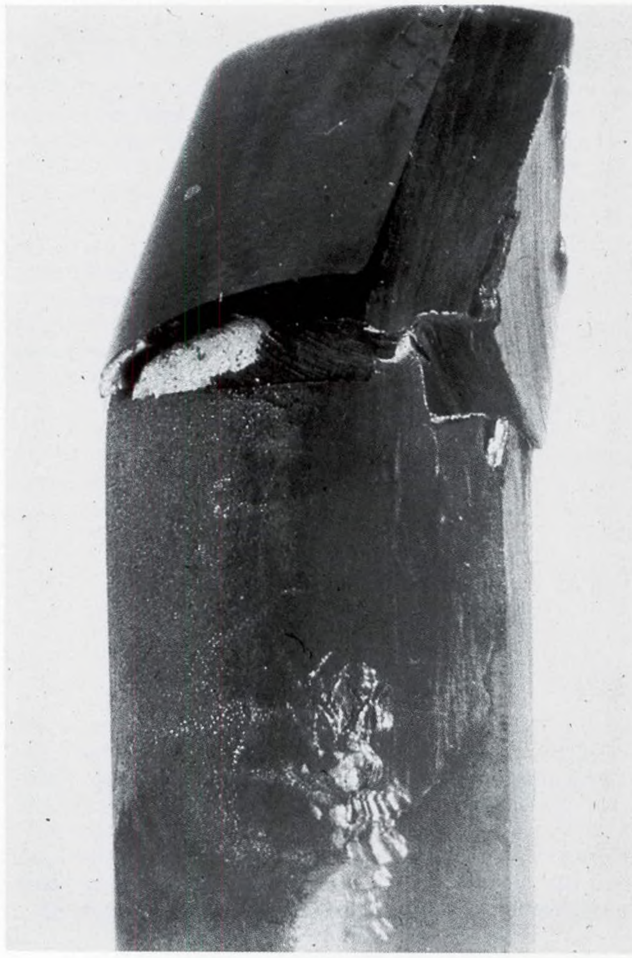


FIG. 4

FIG. 3

vibration was close to the builders' value. It is likely that induced vibratory stresses, probably increased by stress concentration effects of the lack of bonding between the stellite shield and the blade, produced stresses in excess of the fatigue limit of the blade material.

2.2. Blading—missing shrouding

On two occasions within 3 months, the Chief Engineer opened up and examined the LP rotor of this turbine because of vibration and found shrouding missing from the last stage blading (see Fig. 5).

After the first incident, the affected blade segments were replaced from stock. In the course of a thorough investigation following the second failure it was discovered that, during manufacture of the shrouding, the holes to accommodate the blade tenons had been left with sharp edges on the underside, thus introducing stress concentrating notches in the tenon roots during the peening process (see Fig. 6).

FIG. 5

FIG. 6

3. CONDENSERS

3.1 Water box damage

On investigating the source of unusually high bilge water it was found that the main condenser water box was perforated (see Fig. 7).

The damage to the water box was due to repeated impact of the steel carrier for the sacrificial anode, which had become detached from the inspection door and carried round violently in the great turbulence in the cast iron water box (see Fig. 8). The anode support bracket failure was due to corrosion fatigue. Where possible, anodes and indeed all fittings should be located away from the main water flow and also in a position offering the least resistance to water circulation.

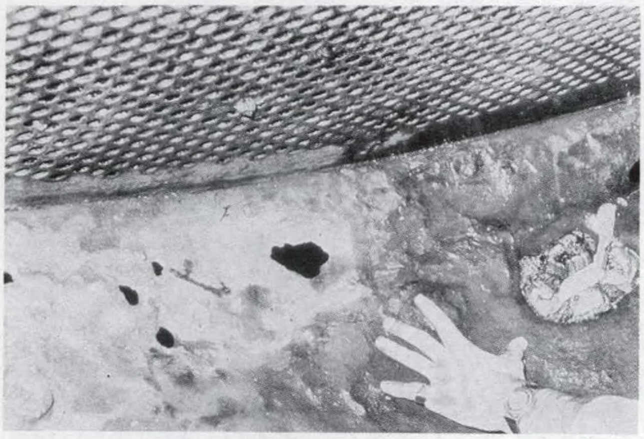


FIG. 7

4. DIESEL ENGINES

4.1. Crankcase explosion

This ship suffered two crankcase explosions. The first happened at 0300 hours and caused minor damage. After waiting for the engine to cool down, a crankcase inspection of the running gear was carried out and, because nothing unusual was found, the engine was restarted and the passage resumed. Shortly afterwards there was a violent explosion which resulted in serious fire and the death of four crew members.

Figure 9 shows the condition of the integral thrust collar, which had been overlooked by the engineers, and Fig. 10 the state of the ahead thrust pads from which the white metal had been completely melted out.

Many integral thrust collars have a separate supply of lubricating oil through a strainer and are fitted with a low pressure alarm. It is essential for safe operation of machinery that strainers and alarms are properly maintained.

4.2. Crankshaft, cracked repair weld

The engine was made in 1959. On a routine inspection after 2 years in service, a severe crack was found in the undercut fillet between crankpin and web (see Fig. 11).

FIG. 8

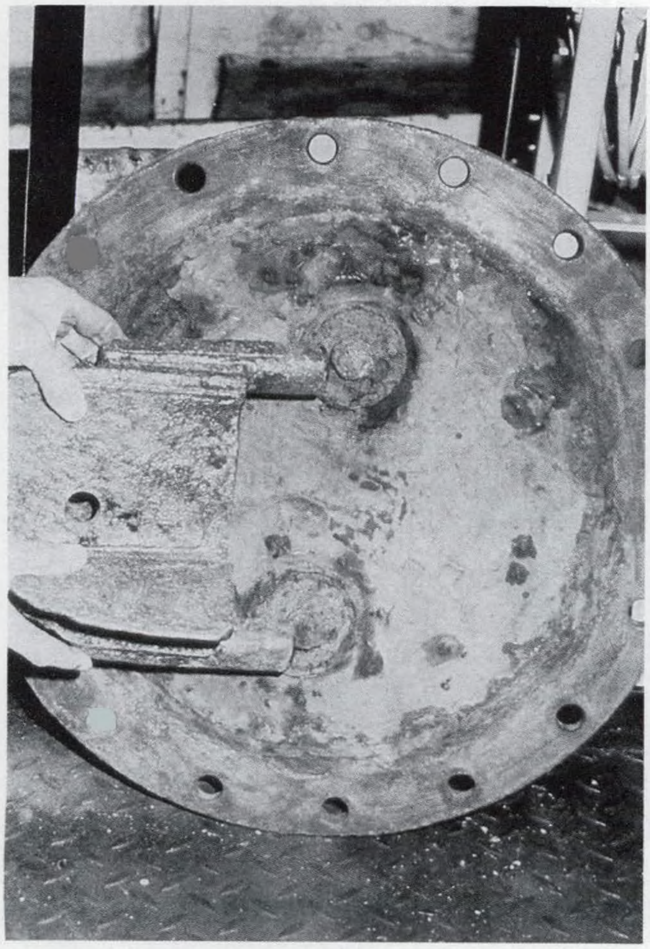
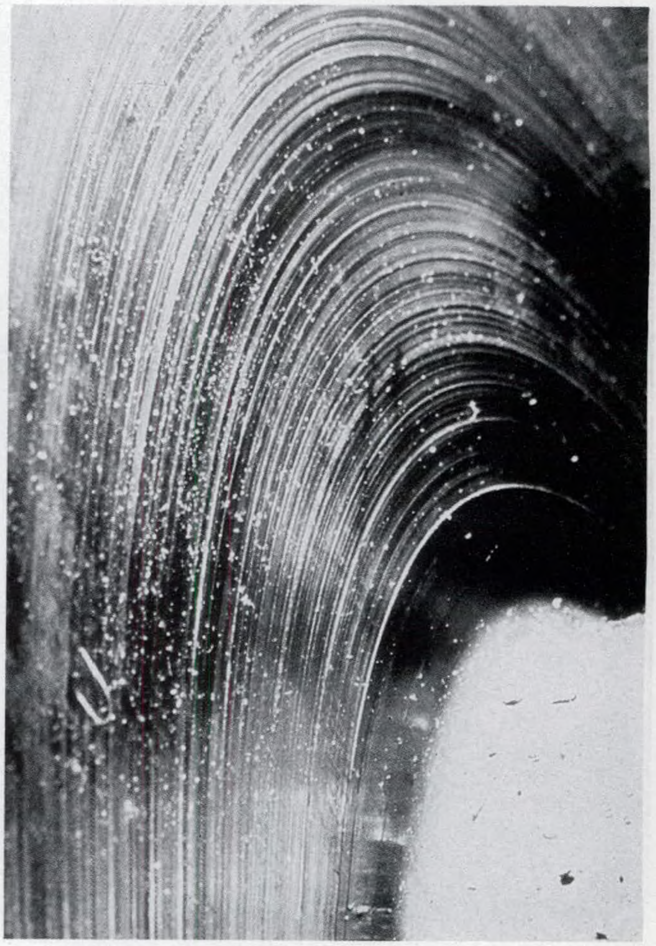


FIG. 9



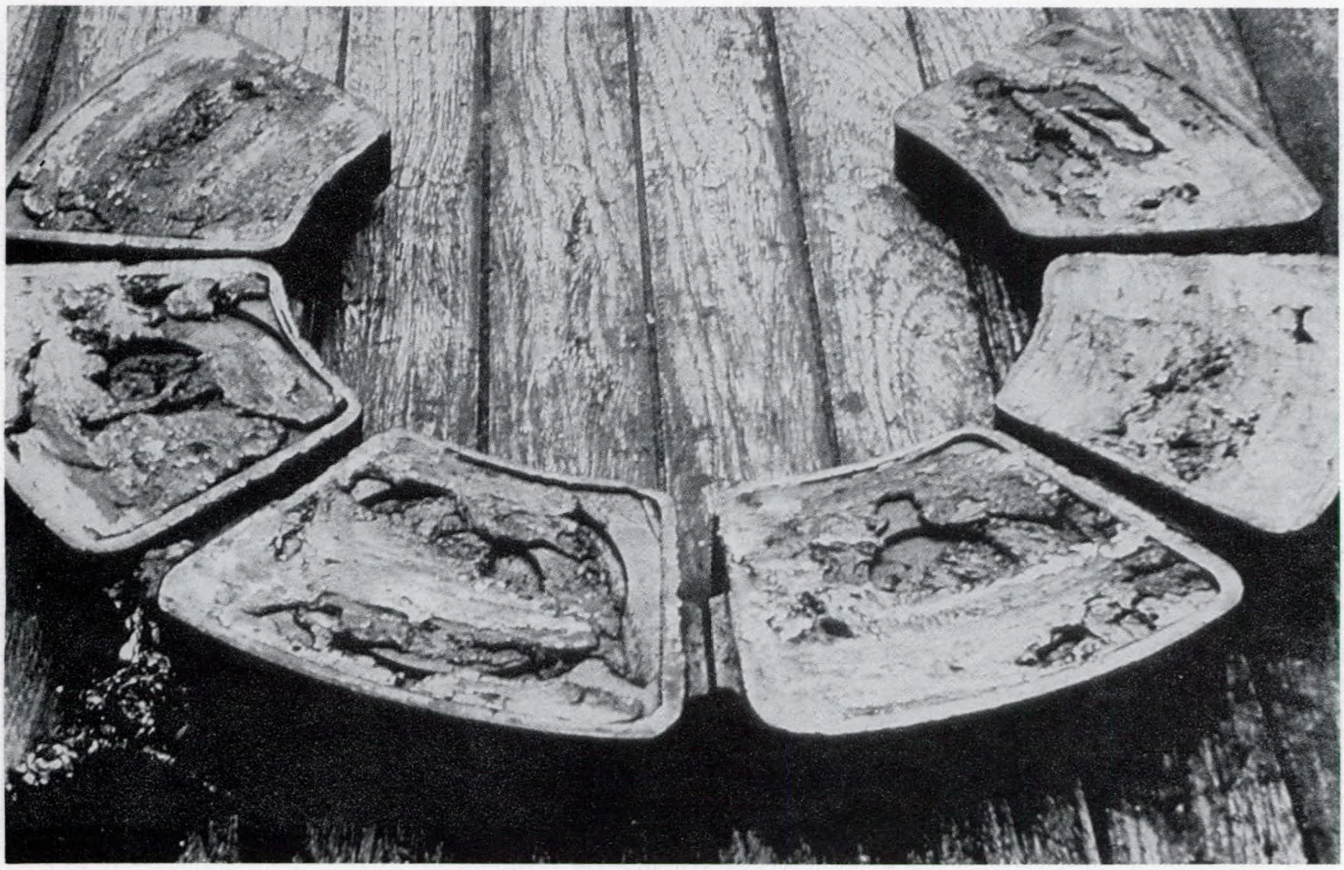
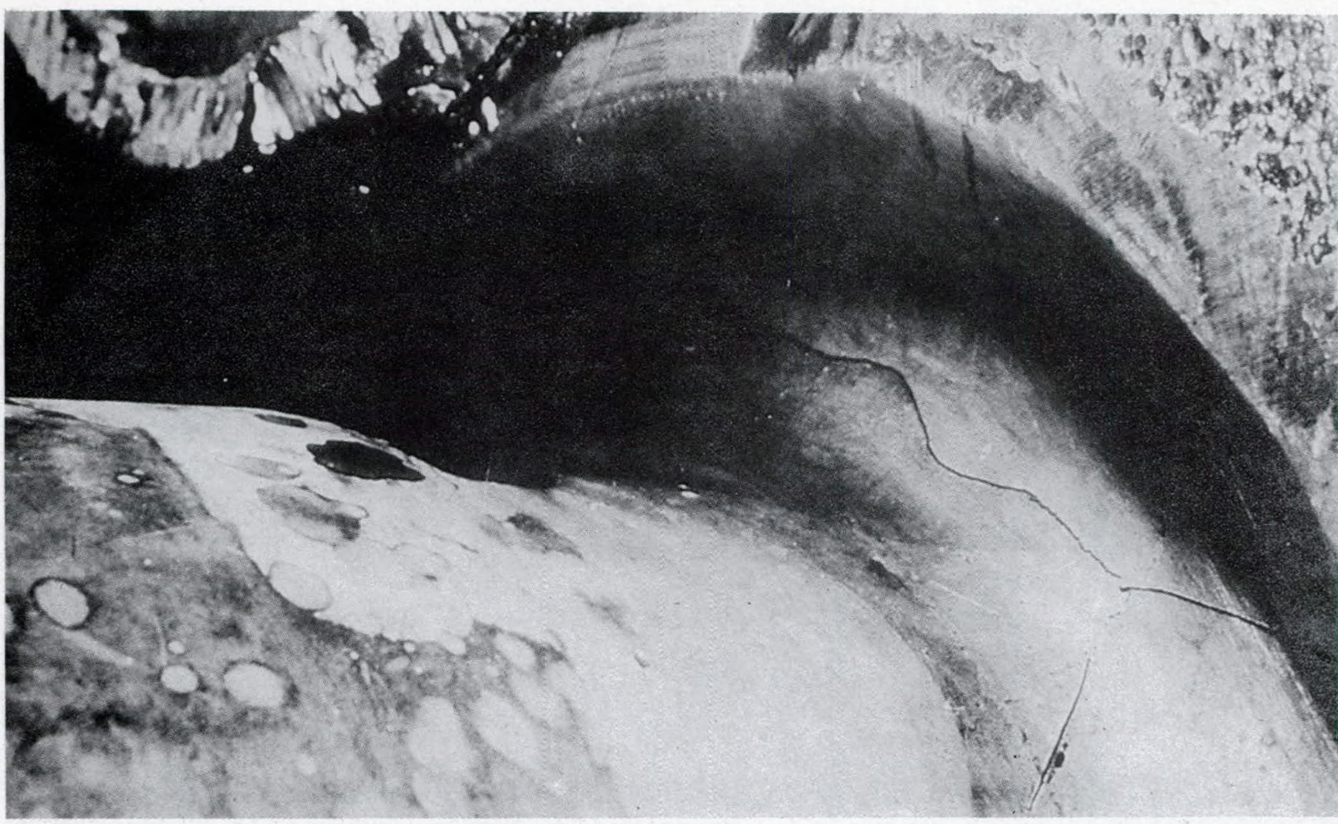


FIG. 10

FIG. 11



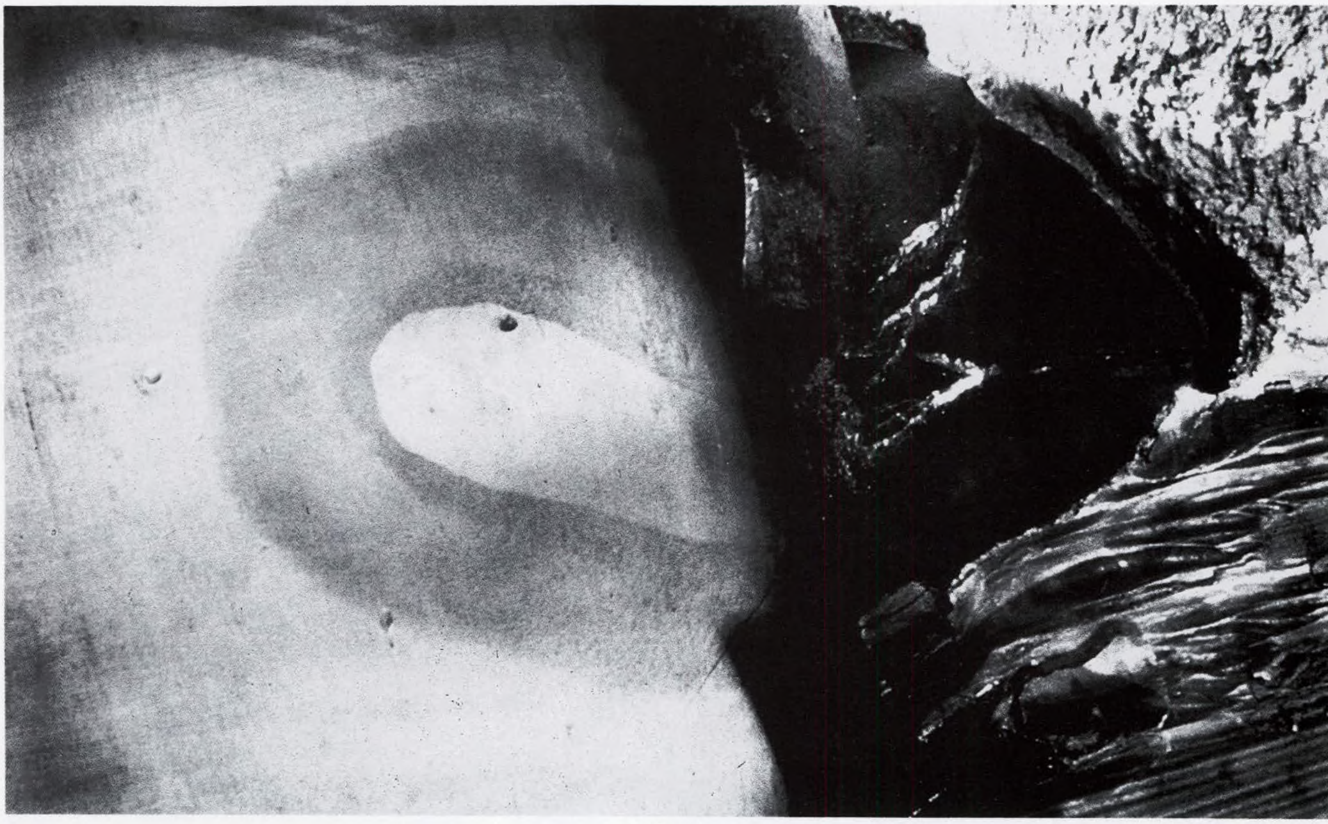


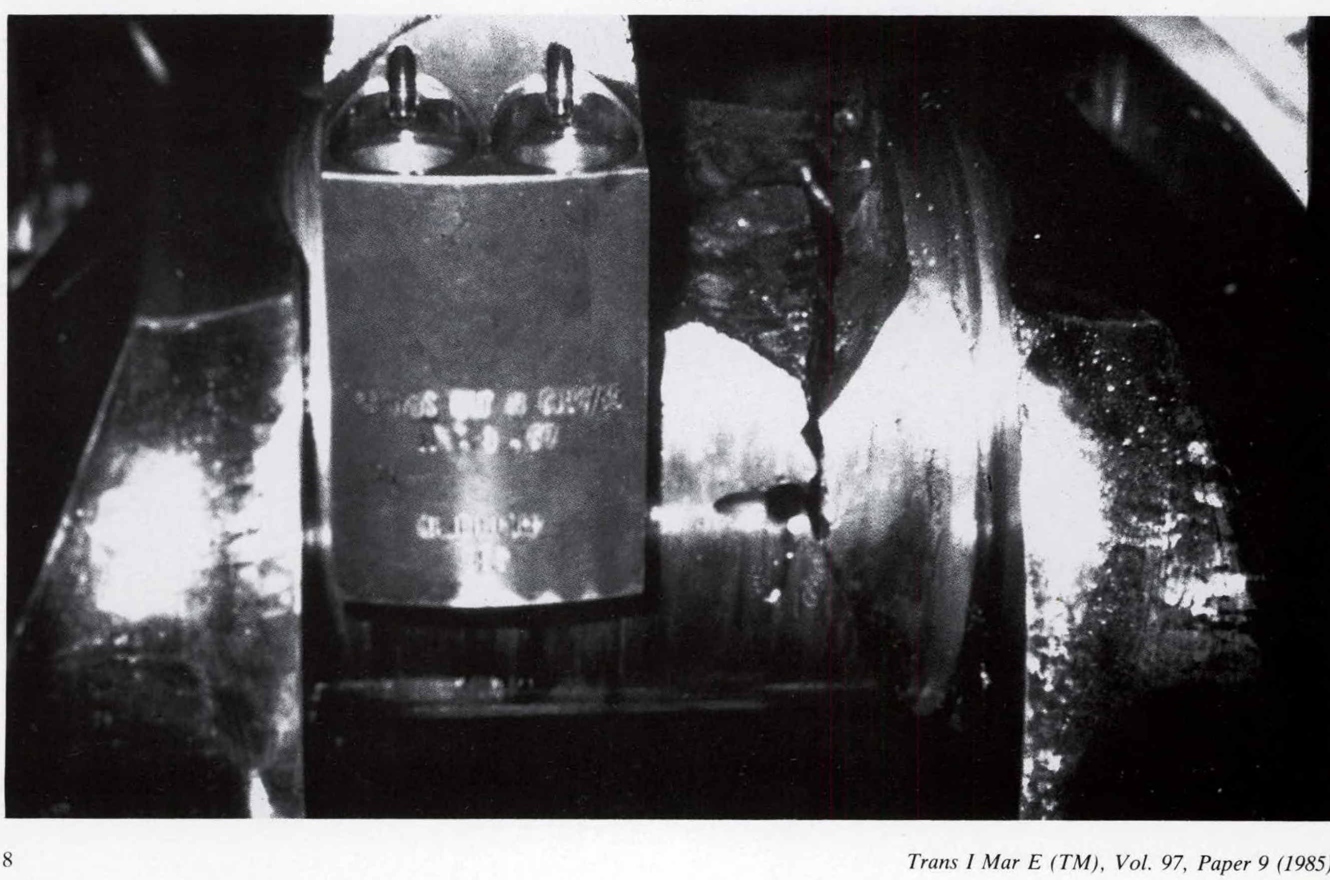
FIG. 12

Investigation revealed that a local repair by welding had been carried out during manufacture in the steel foundry. Figure 12 clearly shows the heat-affected zone after etching.

An engineering investigation may have shown increasing cyclic stresses over a period of time due to, for example, uneven firing of the engine, poor maintenance, changes in duty, misalignment etc. The crankpin could therefore have been subjected to a sufficient number of stress cycles to cause failure in any case, if the fatigue limit of the shaft material had been exceeded.

Even when weld repairs were carried out on steel castings under strict control and with adequate heat treatments, variations in grain morphology and composition, together with probable hardness variation, are likely to give unreliable and

FIG. 13



unpredictable service performance.

For many years the Rules have been explicit on the subject of permitted and prohibited zones for repair welding on castings for crankshafts, because of the cyclic stresses involved.

4.3. Fatigue failure

This medium speed engine has thin wall bearing shells on the crankshaft. There have been many cases of damage of this type following bearing failure (see Fig. 13).

With these bearings it is essential that they have a good fit in their housings, with the locking horns in their correct positions. The clamping of the upper housing should be effective and the bolts tightened to the designers' recommended torque.

Scrupulous cleanliness should be maintained at all times and strict attention paid to lubricating oil hygiene.

Apart from damage to the crankpin as shown in the photograph, dirt trapped between the steel backing in thin wall bearings and the bottom end keep could lead to fretting and the production of fretting fatigue of the surface, which in time may propagate through the keep with disastrous consequences.

4.4. Various cracks

Figure 14 shows the crankpin of a medium speed engine in which the Chief Engineer had ground a crack he had found near the oil hole.

Figure 15 shows the results of magnetic crack detection on the crankpin which, as in common practice, had previously been covered with white dye-penetrant developer to increase contrast. It will be seen that the 9 mm deep and 40 mm long ground zone has not removed the crack which, as indicated at '1' and '2', extends beyond the gouge.

Figure 16 shows the result of a careful test of the crankpin by one of the Society's specialist non-destructive examining surveyors, using an electromagnet which induces magnetic field in the part being tested.

At '1' can be seen a serious branching crack having torsional connotations and large areas of crazed and longitudinal cracking which are the result of excessive heat. Figure 16 also shows a useful technique whereby a permanent record of a magnetic powder 'picture' can be made by the careful laying on of transparent adhesive tape and then transferring it to a sheet of white paper. The process can, of course, be repeated as often as required.

Craze cracking is usually shallow and may frequently be ground out. However, thermal shock cracking, often longitudinal, and fatigue cracks are relatively deep and may extend throughout the hardened layer if present. In the latter case, renewal of the crankshaft is the only reliable course of action. Even when cracking is completely removed by grinding, the affected parts should be checked minutely for significant variations in hardness.

FIG. 14

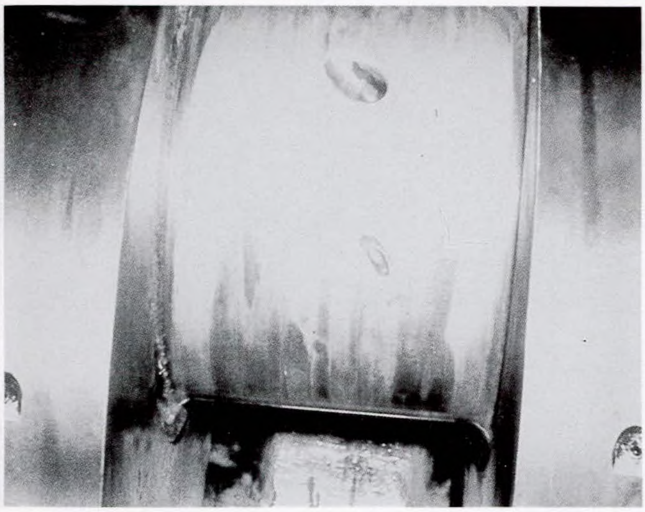


FIG. 15

FIG. 16

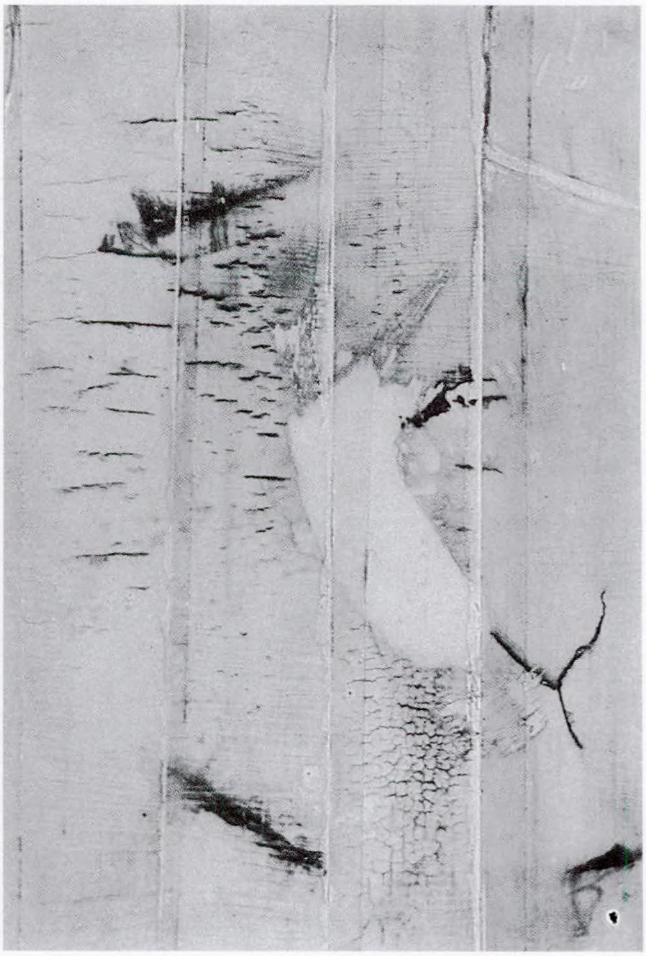


FIG. 17

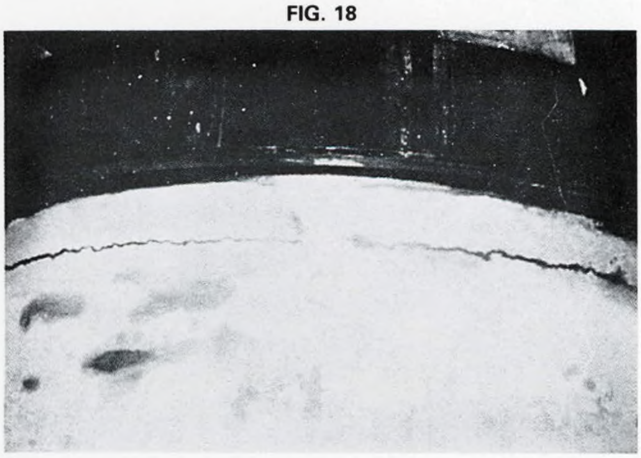
4.5. Corrosion

Some years ago, when there were many engines at sea which did not have the benefit of a diaphragm dividing the scavenge space from the crankcase, the type of damage shown in Fig. 17 was common; and because these engines had water-cooled pistons it was accepted that the corrosion was due to sulphurous contamination of the lubricating oil in the presence of water leaking from the cooling system into the crankcase to form sulphuric acid.

Today, very similar severe damage is being seen but it is known that it is due to microbial infection of the lubricant. Similar damage can result if hydraulic systems and piston coolants become infected.

A number of shipowners have placed 'dip slides' on board their ships for regular use by the Chief Engineers in order to detect the presence of infection before serious damage can occur. When the dip slides prove positive, it is essential to consult a specialist microbiologist to identify the precise nature of the problem and recommend the appropriate biocide.[1,2]

FIG. 18



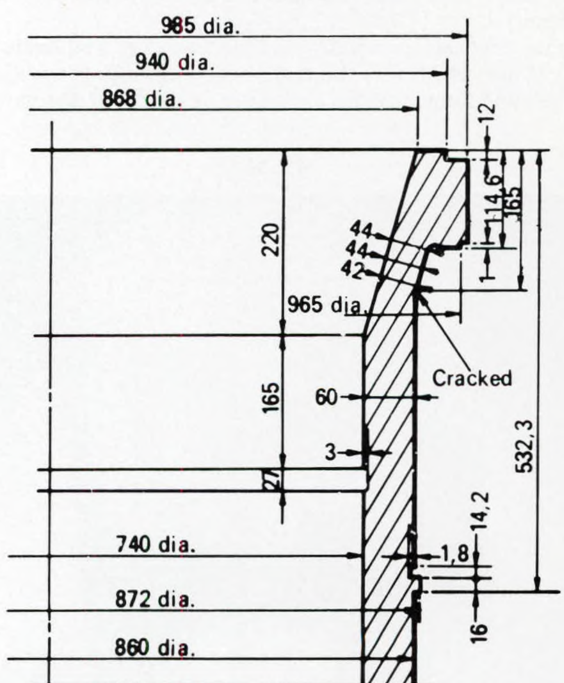
4.6. Cylinder liners

When, at a periodical survey, the liner shown in Fig. 18 was found to be cracked in the bore, it was extracted from the block and renewed. The illustration shows the result of a dye penetrant test on the outer surface of the liner.

It was considered prudent to examine all the other liners in the engine. They were all found to be in the same condition and scrapped.

Figure 19 is a section through the cracked liners and the

FIG. 19 Existing cylinder liner for main engine



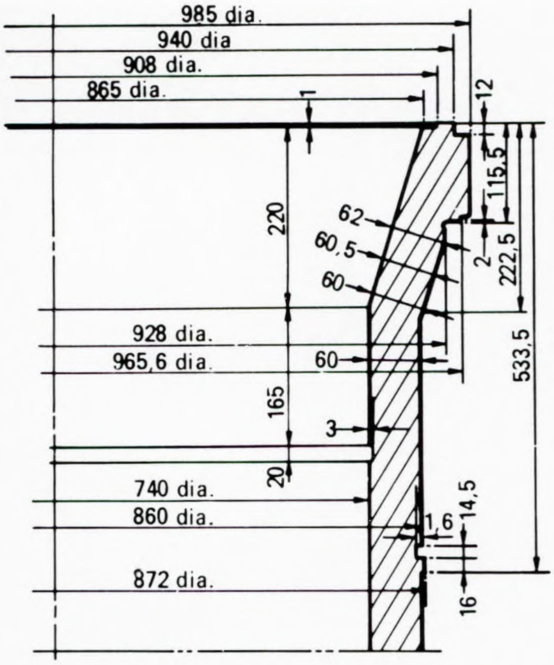


Fig. 20 Ship's spare cylinder liner for main engine

dimensions should be compared with those in Fig. 20, which were measured in the original spare liner secured to the engine room casing side.

Cylinder liners are usually manufactured from grey cast iron, a material which, apart from very isolated occasions, has the same fracture surface appearance whether broken under impact, tensile or fatigue loading conditions. Further, this material exhibits relatively low ductility and the danger of failure by reducing section thickness in order to save weight is obvious.

For a number of years, the principal engine builders have complained in public about the activities of 'pirate' suppliers; the dangers of buying components which do not have the benefits of the designers' research, development and experience are clear. Spare parts may not always be what they appear.

4.7. Piston securing arrangements

During a normal sea passage, a tapping sound was heard in phase with the engine revolutions but the engine was not stopped for investigation. The sound gradually became louder and eventually the engineer on watch telephoned the Chief Engineer.

Figure 21 shows the assembly of piston rod, skirt and head, and attention is drawn to the securing arrangement for the long tubular nuts. To prevent the two set screws from turning, a soft iron tab washer is provided; a tried and trusted device used by mechanical engineers for generations. It is, however, important to remember that these tab washers should be used once and thrown away, otherwise, through fatigue, the tabs are liable to break off with disastrous results, which could have been the cause in this case.

The noise was being caused by the repeated impact of one of the tubular nuts upon the cast iron diaphragm dividing the scavenge space from the crankcase (see Fig. 22).

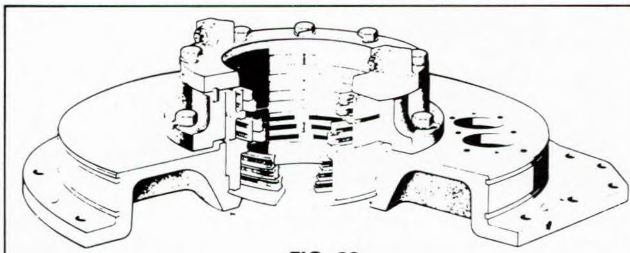
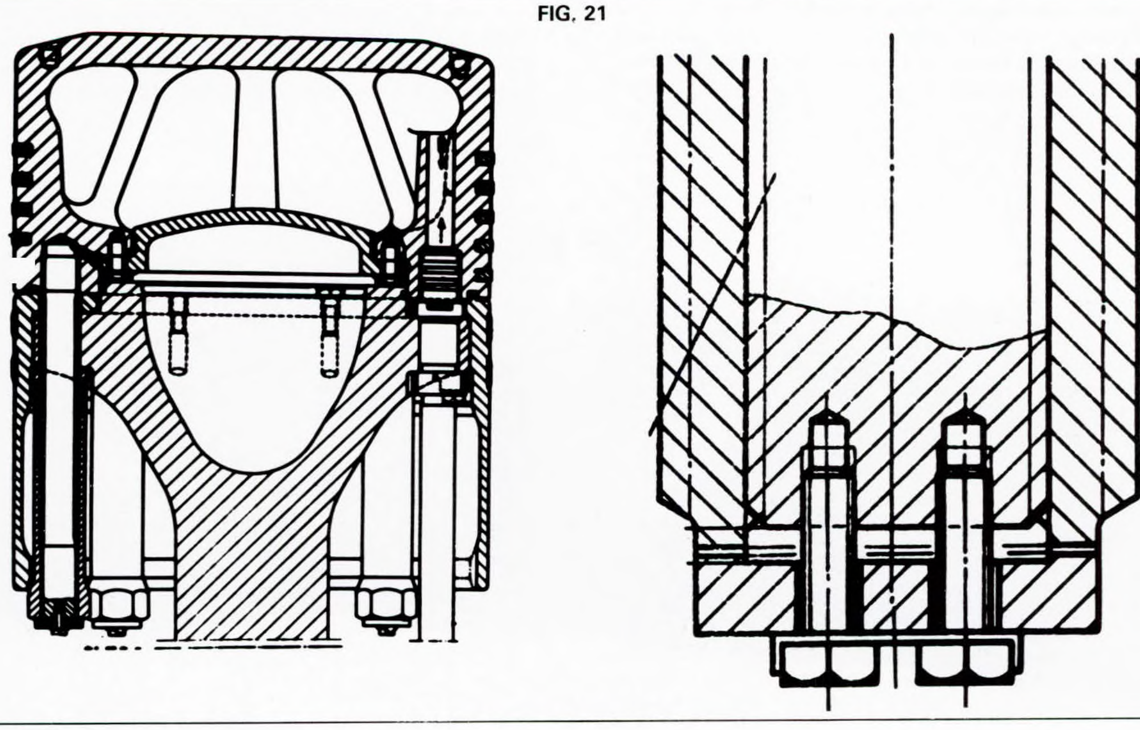


FIG. 22

As the nut continued to turn back, the blows eventually smashed the casting. Pieces were struck by the whirling crank throw, causing sparks, and when the scavenge air blasted into the hot oil-rich crankcase a violent explosion occurred which blew the doors off, not only the engine, but also the engine room.

The Chief Engineer, who was descending the engine room ladders to investigate, died.

FIG. 21



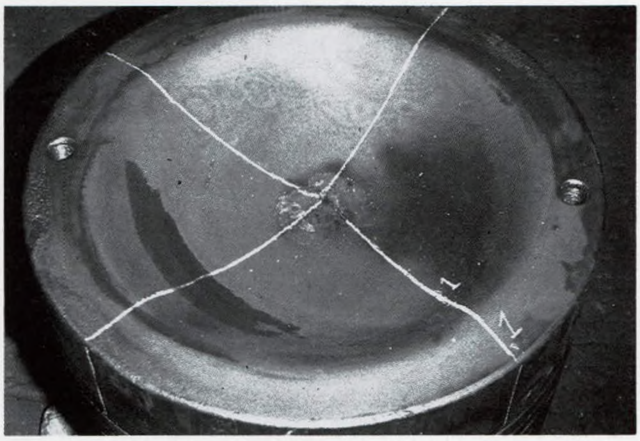


FIG. 23

4.8. Cracked piston crown

Figure 23 shows an oil-cooled piston crown which cracked, allowing quantities of cooling oil into the combustion space resulting in a violent and fatal explosion.

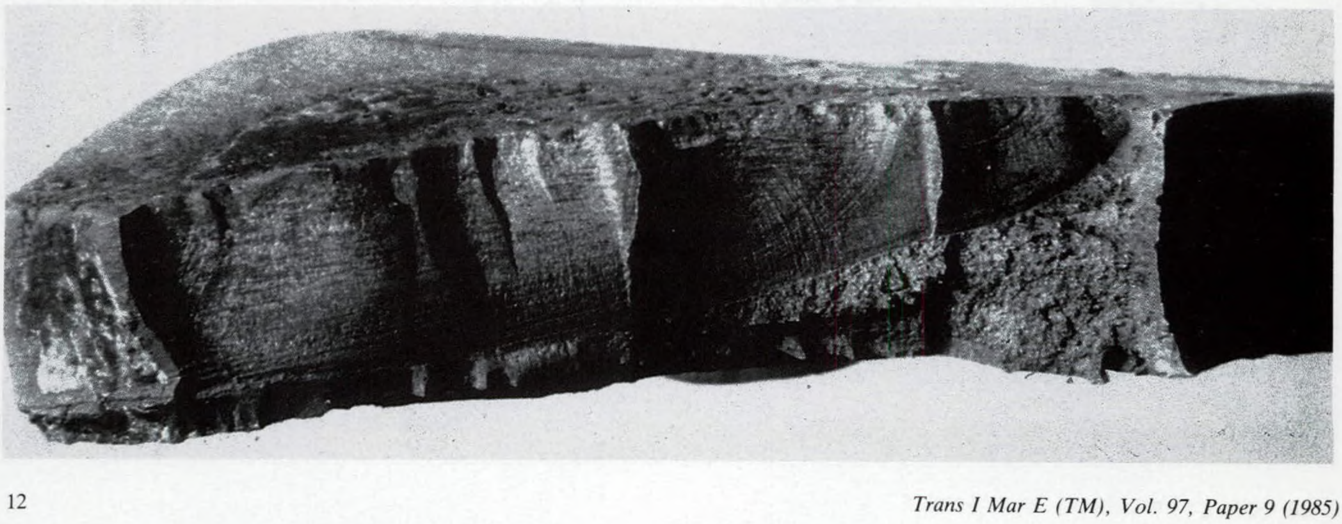
Under investigation, the piston was polished and etched and Fig. 24 shows the cracks and the heat-affected zone in way of unofficial weld repairs which had been performed at the steel foundry without consultation with the surveyors.

The piston crown is subject to arduous service conditions, as evidenced in a recent damage investigation in which the metallurgical structure of the centre of the crown had been modified in a manner which showed that the steel had attained sufficiently high temperatures in service to spherodize the carbides, whereas the structure in way of the ring grooves was typical of normalized medium carbon steel. The piston crown had failed owing to the development of thermal fatigue cracks (see Fig. 25) on both the top and underside surfaces and which penetrated the full thickness.

FIG. 24

No repairs by welding should be carried out on important steel castings which are subject to survey without prior discussion with the Surveyors, to establish whether or not a proper repair can be made. Having decided that repairs may proceed, then the appropriate procedure is to be agreed, and this will include heat treatment. Any other operation is irresponsible.

FIG. 25



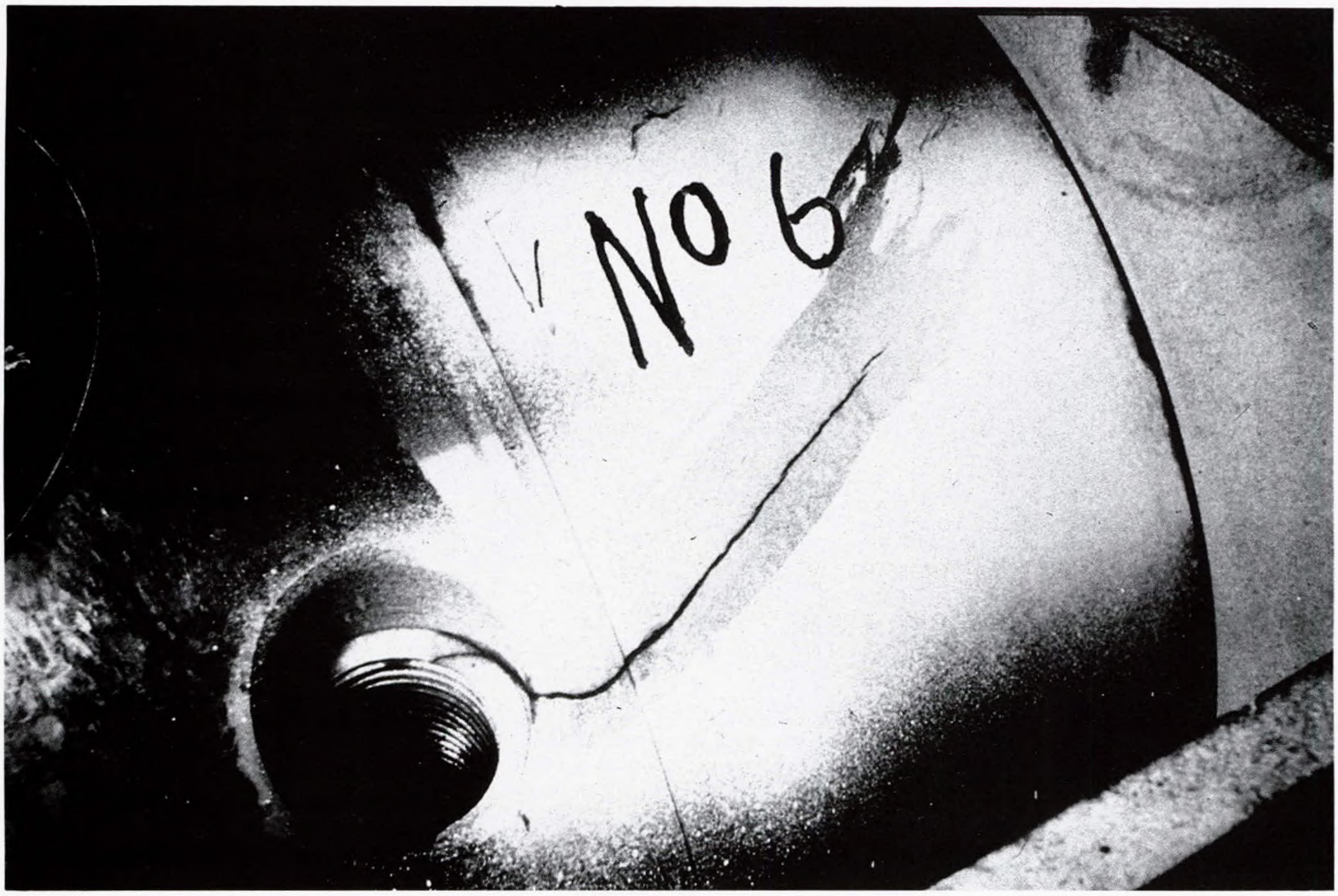


FIG. 26

4.9. Crosshead (stress concentration)

During a routine periodical survey of Nos 4 and 6 crosshead bearings, the pins were found to be cracked as shown in Fig. 26.

As a sensible precaution, all the remaining crossheads were opened up and all were found cracked in the same manner. These cracks originated in the zone of stress concentration caused by the absence of radius on the tool used in forming the counterbores.

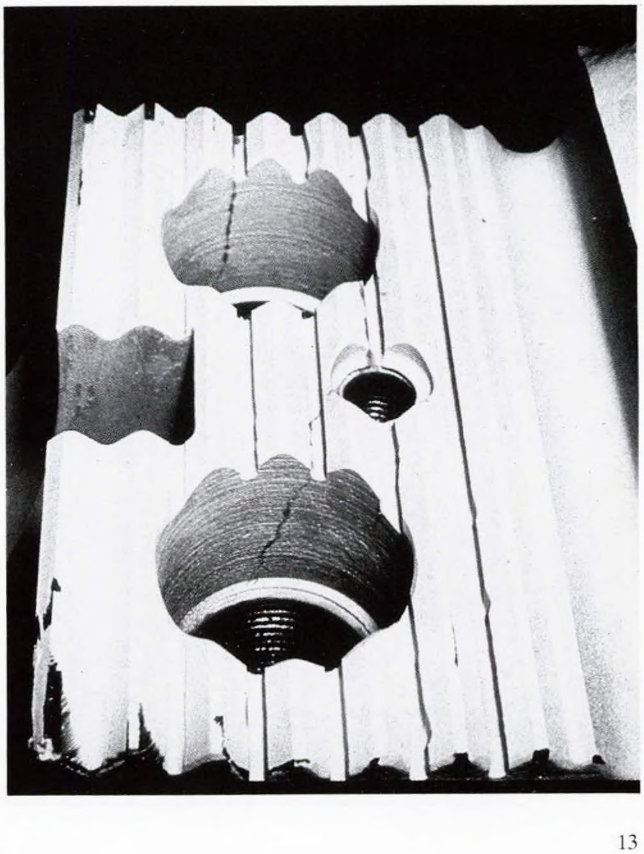
It is not known whether this error originated in the drawing office or the machine shop but it is clear that the danger of sharp corners in stressed components cannot be overemphasized.

4.10. Bedplate (stress concentration)

In this medium speed engine type there were many cracks reported in the grey cast iron bedplates, which were serrated in way of the main bearing keeps, as shown in Fig. 27. A number of bedplates were replaced in nodular cast iron, which was adopted as the material for all future production after the nature and extent of the problem had been recognized. A number of the original bedplates have operated for some years without defect, and many were modified to reduce the stresses in the serrations.

Grey cast iron possesses excellent mechanical properties in compression. The alloy is relatively cheap and is easily cast. However, the metallurgical structure consists of a three-dimensional array of graphite flakes in a matrix which is essentially steel. The flakes can act as stress concentrations and the metal has low ductility. It is worth noting that there is virtually no visual difference between tensile overload, impact and fatigue fractures. On the other hand, in nodular iron the graphite occurs as spheroids or rosettes in the steel matrix.

FIG. 27



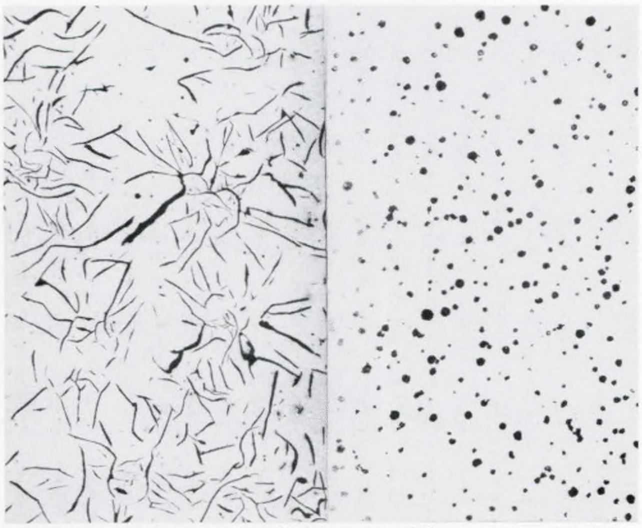


FIG. 28 Flake cast iron (left) and nodular cast iron (right)

FIG. 30

The comparison in Fig. 28 shows the striking difference between the two forms of cast iron. Nodular graphite iron is also relatively cheap, easy to cast and can show ductilities comparable with structural steels.

5. SCREWSHAFTS

5.1. Fracture

In this ship, the carbon steel screwshafts have stainless steel liners shrunk-on in way of the bearings in the stern tubes and 'A' brackets. The length of the shaft between these sleeves is protected by a glass fibre reinforced coating which is fully exposed when the ship is in drydock (see Fig. 29).

Some 12 months after the ship had been in drydock, a propeller was lost owing to fracture of the screwshaft in way of the aft end of the stainless steel liner at the 'A' bracket. The fibre glass coating must have been defective, allowing penetration of sea water to the screwshaft. Corrosion cells formed, particularly at the stress concentration due to the sharp edge of the shrunk-on liner.

The corrosion around the periphery of the shaft had led to the multi-origin corrosion fatigue failure shown in Fig. 30. Numerous radial stepped ridges point to many initiation sites on the surface.

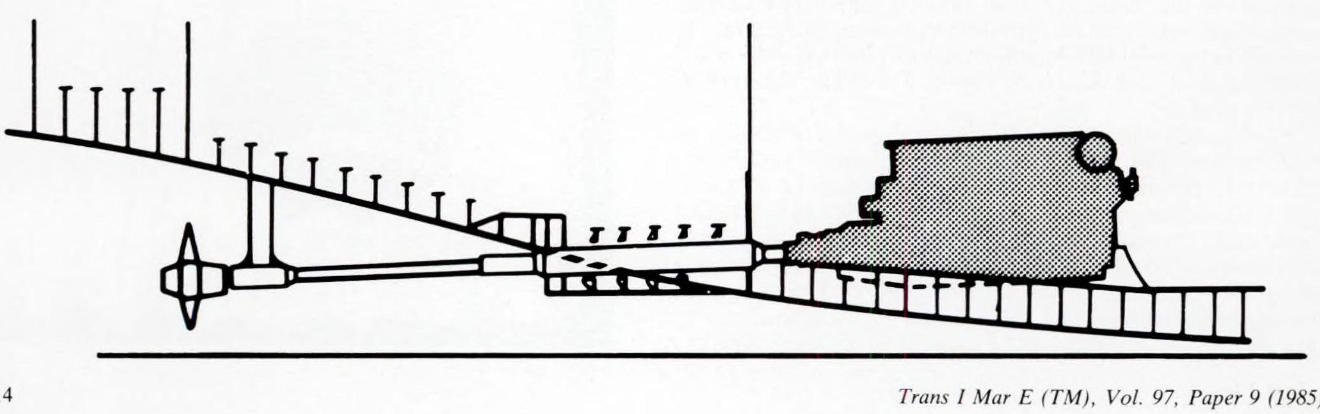
Cyclic stresses in a shaft due to bending or torsion may be innocuous until a corrosion pit provides a stress concentration which leads to cyclic stresses exceeding the fatigue endurance limit.

5.2. Cracked

At the survey of screwshafts having continuous liners, much attention is paid to the condition of the shaft at the top of the cone under the rubber ring, and in cases of doubt a few millimetres are machined from the aft end of the liner before applying magnetic crack detection.

The coupling ends of such shafts should receive equally close scrutiny, because with leaking stern glands pouring sea water copiously over unprotected couplings the conditions are predestined to bring about corrosion pitting which will provide active origins for corrosion fatigue, the stress at this end of the screwshaft being mainly torsional.

FIG. 29



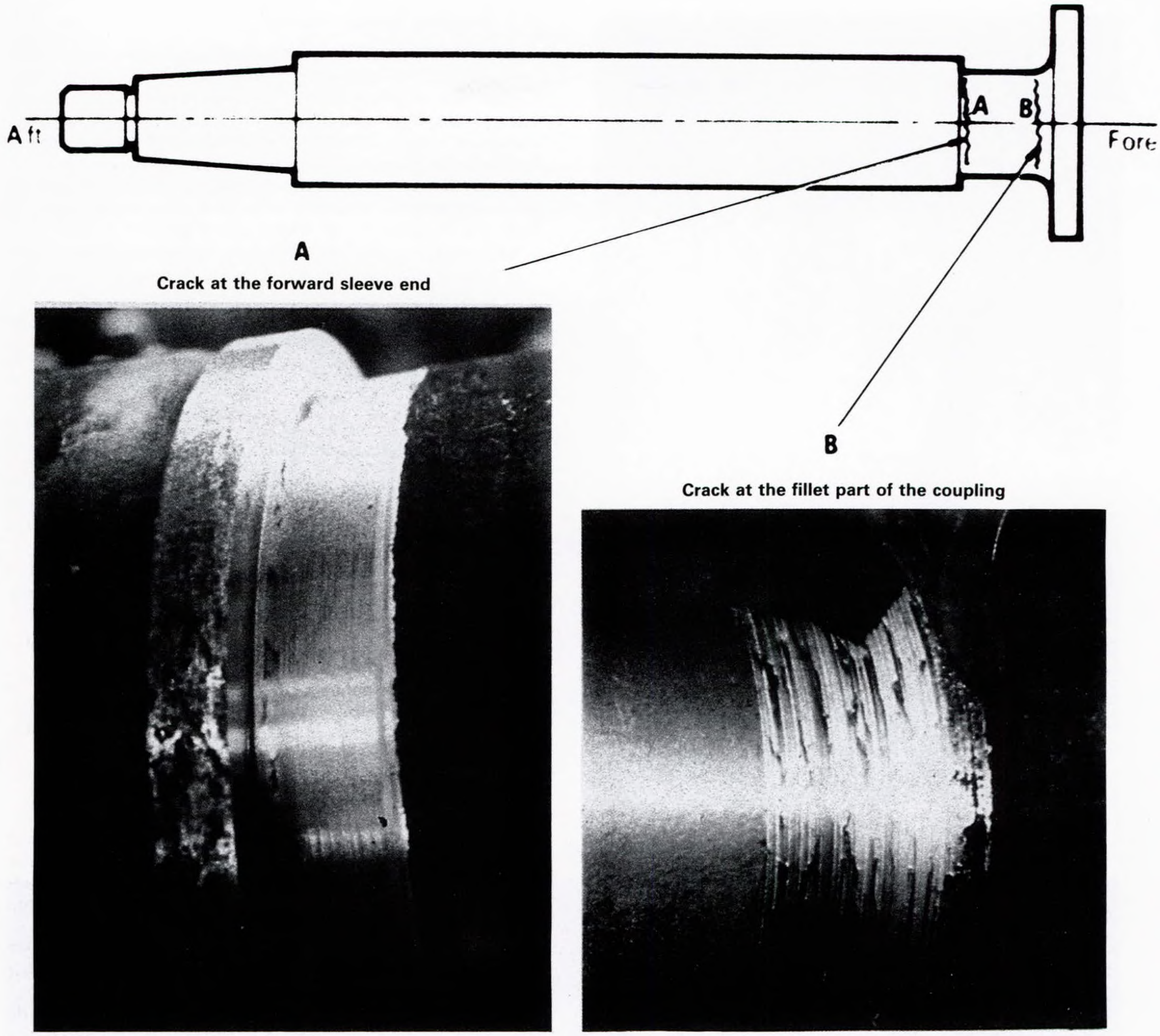


FIG. 31

Figure 31 illustrates a case in which the screwshaft was found to be cracked at the forward end of the shrunk-on bronze liner and also at the coupling. For this case it is probable that misalignment was causing severe bending stresses, resulting in bending fatigue failure in the presence of a corrosive environment.

Operators of ships having continuous liners on the screwshafts are strongly advised to consider protection of the bare steel shafts in way of couplings from the effects of stress corrosion fatigue due to the continuous flow of sea water which is usually experienced as a result of the desire to keep the stern gland packing lubricated and cool.

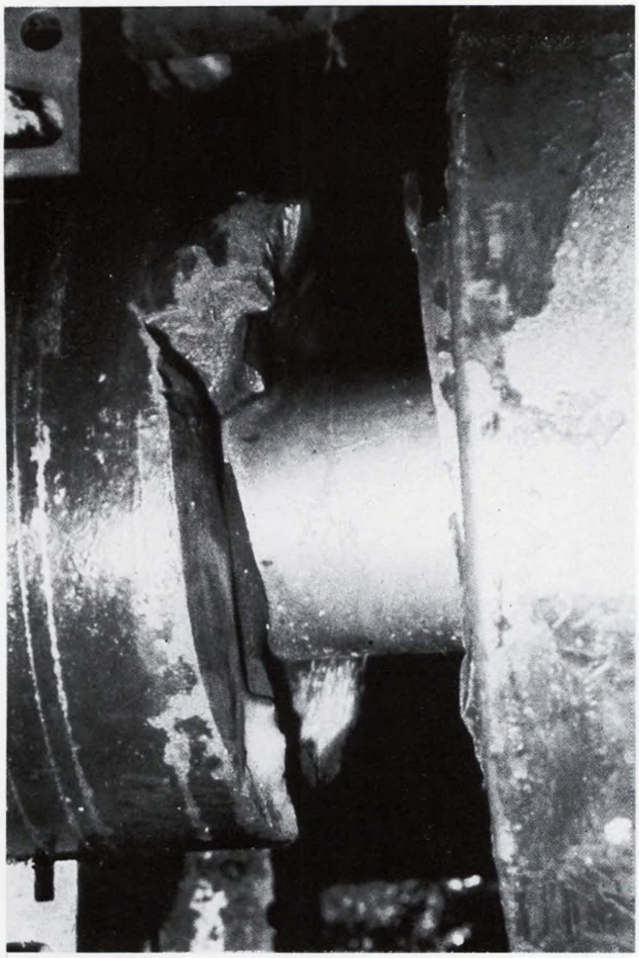


FIG. 32

5.3. Bending fatigue fracture

Figure 32 shows a controllable-pitch propeller shaft which broke at the forward coupling. The stern tube is fitted with a lignum vitae bush and the ship operates in an extremely hostile environment due to sand bars. She has a history of extremely rapid wear-down of the stern bush, renewal of the lignum vitae having taken place at each annual drydocking.

When the screwshaft finally succumbed to the high bending stresses to which it had been subjected, the wear-down of the bush was found to be 19.5 mm! (See Fig. 33.)

High cyclic stresses, well above the endurance limit, due to this serious misalignment had resulted in a significantly short service life.

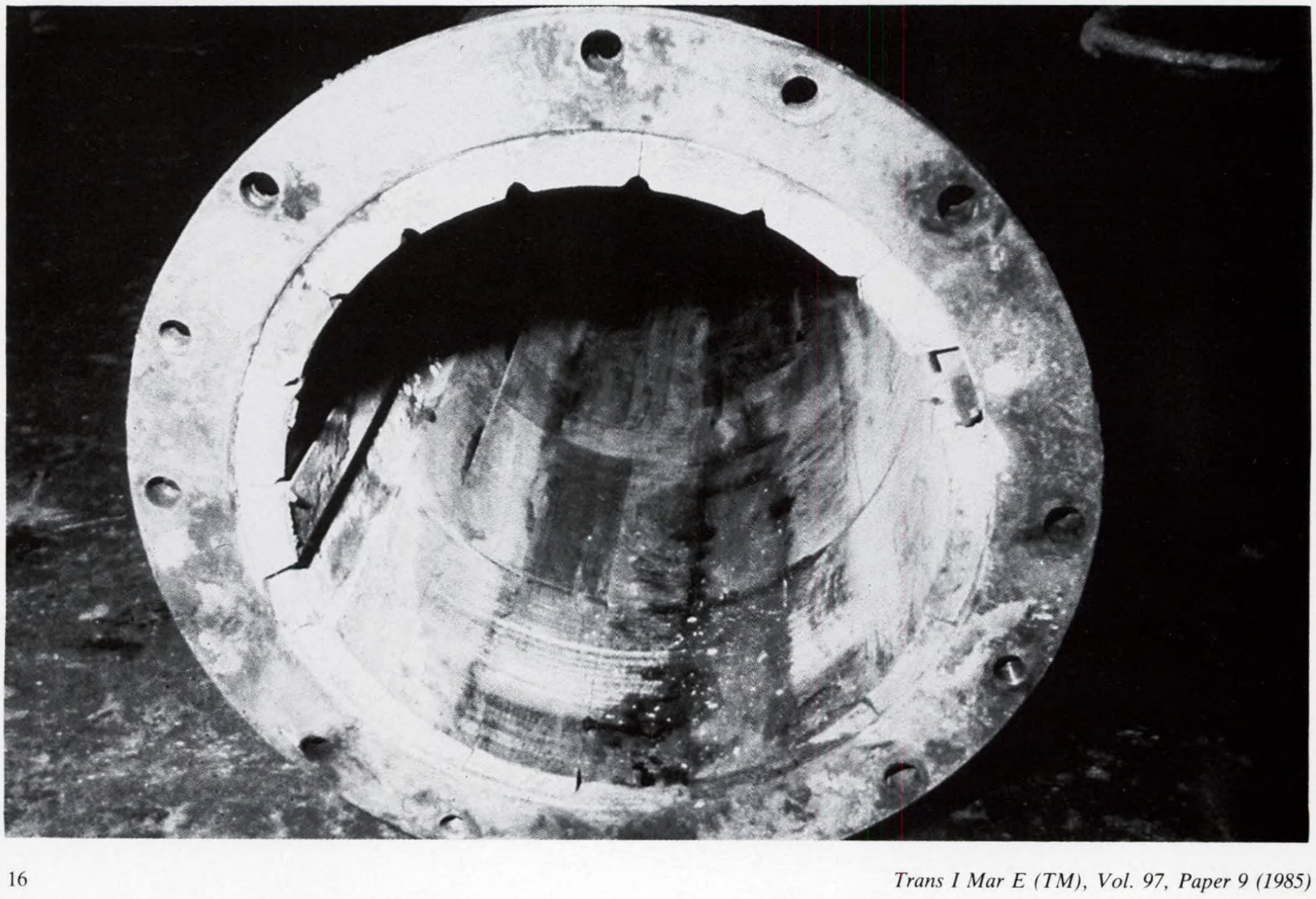
The owners have been advised to consider conversion to an oil-lubricated stern bush with lip seals.

5.4. Magnetic crack detection

Figure 34 shows a crack in the keyway of a screwshaft which originated in the keyway fillet at the top of the cone and extended around the body of the shaft circumferentially, as seen in Fig. 35.

Attention is directed to the brass contact, which was used as one of a pair for magnetic crack detection. It has been the practice to pass an electric current between such terminals

FIG. 33



while spraying the magnetic ink. The use of this technique is to be discouraged. Any movement of the terminal while the current is passing is likely to cause arcing which can create high temperature micro-damage to the surface, giving rise to stress concentrations and ultimate cracking of the part probably because of liquid-metal embrittlement.

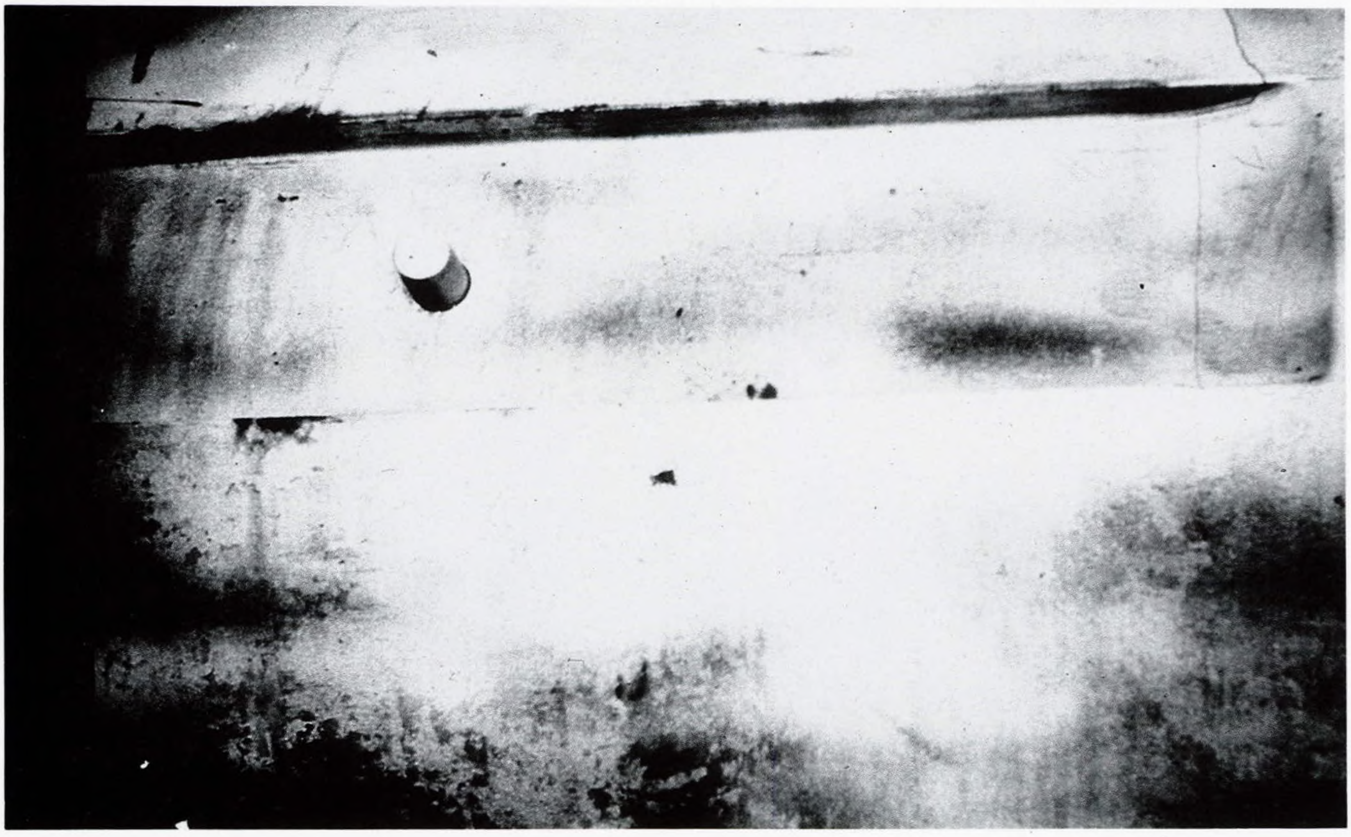
At the present time, no detailed and comprehensive explanation of liquid metal embrittlement has been advanced. It is thought that the surface energy of the solid is reduced by the liquid metal. It is not necessary to have solid and liquid metal in direct contact and embrittlement can occur by transport to the crack tip of atoms of the embrittling phase in the vapour phase, even at temperatures below the melting point of the embrittling phase. The degree of embrittlement has been found greater for steels that are heat-treated or alloyed to produce greater strength.

Brass, aluminium bronze, copper, zinc, tin–lead solder, iridium and lithium have been found to embrittle plain carbon and low alloy steels. Stainless steels have been found quite resistant to liquid metal embrittlement.

Figure 16 in Section 4 shows the excellent results which can be obtained by the use of a permanent magnet or an electromagnetic yoke. When a permanent magnet or an electromagnetic yoke is used, the magnetic field is induced in the shaft and, since no electric current flows, no damage to the components under test can result. It is the Society's experience that this technique produces indications equally sensitive and clear, whilst being more versatile with reference to varying orientations (see Fig. 16, Section 4).

FIG. 35

FIG. 34



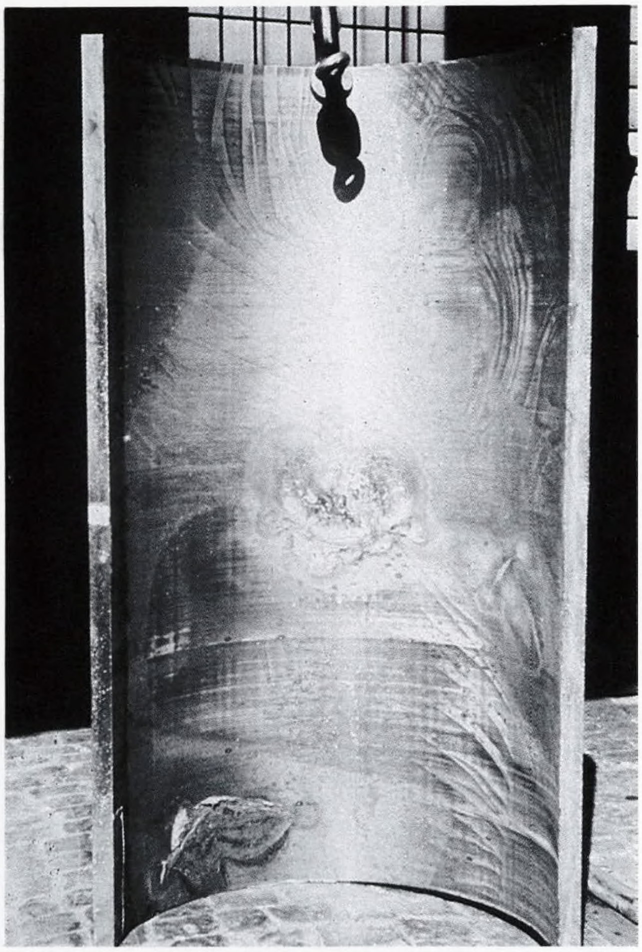


FIG. 36

6. SCREWSHAFT LINERS

6.1. Cracked

Occasionally cracks are found in bronze screwshaft liners, as shown in Fig. 36, and suggestions will be made that the cracks should be chipped or ground out and the resulting groove filled up with a sealing compound.

These proposals should be vigorously resisted because experience has shown that in such cases serious damage will probably have resulted to the body of the steel shaft underneath, due to the establishment of an electrolytic cell in the presence of torsional and bending stress, giving yet another example of corrosion fatigue which may originate from pitting corrosion or stress corrosion cracking.

In this case the liner was removed from the shaft and the shaft was found to have developed severe cracks following the precise line of the cracks in the liner (see Fig. 37).

FIG. 37

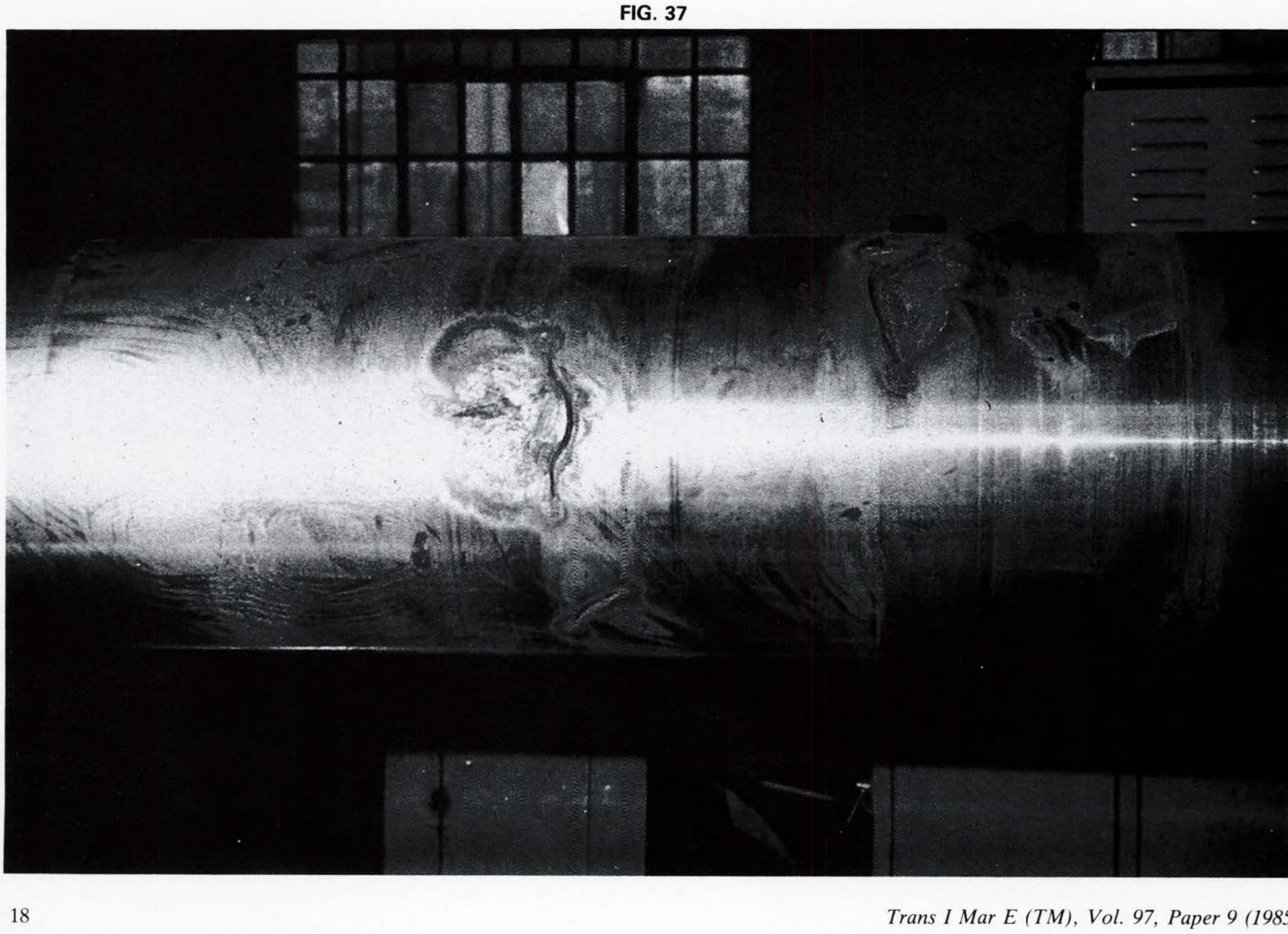


FIG. 38

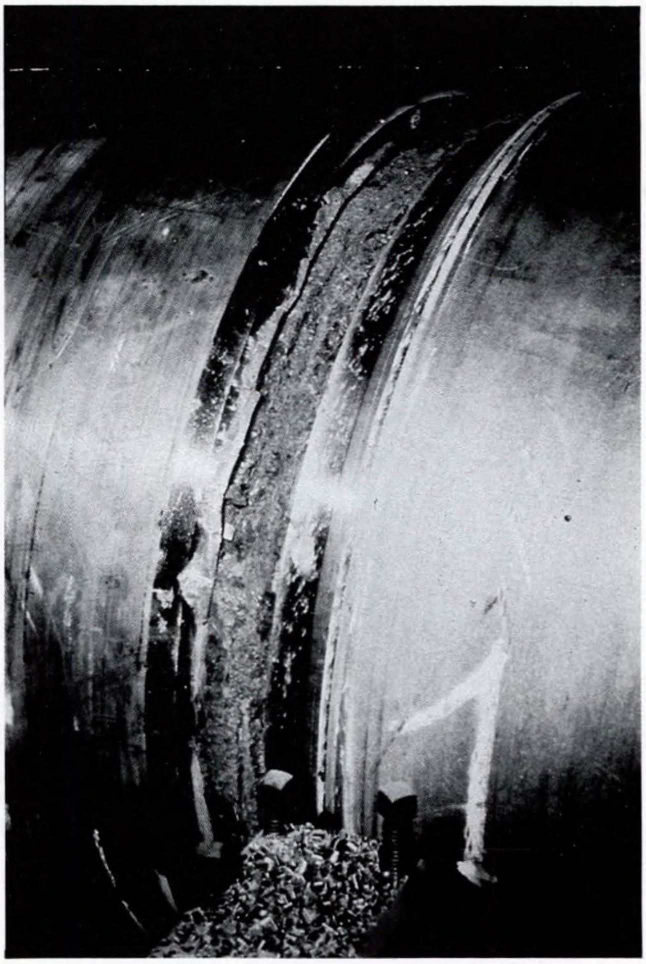


FIG. 39

6.2. Cracked welds

This screwshaft was fitted with bronze liner in three sections having two circumferential welds. During the shaft survey, a crack was seen at the side of one of these welds (see Fig. 38). The shaft was placed in a lathe for investigation and, after machining the weld material away, a very deep crack was exposed in the body of the shaft, exactly in line with the crack which had been found in the liner (see Fig. 39).

The liner material was subject to chemical analysis for lead content and was found to be far in excess of the 0.5% maximum permitted by the Rules to ensure weldability. Lead is frequently added in the foundry to improve machinability but it may also occur as an impurity in the foundry raw materials. Lead will not dissolve to any significant extent in iron-based alloys nor in many other engineering metals but will exist as grain boundary films and, at higher concentrations, as discrete globules which are soft and ductile.

Lead has a relatively low melting point (232°C). When present in materials which are to be welded, the lead melts at low temperatures and results in grain boundary cracking.

FIG. 40

7. PROPELLERS

7.1. Fractured blade

Figure 40 shows the fracture face of a broken propeller blade. The cause of the failure was investigated and proved to be a tiny spot of welding on the blade surface, presumably for 'cosmetic' reasons (see Fig. 41). This introduced a stress concentration in a position of high stress, with a disastrous result.

Small surface imperfections on propeller blades are much better dealt with by smooth grinding and blending. Where it is

FIG. 41

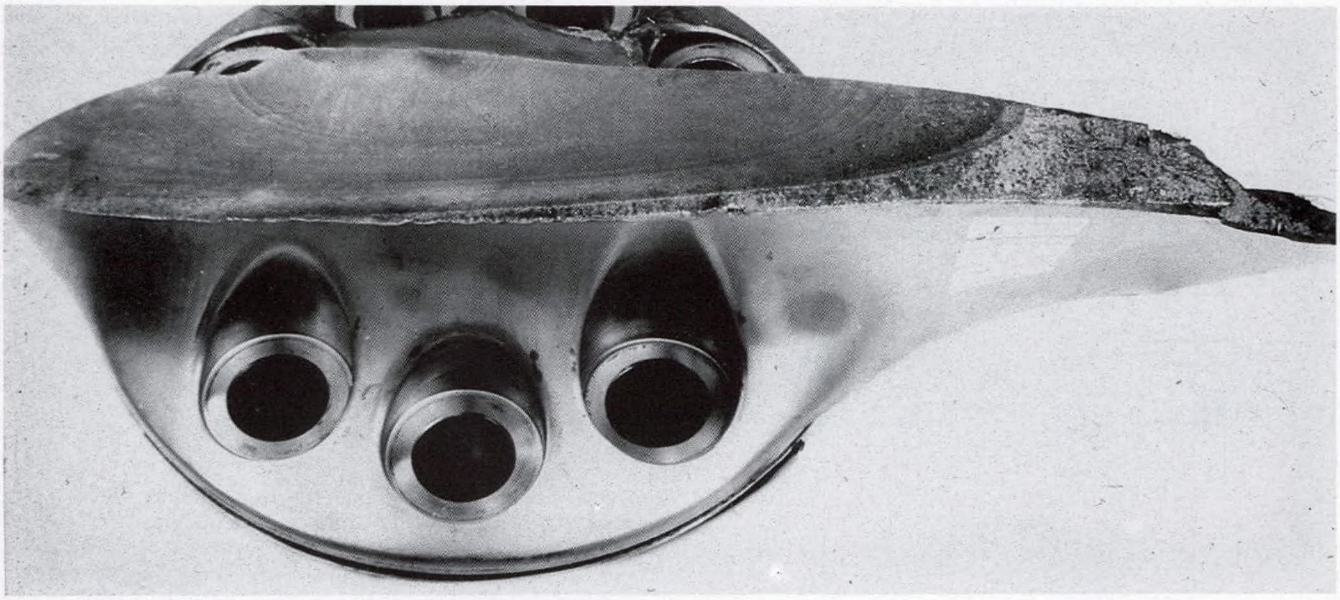


FIG. 42

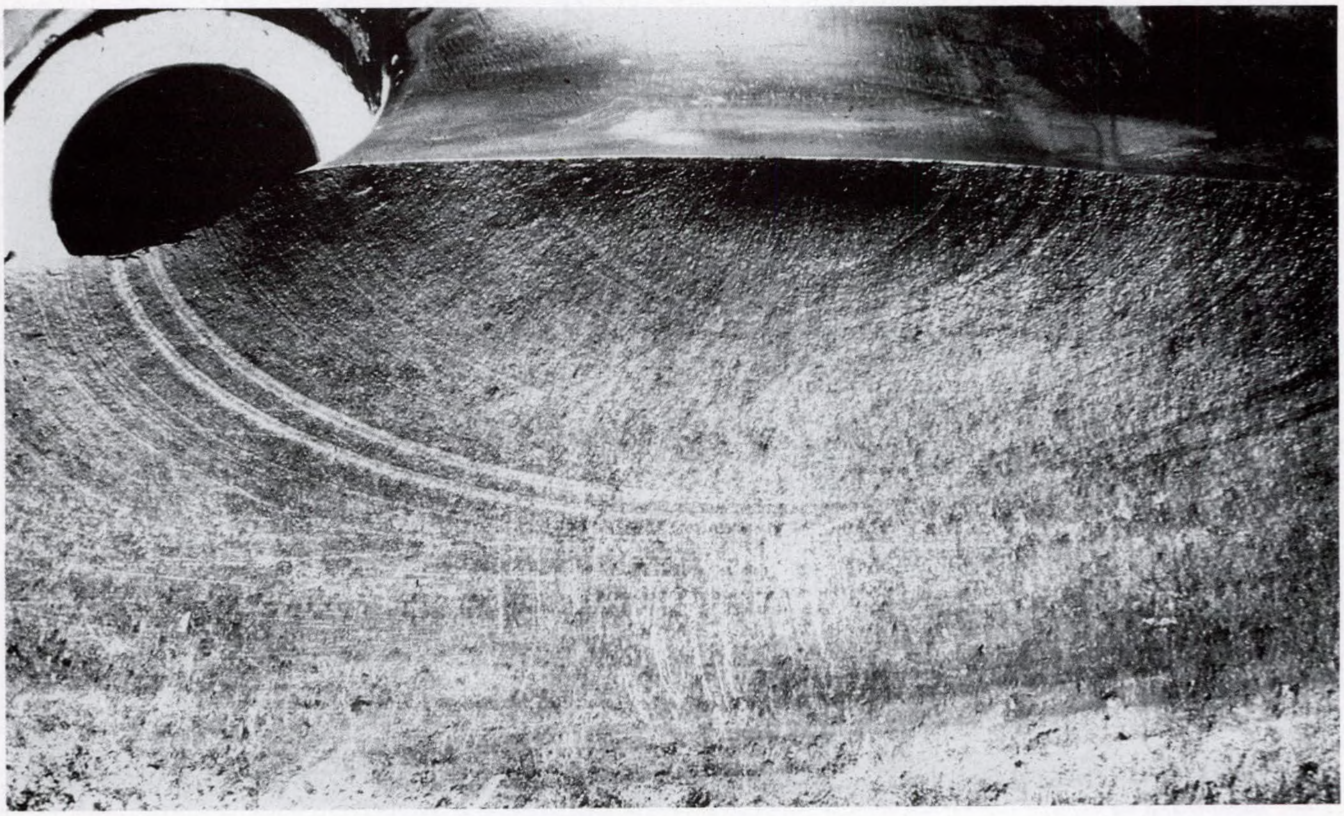
desired to repair by welding areas damaged by cavitation erosion, the surveyors should refer to the Rules for guidance, and bear in mind that some valuable advice will be available from the propeller manufacturers.

Propeller blades have also been lost on many occasions from fatigue cracks propagating from a subcutaneous area of shrinkage, usually on the pressure face. Many bronze and nickel aluminium bronze propellers on examination are found to have well-distributed pockets of solidification shrinkage, which individually and in relation to the size of the propeller are small.

Whilst shrinkage represents a discontinuity and therefore a weakness, the cyclic stresses experienced during operation must be significant to cause failure by fatigue.

The propeller blade fracture shown in Figs 42 and 43 is a similar case, in which a stabilised martensitic steel failed by fatigue originating from a small casting flaw on the pressure face. The extent of the fatigue crack prior to final rupture and the small size of the flaw indicate that the principal cause of the failure was cyclic stresses probably slightly greater than the endurance limit of the alloy. Note that this fracture is in a region of high stiffness. Fixed-pitch propeller blades made in copper alloy examined by the Society's laboratory have been found to fail further from the hub.

FIG. 43



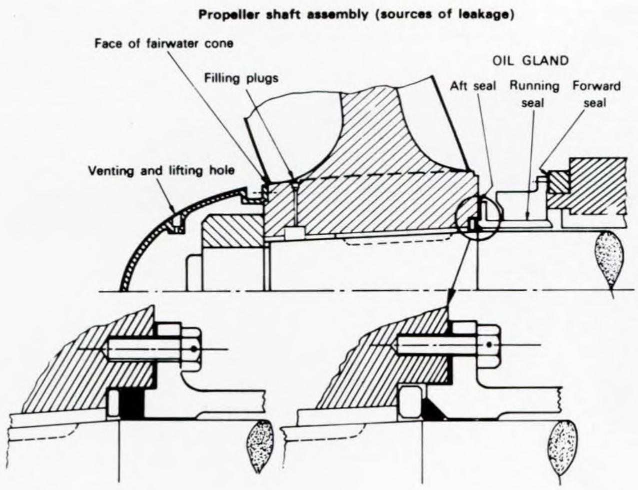


FIG. 44

7.2. Sources of leakage

Shortly before a ship was launched, air pressure was applied to the propeller/shaft assembly and a soapy water test proved most revealing. In Fig. 44, attention is drawn to the large flat face joints and the holes, which require to be very carefully sealed at first assembly and after subsequent maintenance overhauls.

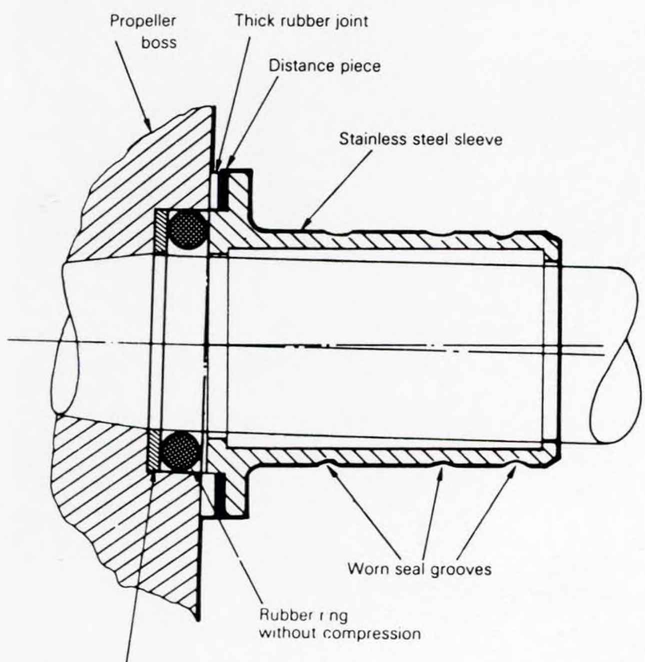
7.3. Oil gland sleeve

In order to avoid the expense of machining a worn oil gland sleeve, it was decided to move the grooves out of line with the seal rings by placing a distance piece between the sleeve flange and the propeller boss (see Fig. 45). The idea seems in order, but unfortunately the thickness of the distance piece chosen was such that the flange spigot came out of the recess in the boss. The result was that the true alignment was lost and the rubber seal at the top of the shaft cone became ineffective.

The greatest care should be taken before making any changes to original designs.

These stainless steel sleeves can now be supplied in halves, which permits removal for machining without removing the propeller. A distance piece can be fitted between the stern tube and the outboard gland which can be removed in the event of grooves being found on the sleeve as illustrated, in order to provide the displacement of the sealing rings to bring them in contact with an unworn part of the sleeve.

FIG. 45



8. ENGINE ROOM FIRES

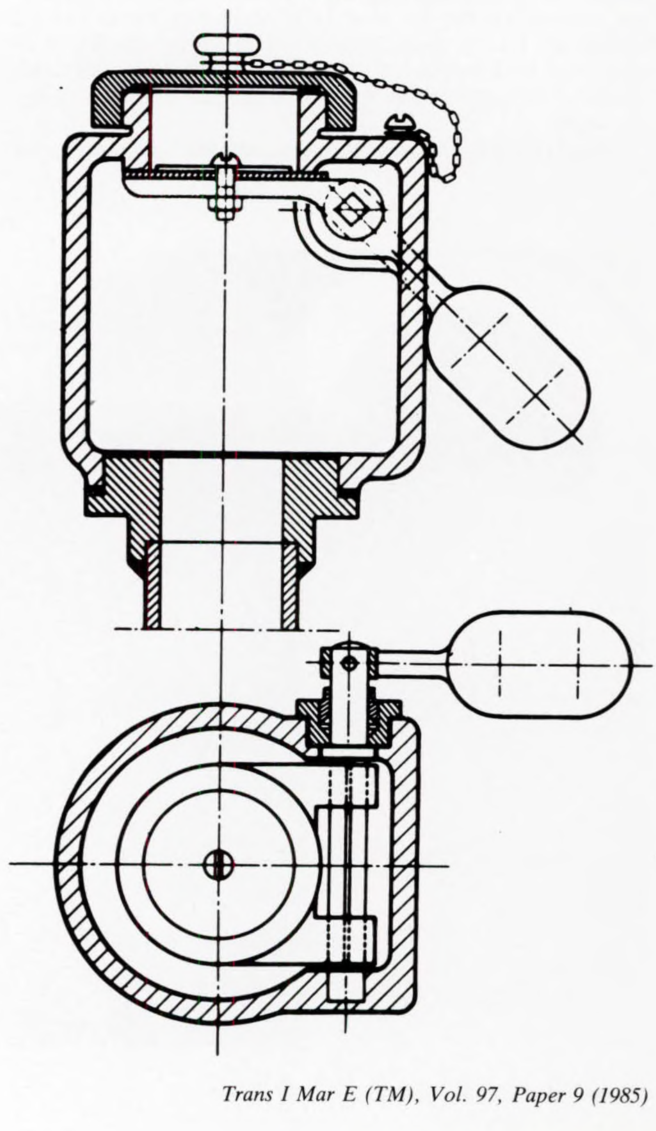
8.1. Self-closing cocks

Short sounding pipes to fuel tanks in machinery spaces are at present permitted by the Rules of the Classification Societies but they are required to be provided with self-closing devices and, if cocks are proposed, these are to have parallel plugs.

International discussions are going on with a view to the abolition of short sounding pipes to fuel tanks but, in the meantime, there are very many at sea. They should be used with great care, especially during bunkering operations.

Figure 46 shows an excellent weighted lever self-closing device through which a fountain of gas oil emerged, setting fire

FIG. 46



to the engine room and causing great damage. There was no personal injury or loss or life because the person concerned was on deck talking to the crew of the bunker barge, and became aware of trouble when gas oil emerged from the air pipes on deck. Only then did he realize the significance of his having lashed the weight in the open position to simplify the task of sounding the tank.

Forty years ago, when one of the authors was serving at sea in the British Merchant Navy, there were several reliable instruments in common use for measuring liquid levels in tanks and it is surprising that the industry is still using the primitive and dangerous short sounding pipe for this purpose.

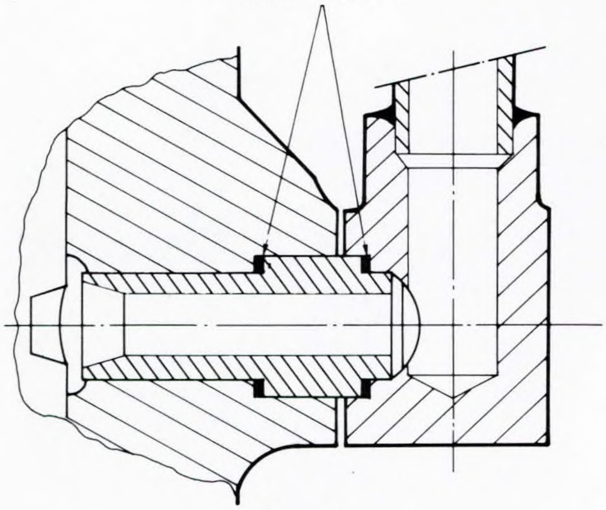


FIG. 47

8.2. Fuel pipe joint material

Fire broke out in the engine room of a twin-screw ship fitted with medium speed engines. Investigation revealed that a joint had failed in the high pressure fuel system at the discharge from the fuel pump. Copper ring joints were found in those places where the designers specify that only monel metal is to be used (see Fig. 47).

These joints are subjected to shock loading in service and under these conditions copper becomes work-hardened and brittle, whereas monel metal does not.

A Service Bulletin on this subject has been issued by the designers to all operators of their engines, but many others should benefit from becoming aware of the danger which has been described.

8.3. Fuel pipe clips

Figure 48 shows the results of a severe engine room fire which broke out in a medium speed engined container ship when a fuel pipe broke at the cylinder tops. When the pilot is on board and 'Stand by' is rung on the telegraph and the engineers are tidying up after some routine planned maintenance, it is essential that the 'Stand by' signal is not accepted until all pipe clips and shields are replaced. Once the passage has begun, these vital items are liable to be overlooked and the consequences may be disastrous.

FIG. 48

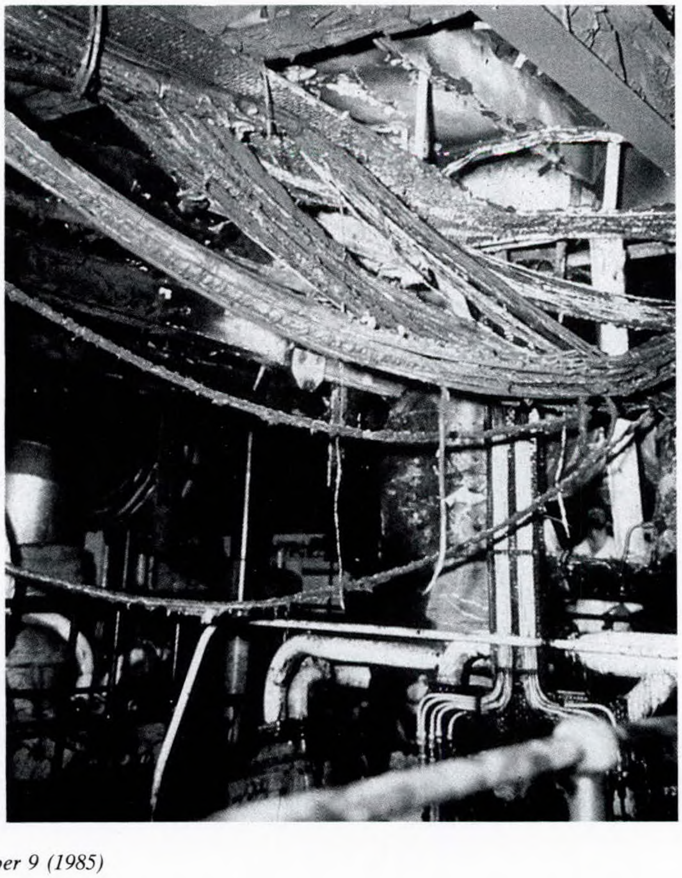


FIG. 49

8.4. Service modifications

An impulse damper in the main engine fuel system fractured and caused fuel to spray over a hot exhaust manifold, the resulting fire being nearly catastrophic.

The component which failed was to an original design made in grey cast iron but incorporated a modification carried out by the manufacturers and intended to reduce leakage around the piston. An internal groove was machined in the cylinder bore to accommodate a sealing 'O' ring. The bottom of the groove had sharp corners with no trace of radius.

Examination of the failed component showed that the material of the casing possessed satisfactory mechanical properties and had a metallurgical structure typical of grey cast iron. The fracture originated in one of the corners in the internal groove. The cross-section of the component had not been increased to compensate for the material removed by the groove, which had penetrated over 60% of the casting thickness in an alloy with low intrinsic ductility and poor notch impact properties.

This is a clear example of the dangers of introducing stress concentrations into a component subjected to fluctuating stress in service (see Figs 49, 50 and 51).

FIG. 50

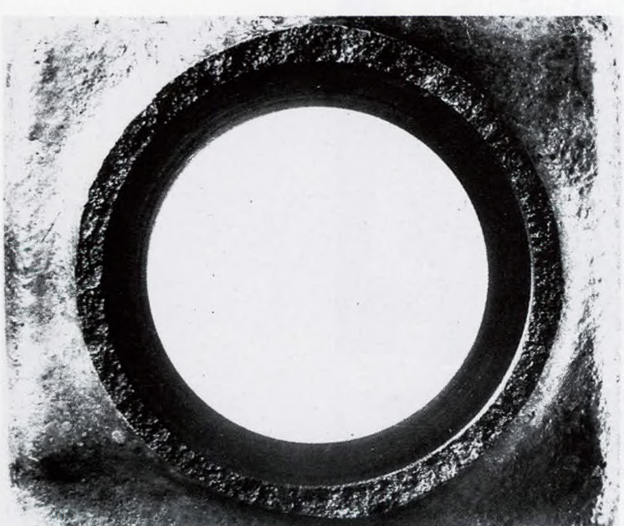


FIG. 51

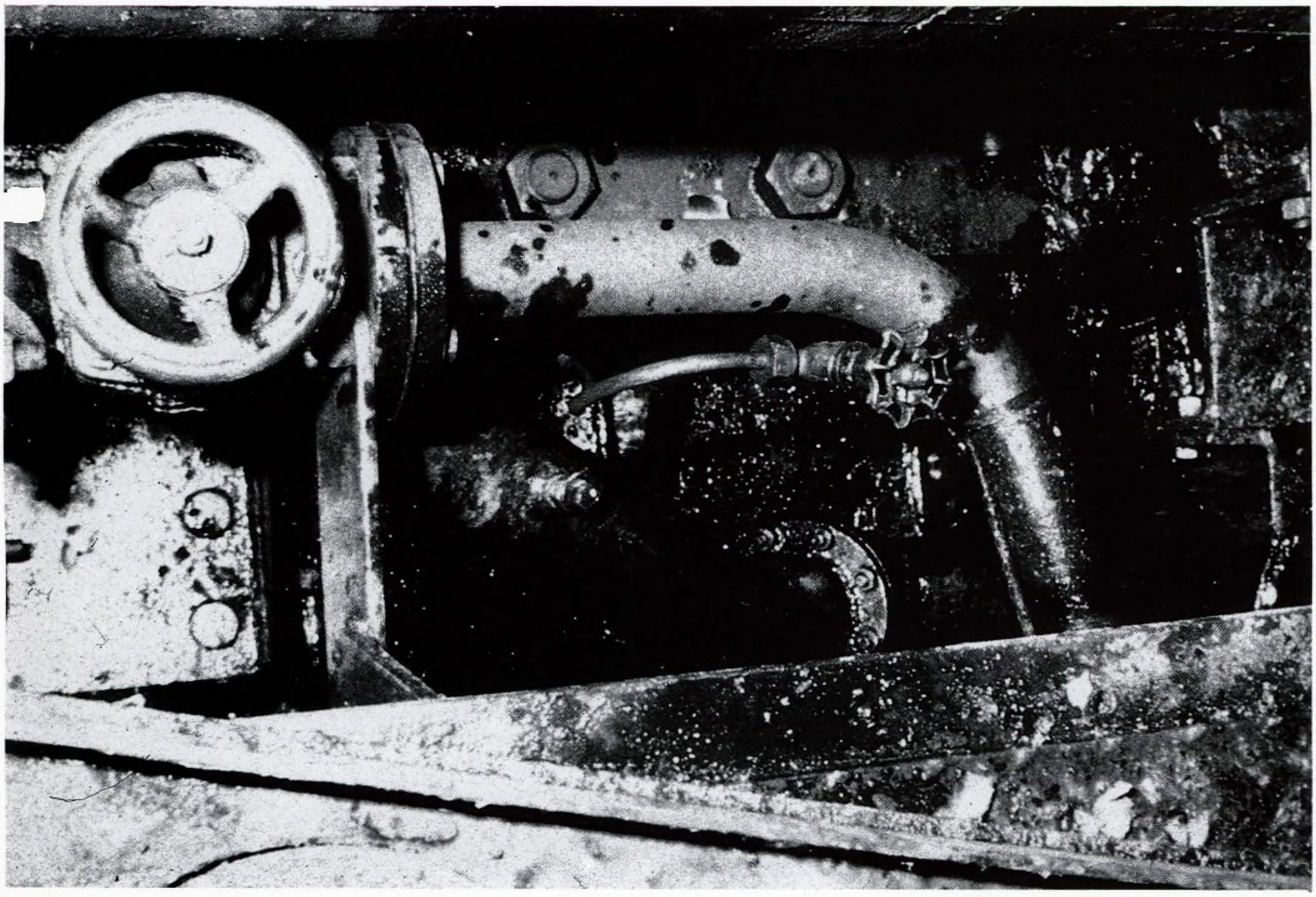
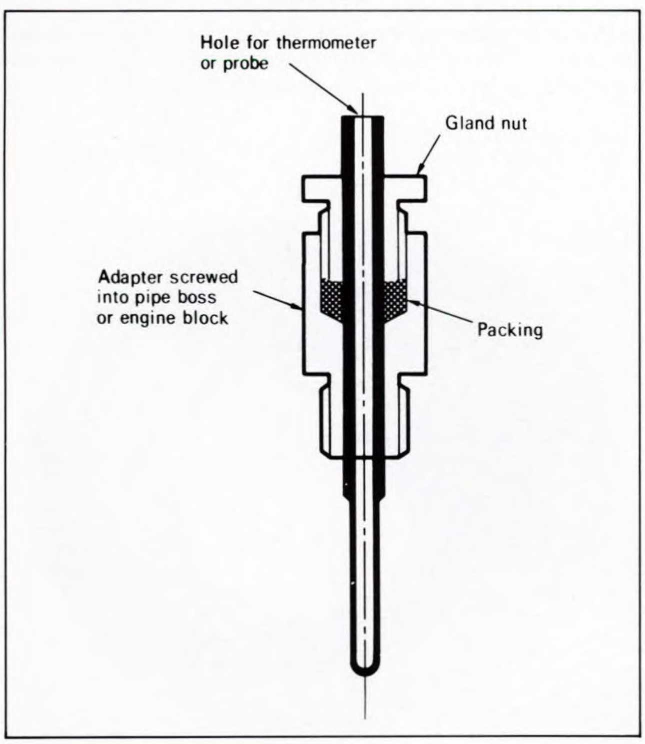


FIG. 52

FIG. 53



8.5. Lubricating oil pressure gauge pipe

An engineer noticed oil spreading over a floorplate in the auxiliary engine room of a large motor ship. When he lifted the plate to investigate, a jet of lubricating oil rose into the air and descended upon an adjacent auxiliary engine. A serious fire broke out. Figure 52 shows the copper pressure gauge pipe which had work-hardened and fractured.

The pipe had been connected to one pipe and clipped to another and in these circumstances relative motion could be expected due to vibration.

This would appear to be an ideal application for using a pressure transducer sending a low voltage electrical signal to the control room, rather than leading a copper pipe through a long and tortuous route to the pressure gauge.

This is another example of the danger of subjecting copper-based alloys to fluctuating shock loading. The case quoted in Section 8.2. and illustrated in Fig. 47 also refers to this danger.

8.6. Thermometer pocket

In Fig. 53 it will be noted that the pocket for the bimetallic sensor is retained in place by pressure on the gland packing.

A fire broke out in the engine room when the pocket was ejected from the auxiliary engine lubricating oil cooler by the pressure of the oil after the packing had hardened and shrunk.

The simple modification of providing the pocket with a small integral collar at its lower end would have prevented this incident and all concerned with thermometer pockets should be aware of the danger.

9. FLOODING

9.1. Sea water cooling pump discharge pipe

Figure 54 shows the position of a main sea water cooling pump in a large bulk carrier. Halfway across the Atlantic Ocean, midway between the coasts of Brazil and Mauretania and on passage to the Black Sea, a large piece broke out of the cast iron discharge bend from the pump, located below the floorplates.

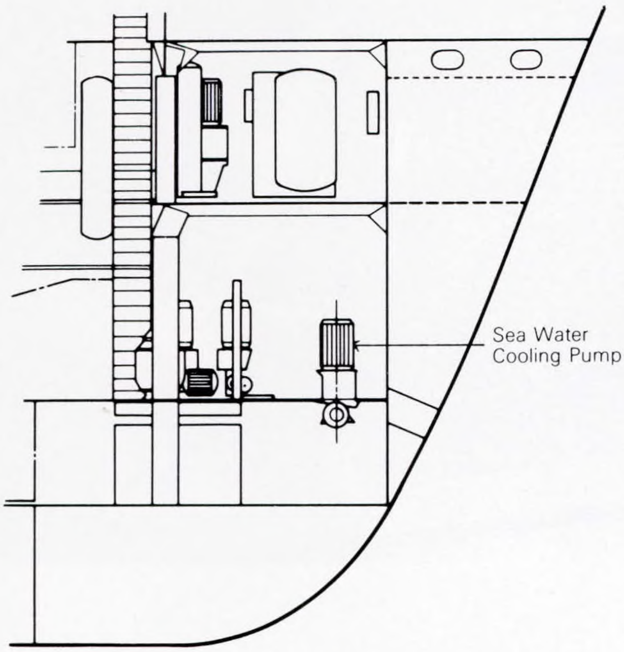


FIG. 54

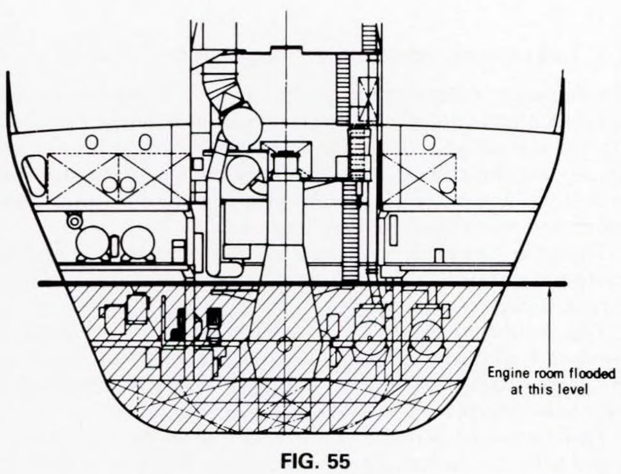
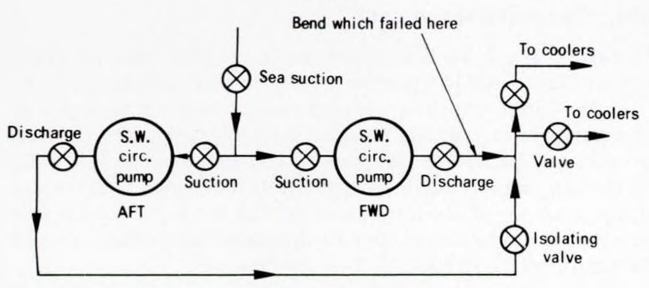


FIG. 55

FIG. 56



When the crew realized that there was a serious increase in the depth of water in the bilges, they attempted to close all sea suction valves and were unable to do so. The engine room was abandoned and the water rose to the level shown in Fig. 55, completely immobilising the ship.

Despite the fact that the sea suction valves could not be closed (which in itself is a serious reflection upon the standard of maintenance on board), had the crew identified the source of the inrush of water and been thoroughly familiar with the pipe arrangement there were other means available to them to stop the flooding (see Fig. 56). Owing to a draught restriction at the intended port of discharge, the ship was only partially loaded. Had she been fully laden she could have sunk.

Eventually the ship was towed to a port of refuge for sealing of the sea inlet by divers and professional de-watering of the engine room. She was then towed on to discharge her cargo as planned, and back to a Mediterranean port for extensive and expensive repairs.

The importance of maintaining sea inlet and overboard discharge valves in efficient condition cannot be overemphasized.

One of the authors is reminded of a survey in drydock in the early 1950s of a weather ship which had been a corvette in the Royal Navy. When the sea valves were opened up it was found that the emergency bilge valve (sometimes known as the bilge injection valve), the largest bilge valve in the engine room, was a screw-lift valve.

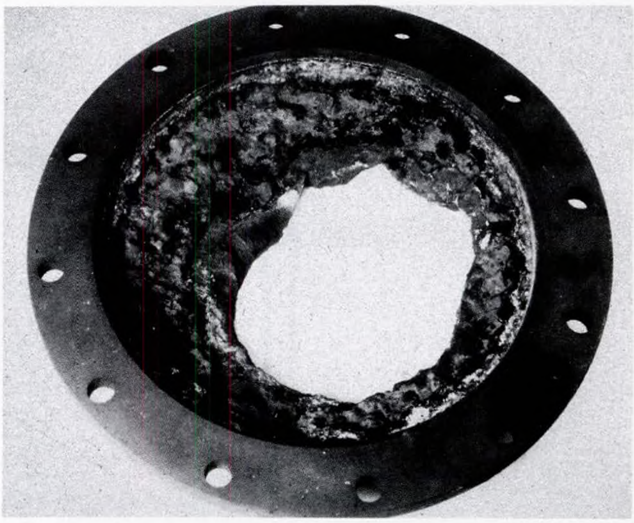
This arrangement was fitted in Naval practice under their pumping and flooding requirements but is of course contrary to the Society's Rules, which require all bilge valves to be of the non-return type.

9.2. Lubricating oil cooler cover

The failure at sea of the cast iron cover of a lubricating oil cooler on an auxiliary oil engine caused serious flooding of the engine room and the Master was compelled to put into a port of refuge to seek assistance (see Fig. 57).

The failed parts, together with other similar covers from the ship, were examined at the Society's laboratory at Crawley and it was concluded that the severe deterioration of the cast iron had been due to the galvanic system set up through sea water in the presence of copper alloys, aggravated by pollution of the water and the presence of stray electric currents.

FIG. 57



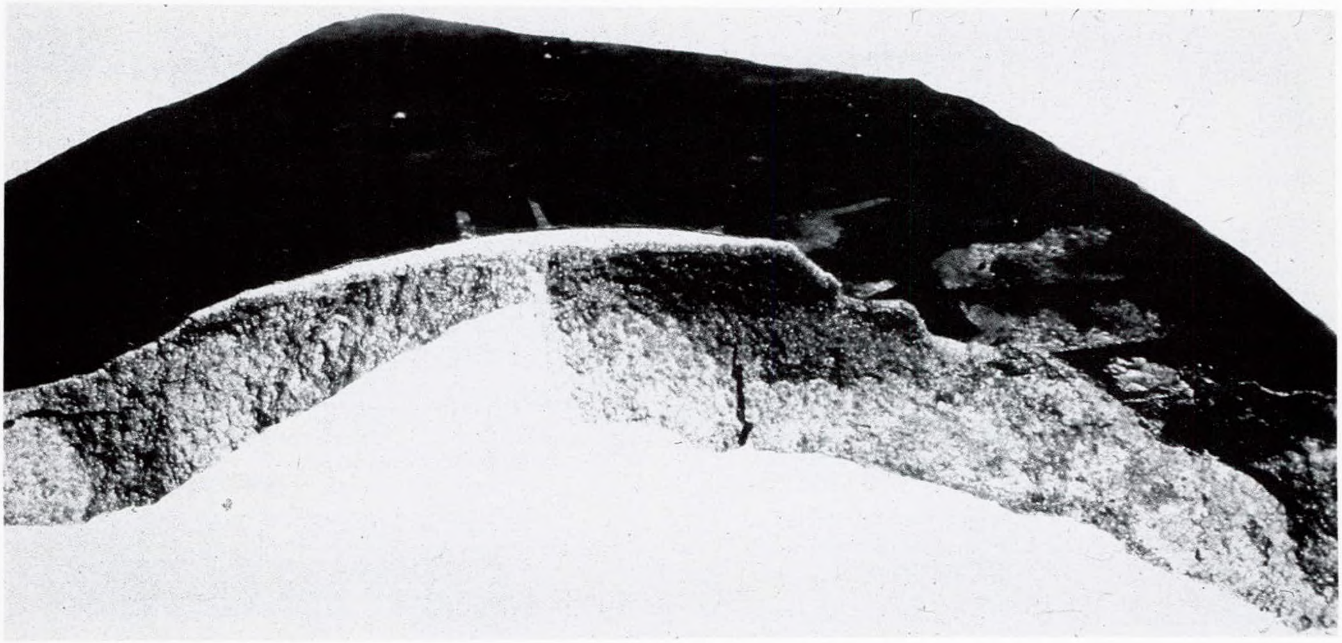


FIG. 58

A very important clue to the state of the castings emerged when an apparently undamaged cover was picked up and found to be unexpectedly light in weight. A tap with a hammer resulted in a large piece falling out (see Fig. 58).

The greater part of the central dome of the cover was completely oxidized to a mixture of graphite and iron oxide.

CONCLUSION

A glance at the table of contents will show that serious trouble can arise in quite unexpected parts of marine machinery installations. It is emphasized that these are not isolated cases, there being many more instances on record of serious damage resulting from carelessness, inattention to detail and lack of cleanliness.

It is not feasible to catalogue all possible causes of failure but it is hoped that the cases shown in the paper will serve to draw attention to the fact that much of the damage being suffered in ships is avoidable. Each case contains a lesson to be learned.

REFERENCES

1. E. C. Hill, 'Microbial degradation of marine lubricants—its detection and control'. *Trans IMarE*, Vol. 90, Series A, Paper 2, pp. 197–216 (1978).
2. 'Microbial Attack on Modern Lubricating Oils'. Symposium at The Institute of Marine Engineers, June 1977.
3. Merchant Shipping Notices (see Appendix).

ACKNOWLEDGEMENTS

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Thanks are also due to Mr Graham Pumphrey, Technical Illustrator, Lloyd's Register of Shipping, for his assistance over a long period.

Responsibility for all opinions expressed in the paper rests with the authors.

APPENDIX

The following Merchant Shipping Notices are reproduced by kind permission of the Department of Transport Marine Directorate:

- M.443 Fires in engine rooms.
- M.474 Explosions in diesel engined vessels.
- M.651 Fires involving lubricating oil.
- M.681 Fixed fire smothering gas installations: siting precautions for CO_2 cylinders.
- M.707 Fires involving low pressure oil fuel pipes.
- M.709 Fire fighting on small cargo ships.
- M.750 Prevention of oil fires in machinery spaces of ships.
- M.765 Maintenance and ready availability of fire appliances.
- M.825 Precautions to be taken to prevent the accidental release of CO_2 fixed fire smothering systems.
- M.852 Use of diesel engine starting aids containing flammable mixtures.
- M.908 Heating appliances burning solid fuel.
- M.910 Loss of life in cargo tanks, cargo holds and other enclosed spaces.
- M.946 Fires involving electric heating or drying apparatus.
- M.971 The safe carriage of coal cargoes—emission of flammable gases and spontaneous combustion.
- M.984 Use of liquefied petroleum gas (LPG) in domestic installations and appliances on ships, fishing vessels, barges, launches and pleasure craft, explosions, fires and accidents resulting from leakage of gas.
- M.986 Implementation of United Kingdom Requirements for inert gas systems.
- M.1022 Fires involving deep fat fryers.
- M.1136 Fires involving oil fired appliances.

BOARD OF TRADE MERCHANT SHIPPING NOTICE No. M. 443

FIRES IN ENGINE ROOMS

Notice to Shipowners, Masters and Chief Engineers

Since this Notice was first issued responsibility for merchant shipping has been transferred from the Ministry of Transport to the Board of Trade

The Ministry of Transport wish to draw attention to the following matters mentioned in the report of a Court of Formal Investigation:

(*a*) the Court was not satisfied from the evidence that boat drills co-ordinated as between the deck and engine room departments were held at proper intervals;

(*b*) the Court thought that the evidence tended to show that no one in the deck department knew anything about the emergency fire pump in the steering flat and said that since it is possible to envisage disasters in which the whole of the engine room staff is cut off or disabled, it would seem proper that the deck department should have knowledge of and means to operate a pump of this sort;

(*c*) the Court emphasized that careful thought must be given to the positioning of fire extinguishers at strategic points in engine rooms, particularly in older vessels.

The Ministry wish to endorse the comments made by the Court on the above points and to request that appropriate action be taken by all those concerned. In relation to point (*b*) above, it is recommended that emergency fire pumps should be used for regular wash down service.

Ministry of Transport
London W1
October 1960

MS 7/8/033

Reprinted by the Board of Trade
August 1968

Reprinted by Department of Trade
July 1975

Reprinted by Department of Trade
December 1975

Printed in England by Her Majesty's Stationery Office at HMSO Press, Harrow
C829617 Dd 200568 5,005 12/75

MINISTRY OF TRANSPORT NOTICE No. M. 474

EXPLOSIONS IN DIESEL ENGINED VESSELS

NOTICE TO SHIPOWNERS,
SHIPBUILDERS AND CHIEF ENGINEERS

The Court of Formal Investigation which inquired into the explosion on the m.v. "Capetown Castle" on 17th October 1960 found that the explosion, which led to serious loss of life, may have occurred owing to an accumulation of oil in the air starting system of the port engine. An initial explosion led to flame acceleration which caused film detonations involving compressor oil in the main air pipe lines.

It had apparently been the practice on this vessel to clear choked drains on starting air pipe lines by means of a portable oil pressure pump, using lubricating oil as the pressure medium. The Court pointed out that this practice could result in oil being forced into the air pipe lines.

It is therefore recommended that:

(a) Oil force pumps should not be used to clear drains on starting air pipe lines.

(b) Oil from any source should, as far as practicable and reasonable, be excluded from air pipe lines. In particular, air compressor discharge lines should be provided with means for effective interception and draining of oil and water. If necessary, filters or separators should be fitted for this purpose and drains of adequate size and number should be fitted to air pipes, receivers and other fittings to avoid any accumulation of oil at low points in the system.

(c) Periodic inspections should, where practicable, include examination of air pipe lines to ensure that measures taken are effective.

Ministry of Transport,
London, S.E.1.
February 1963

MS. 7/8/045

Printed by H.M. Stationery Office Press, Harrow
(87043) Wt. 8313/M.3009 12M 1/63

DEPARTMENT OF TRADE AND INDUSTRY MERCHANT SHIPPING NOTICE No. M.651

FIRES INVOLVING LUBRICATING OIL

Notice to Shipowners, Masters and Skippers

This Notice supersedes Notice No. M.516

A number of cases have arisen of serious fire arising from a leakage or release of lubricating oil from engine crankcases, storage tanks, pipes, joints, heaters and filters being ignited by contact with hot surfaces or sparks. The following is a typical example and relates to a severe fire in an engine room following an explosion in the main diesel engine as a result of which the vessel was immobilised for twelve hours.

The explosion was caused by piston cooling oil being discharged from a fractured piston rod sleeve into one of the main engine cylinders and thence into the exhaust manifold where it formed an explosive mixture with scavenging air. A section of the manifold was shattered and flaming oil was sprayed about the forward end of the engine room and all over the main switchboard.

A 34-gallon froth extinguisher was used on the rapidly developing fire without much effect and the situation was beyond immediate control. The main engines were stopped but it was impossible to remain in the engine room, and the chief engineer and his staff operated the appropriate remote controls to stop the auxiliary machinery and shut off all fuel supplies to the machinery. All openings to the engine room were closed and CO_2 gas was injected to smother the fire. Six hours after the outbreak the chief and second engineers were able to enter the engine room from the tunnel door and put out all smouldering fires with hoses connected to the emergency pump.

The casualty shows that lubricating oil fires are potentially as dangerous as those from fuel oil and demonstrates the effectiveness of a fixed fire extinguishing installation and well fitting closing appliances in extinguishing a fire which is of such proportions that everyone is driven out of the machinery space.

Department of Trade and Industry
Marine Division
London WC1
December 1972

(MS 2/1/0151)

Printed in England by Her Majesty's Stationery Office at HMSO Press, Harrow
172529 Dd 888926 21,000 1/73

DEPARTMENT OF TRADE MERCHANT SHIPPING NOTICE No. M.681

FIXED FIRE SMOTHERING GAS INSTALLATIONS: SITING PRECAUTIONS FOR CO2 CYLINDERS

Notice to Owners, Masters and Officers of Merchant Ships and Fishing Vessels

Recent resurveys of CO2 installations employing a gang release system for total flooding of the machinery spaces has shown that in ships where the CO2 cylinder storage room is subject to severe vibration, or in cases where cylinder clamps have not been tightened properly after the cylinders have been removed for weighing or replenishment, cylinders have rotated resulting in some cases to malfunction and in some cases to the premature release of CO2 gas. In many cases the rotation of the cylinders has been such that operation of the system, if it had been required, would not have been possible due to misalignment of the valve operating levers.

To minimise this danger it is advisable in existing installations that arrangements for clamping and verifying the alignment of cylinders should be carefully checked at regular intervals between the surveys or inspections normally carried out by the Department's Surveyors.

Department of Trade
Marine Division
London
May, 1974

(MS 22/3/0385)

Printed in England by Her Majesty's Stationery Office at HMSO Press, Harrow
C812374 21M 5/74

Department of Trade Merchant Shipping Notice No. M.707

FIRES INVOLVING LOW PRESSURE OIL FUEL PIPES

Notice to Shipowners, Shipbuilders, Enginebuilders and Masters

1. A number of serious fires in machinery spaces have originated from the fracture of low pressure fuel oil pipes, operating at nominal pressures up to about 4 bars (58·8 lbsf/in 2) and associated with main propulsion or auxiliary diesel engines operating at above 300 RPM.

2. The low pressure pipes most frequently involved in fires investigated by the Department are the fuel pump suction rail carrying the discharge pressure from a fuel booster pump, pipes connecting the fuel rail to the fuel pumps and small bore copper pipes connected to the fuel suction rail for various purposes. Failures have often been associated with pressure fluctuations within the pipe or vibration from external sources.

3. In the light of this experience these fuel pipes should wherever possible, be located well away from potential ignition sources. It is recognised that choice of location may be limited in many cases but some of the small bore connections mentioned above could be made in safe positions. Where pipe fracture or coupling failure could lead to fuel spraying on a hot surface, for example, the engine exhaust-system, it is recommended that suitable screening arrangements should be provided to deflect the oil to a safe place.

4. Some of the fires investigated, in machinery spaces with limited headroom over the engine tops, have damaged essential electrical cables carried in trays attached to the deckhead over the engine; where there is no alternative route available, consideration should be given to the protection of the cables from fire damage. Such fire protection should take into account the cable rating and the normal heat dissipation requirements.

5. Ship's staff should ensure that any fuel leakage is dealt with promptly and maintain screening arrangements, and pipe securing arrangements in an efficient condition.

Department of Trade,
Marine Division
London
January, 1975

MS 7/3/0969

Printed in England by Her Majesty's Stationery Office at HMSO Press, Harrow
C819379 Dd 200468 21M 2/75

Department of Trade Merchant Shipping Notice No. M.709

FIRE FIGHTING ON SMALL CARGO SHIPS

Notice to Shipowners, Masters and Seamen

(*This notice supersedes Notice No. M.591*)

The Department's investigation of an incident for which a small coastal tanker was abandoned by the crew following a serious fire in the engine room brought to light that the fire was caused by a fuel line breaking off and allowing fuel to flow over the engine and thus ignite; the fire burned until the contents of the fuel tank were exhausted. Because of lack of supervision in the machinery spaces the fire was not detected in the early stages and when it was detected the procedure followed by the crew in fighting the fire was not entirely satisfactory.

It is apparent that the crew had not received adequate training in fire fighting methods and that the master and engineer had insufficient knowledge of the use of the emergency controls provided. The simple act of closing the fuel tank valves by the remote control and thus shutting off the fuel supply would have gone a long way towards limiting the spread of the fire on this vessel.

The Department wish to draw attention to the necessity for proper crew training as required by Rules 5(3) and 5(4) of the Merchant Shipping (Musters) Rules 1965 and to emphasise in particular the importance of ensuring that all crew members have a proper knowledge of the use of the fire fighting appliances provided. Masters are reminded that under Section 68(1) of the Merchant Shipping Act 1970 an official log book must be kept and under Rule 3 of the Merchant Shipping (Official Log Books) Regulations 1972 (S I 1972 No 1874) and Rule 3 of the Merchant Shipping (Official Log Books) (Fishing Vessels) Regulations 1972 (S I 1972 No 1873) entries must be made in the official log book of each occasion on which the life-saving appliances and equipment are examined and of the reasons why any drill or examination was not carried out.

The Department also wish to draw attention to the importance of close supervision of machinery spaces on small cargo vessels not equipped to run unattended and not having fire detection facilities, and to the necessity for masters and engineers of ships of this type to be familiar with all the emergency controls provided for the safety of the vessel.

Department of Trade
Marine Division
London
April, 1975 (MS 7/3/0768)

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Department of Trade Merchant Shipping Notice No. M.750

PREVENTION OF OIL FIRES IN MACHINERY SPACES OF SHIPS

Notice to Shipowners, Shipbuilders, Engine Builders, Masters and Engineer Officers

(*This Notice Cancels Notices Nos. M.439 and M.617*)

A number of serious fires have occurred in ships' engine and boiler rooms and the Department of Trade recommends that the precautions for preventing fires described in this Notice should be taken.

OIL IGNITED BY CONTACT WITH HEATED SURFACES

The following cases have occurred of accidental ignition of oil by contact with heated surfaces.

In a foreign-going passenger vessel the overflow pipe from an unpurified diesel oil tank was an open goose neck situated within the engine room. When the tank was inadvertently over-filled, oil poured from this goose neck onto the hot exhaust of an auxiliary engine and ignited. The ensuing fire was soon out of control and the machinery space abandoned. The passengers and some of the crew were forced to abandon the vessel in the ship's lifeboats and the vessel was eventually towed to port for repairs.

A similar incident occurred on a small trawler. It was the normal practice when filling the "stand by" daily service tank to overflow it into the "in use" tank through an overflow pipe. However, in this instance a small sounding plug had been removed from the top of the "stand by" tank, and the excess oil flowed not into the other tank but out of the plug hole and down onto the main engine, where it ignited immediately. The fire was controlled by the crew using normal equipment and techniques, but the chief engineer received extensive burns about the head and shoulders which necessitated a prolonged stay in hospital and a skin graft.

Overflow incidents of this type often occur during bunkering. In one case on a 250,000 ton steam turbine tanker the gas oil tanks were so arranged that the service tank overflowed into the double bottom tank. However, during bunkering both these tanks became full and excess gas oil flowed up their common vent pipe, which terminated with a goose neck inside the funnel casing. This oil was partially retained in the funnel where it was in contact with the boiler and auxiliary diesel exhausts, and part escaped via a small scupper onto the funnel deck where it saturated the lagging of hot pipes. The result was a fire in both spaces, showering burning gas oil into the engine room starting secondary fires.

In another case, a fuel line was fitted with duplex filters with a change-over cock, the handle of which also acted as a safety device which should have made it impossible to open up the filter under pressure. When examined it was found that the change-over handle could be put on the wrong way round, i.e. the handle could indicate and protect one filter when in fact the other filter was under pressure. In this case, the filter indicated as being out of use was being slackened off preparatory to cleaning and the resulting spray of fuel oil striking the hot exhaust caused an immediate and serious fire. In somewhat similar circumstances involving a lubricating oil filter, a fire resulted in the death of one of the ship's officers.

Lubricating oil fires are potentially as dangerous as those from fuel oil. In one incident, an explosion was caused by piston cooling oil being discharged from a fractured piston rod sleeve into one of the main engine cylinders and thence into the exhaust manifold, where it formed an explosive mixture with scavenging air. A section of the manifold was shattered and flaming oil was sprayed about the forward end of the engine room and all over the main switchboard.

A 34-gallon froth extinguisher was used on the rapidly developing fire without much effect and the situation was beyond immediate control. The main engines were stopped but it was impossible to remain in the engine room, and the chief engineer and his staff operated the appropriate remote controls to stop the auxiliary machinery and shut off all fuel supplies to the machinery. All openings to the engine room were closed and CO_2 gas was injected to smother the fire. Six hours after the outbreak, the chief and second engineers were able to enter the engine room from the tunnel door and put out all smouldering fires with hoses connected to the emergency pump.

A number of serious fires in machinery spaces have originated from the fracture of low pressure fuel oil pipes, operating at nominal pressures up to about 4 bars (58·8 lbsf/in²) and associated with main propulsion or auxiliary diesel engines operating at above 300 RPM. The low pressure pipes most frequently involved in fires investigated by the Department are the fuel pump suction rail carrying the discharge pressure from a fuel booster pump, pipes connecting the fuel rail to the fuel pumps and small bore copper pipes connected to the fuel suction rail for various purposes. Failures have often been associated with pressure fluctuations within the pipe or vibration from external sources.

Numerous cases similar to those above are recorded in the Department's casualty records and many could have been easily avoided. In order to prevent similar accidents on new or existing ships the following precautions are recommended:

(1) **Overflow Arrangements**

(*a*) Steps should be taken to ensure that overflow arrangements do not permit the overflowing oil to come into contact with boilers, hot engine parts, or other heated surfaces where it might be ignited. Where oil tight flats are fitted with drain pipes, these should preferably be open pipes; but readily accessible cocks would not be objected to and may even be necessary where inter-flooding of two separate watertight compartments could occur through the drains;

(*b*) Overflows from settling tanks and daily service tanks should be led back to the storage tanks or to an overflow tank. An alarm device should be provided to indicate when the tanks are overflowing.

(2) **Sounding Arrangements**

(*a*) Care should be taken to see that the sounding arrangements or oil level indicating gear on settling tanks and daily service tanks are such as will not permit the escape of oil should the tanks be overfilled;

(*b*) Oil level indicators should be of a type which will not allow oil to escape in the event of damage to them. It is preferable that they should be of a type which does not require piercing of the lower part of the tank. Round gauge glasses should not normally be fitted to oil tanks, but suitably protected gauges having flat glasses of substantial thickness and self-closing fittings may be allowed.

(3) **Fuel Oil Pipes**

(*a*) Oil pressure pipes which are used for conveying heated oil should be placed in conspicuous and well lit positions above the platform;

(*b*) Small bore flexible pipes intended to convey oil should be made of suitable fire resisting material. All other pipes should be made of steel or other suitable material;

(*c*) Where pipe fracture or coupling failure could lead to fuel spraying on a hot surface, for example the engine exhaust-system, suitable screening arrangements should be provided to deflect the oil to a safe place.

(4) **Oil Fuel Units**

(*a*) Where oil which might escape from any oil fuel pump, filter or heater may come into contact with boilers or other heated surfaces, provision should be made to prevent this by the erection of suitable screens;

(*b*) Save-alls or gutters should be provided under the oil fuel pumps, heaters or strainers, to catch oil leakage or oil that may be spilled when any cover or door is removed, and likewise at the furnace mouths to intercept oil escaping from the burners;

(*c*) Any relief valve fitted to prevent overpressure in the oil fuel heater should be in closed circuit;

(*d*) Master oil valves at the furnace fronts should be of the quick closing type fitted in conspicuous and readily accessible positions. It is recommended that they be painted bright red for identification in an emergency;

(*e*) Provision should be made to prevent oil from being turned on to any burner unless it has been correctly coupled to the oil supply line, and to prevent the burner being removed before the oil is shut off;

(*f*) A suitably mounted plan of the oil fuel arrangements should be furnished for the guidance of the engineer officers.

(5) **Means of Escape**

There should be at least two means of escape from spaces containing boilers or machinery.

FURTHER PRECAUTIONS

In the interests of safety, owners of cargo ships should arrange that the oil fuel installations comply generally with the Department of Trade requirements in regard to such installations on passenger ships.

Serious fires have often originated from apparently insignificant causes such as burning oil running out of the furnace fronts on to the tank top, or a spray of oil from either a defective gland or joint or a fractured pipe, not perhaps readily noticeable but easily ignited. The conditions which are most dangerous and which it is most important to avoid are conditions which will allow a small fire to spread to waste oil, in the bilges or on double-bottom tank tops, and so get rapidly out of control. Cleanliness is essential for safety and a high standard of cleanliness must be maintained.

Woodwork or other readily combustible material should not be used in boiler rooms and machinery spaces where oil fuel is used. No combustible material should be stored near any part of the oil fuel installation. Bituminous or similar flammable compounds which give off noxious fumes on combustion should not be used in boiler and machinery spaces.

Special attention should be given to the positions and condition of the fire extinguishing appliances including hydrants, hoses and spray nozzles, fire extinguishers, the means for closing the machinery spaces to exclude air in a fire and the means for remote control of fixed fire extinguishing installations and of oil fuel valves.

Some of the fires investigated, in machinery spaces with limited headroom over the engine tops, have damaged essential electrical cables carried in trays attached to the deckhead over the engine; where there is no alternative route available, consideration should be given to the protection of the cables from fire damage. Such fire protection should take into account the cable rating and the normal heat dissipation requirements.

Change-over cocks and their safety devices associated with duplex filters in fuel and lubricating oil systems should be designed and maintained to ensure that the working filter cannot be opened up inadvertently.

Ship's staff should ensure that any fuel leakage is dealt with promptly, and should maintain screening arrangements and pipe securing arrangements in an efficient condition.

As the froth making liquids of chemical extinguishers are more likely to deteriorate at higher temperatures, those extinguishers should be kept in the coolest practicable places.

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DEPARTMENT OF TRADE MERCHANT SHIPPING NOTICE No. M.765

MAINTENANCE AND READY AVAILABILITY OF FIRE APPLIANCES

Notice to Shipowners, Masters and Officers

It is a principle of fire fighting that all equipment must be maintained in good order and be kept available for immediate use at all times. This applies equally to such equipment as fire extinguishers and hoses as it does to fire pumps and fixed fire extinguishing systems.

2. A number of cases have arisen in which non-portable fire extinguishers have been secured in such a manner that, in an emergency, they could not have been immediately brought into use. The extinguishers concerned were of the 10 gallons capacity chemical foam type mounted either on two wheels or trunnions and supported on a steel foot or leg. Operation of the extinguisher included rotating it from the vertical through 90 degrees to a horizontal position thus mixing the chemical solutions. It has been found that the foot or leg supporting the extinguisher has been adapted as a means of bolting the appliance to the deck in order to prevent inadvertent operation in a seaway. When required in an emergency, the extinguishers could not be released without the use of spanners.

3. It is recommended that extinguishers of this type should be secured by a band type bracket fitted in halves round the body of the extinguisher with a non-corrodible hinge and securing pin. Whatever method is chosen to secure the extinguisher it should be capable of ready release without the use of tools.

4. In other cases, emergency fire pumps have been found to be defective when required in an emergency or in the course of testing for statutory survey. It should be recognised that a defective emergency fire pump would involve the detention of a ship until the pump is repaired or other acceptable arrangements are made.

5. Ships' staff should regularly examine and test all safety equipment to ensure that it can be brought into use immediately in an emergency.

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DEPARTMENT OF TRADE MERCHANT SHIPPING NOTICE No. M.825

PRECAUTIONS TO BE TAKEN TO PREVENT THE ACCIDENTAL RELEASE OF CO_2 FIXED FIRE SMOTHERING SYSTEMS

Notice to Owners, Masters and Officers of Merchant Ships and Fishing Vessels, and to Ship Repairers

1. In recent years there have been a number of incidents involving loss of life when the CO_2 Fixed Fire Smothering System has been released accidentally while a ship has been in port undergoing maintenance or repair. Similar incidents have also occurred due to careless actions by crew members when the ship has been in service, either with the ship at sea or during a period in port.

2. The accidents have occurred when work was being carried out either on the CO_2 system or in the space containing the CO_2 cylinders. The lives of men working in that space, in the engine room, in the cargo spaces or in other spaces connected to the CO_2 system were endangered by a failure to issue suitable instructions or where necessary to guard against accidental release.

3. Shipowners will be aware that responsibility for fire protection and initial fire-fighting measures remains with them unless and until they delegate that responsibility: in which case there should be a clear written agreement between them and the ship repairers. Paragraph 30 of the "Report of the Working Party on fire prevention and fire-fighting on ships in port", reproduced for information as an appendix to this notice, deals with this point. (An extract from this report may be found at Appendix B of the *Survey of fire appliances—Instructions for the guidance of surveyors*, published by HMSO).

4. Similarly where work is to be carried out on any part of the CO_2 system, including the remote controls, or in any space containing CO_2 cylinders or a CO_2 bulk storage unit, the Department considers that the responsibility for ensuring continued protection against accidental release of gas remains with the owner, unless there is a clear written agreement which delegates that responsibility to the ship repairer or the company undertaking the work.

5. When the nature of the work requires the system to be made inoperative or where it has to be temporarily immobilised to permit safe working, the owner or his representative should first give careful consideration to the various fire risks in the spaces normally protected by the CO_2 system. In addition, during the period while the system is not available, work which would increase the hazard within the protected spaces should not be permitted.

6. Where the system has been made inoperative or temporarily immobilised to permit safe working the owner or his representative should ensure that the system is restored to its operating condition on the completion of the work. In the cases where the responsibility for ensuring against accidental release has been delegated in writing to the ship repairer or to a company undertaking work on the system, the owner or his representative in conjunction with a representative from the other company should ensure that the system is restored to its operating condition.

7. To prevent unauthorised use, the space containing the CO_2 cylinders or the CO_2 bulk storage unit should normally be kept locked at all times, with one of the keys being readily available in a glass fronted case near to the entrance to the space.

Department of Trade
Marine Division
London WC1V 6LP
January 1978

APPENDIX

REPORT OF THE WORKING PARTY ON FIRE PREVENTION AND FIRE-FIGHTING ON SHIPS IN PORT

30. In ships under construction the responsibility for fire-prevention and initial fire-fighting measures rests entirely with the shipbuilder. In all other cases it remains the shipowner's responsibility throughout, unless and until he delegates that responsibility, in which event there should be a clear agreement between the shipowner and ship repairer. Divided responsibility must always be avoided; it can only lead to confusion and has been the main cause of the disastrous results of some fires. We strongly recommend, therefore, that in relation to ships undergoing major repair there should be a clear (preferably written) agreement between the owners and repairers concerned setting out in precise terms where the responsibility for fire protection lies. The terms of this agreement should be made known to all concerned and should include a clause stating which party accepts responsibility for recommending a cessation of pumping water into a ship on fire on the ground that further water would imperil the ship's stability.

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DEPARTMENT OF TRADE — MERCHANT SHIPPING NOTICE No. M.852

USE OF DIESEL ENGINE STARTING AIDS CONTAINING FLAMMABLE MIXTURES

Notice to Shipowners, Fishing Vessel Owners, Engine Builders, Masters, Skippers and Engineer Officers

A serious accident occurred recently on a small diesel-engined vessel, not of United Kingdom registry, as a result of which one man died and three others suffered severe burns. When the engine, arranged for compressed air starting, was being started an explosion occurred in one of the cylinders. The explosion smashed the cylinder and caused a severe fire in the engine room. The fire was fed by diesel oil from the broken fuel main and intensified by escaping compressed air.

The primary cause of the explosion was determined by the investigating authority to have been the introduction into the air intake manifold, by aerosol spray, of an excessive quantity of a fluid sometimes used for assisting the starting of diesel engines.

All persons concerned with the operation of diesel engines are advised to bear in mind the dangers that can arise from the use of volatile, low flash point starting fluids in engines, particularly those which are started by admission of compressed air to the cylinders.

Regardless of the engine starting arrangements, such fluids should always be used in accordance with makers' instructions but never at the same time as cylinder or manifold heater plugs are being used, or when the engine is hot.

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Department of Trade
London WC1V 6LP
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DEPARTMENT OF TRADE — MERCHANT SHIPPING NOTICE No. M.908

HEATING APPLIANCES BURNING SOLID FUEL

Notice to Owners, Masters, Officers and Seamen of Merchant Ships and Yachts; and to Owners, Skippers and Crews of Fishing Vessels

This Notice supersedes Notice No. M.575

1. A number of deaths have occurred where seamen have been asphyxiated by fumes given off from heating appliances burning solid fuel.

2. Where any such oxygen-consuming appliances, whether permanent or temporary, are in use on board the following precautions should be strictly observed:

(i) **Heating appliances.** The heating appliance itself should be regularly and frequently examined to ensure that it is maintained in a condition which will enable it to function properly. Particular attention should be paid to the following points:
- (*a*) doors where fitted should be capable of being completely closed and where mica panels are incorporated these should be intact;
- (*b*) draught regulators should function properly;
- (*c*) the separate components forming the appliance must fit properly and be free from cracks;
- (*d*) the flue pipe must be unobstructed by soot deposits—any horizontal (or near horizontal) lengths of flue should receive frequent attention.

(ii) **Ventilation.** In cases where deaths have occurred in the circumstances referred to above, the ventilation system has been found inefficient due to having been interfered with or neglected. It is not unusual to find inlet ventilators deliberately blocked, and butterfly and sliding vents in cabin doors have been found to be in the closed position and immovable.

It cannot be too strongly impressed upon all concerned that adequate ventilation of accommodation, and in particular of sleeping rooms, is of primary importance and on no account must a ventilation system be interfered with so as to prevent its proper functioning.

3. **It is recommended that a copy of this Notice should be posted up in all spaces heated by solid fuel appliances.**

Department of Trade
Marine Division
London WC1V 6LP
November 1979

Dd 563532 15,005 12/79 Ed (16933)

DEPARTMENT OF TRADE — MERCHANT SHIPPING NOTICE No. M.910

LOSS OF LIFE IN CARGO TANKS, CARGO HOLDS AND OTHER ENCLOSED SPACES

Notice to Owners, Masters, Officers and Crew Members of all Merchant Ships and to Shipbuilders

1. Within the last few years a number of seamen have lost their lives in cargo tanks, cargo holds and other enclosed spaces.

2. In one incident seven men were killed when they were overcome in the cargo tank of a product tanker. Initially a crew member entered the tank, which contained a few feet of slops comprising tallow, vegetable oils and seawater, prior to the commencement of a tank washing operation. This was contrary to normal procedures because the tank had not been ventilated nor had the atmosphere been tested to ascertain whether it was safe to enter. When it was realised that the crew member was in some difficulty and before it was appreciated that this was because the atmosphere in the tank was unsafe, six other crew members had rushed into the tank to assist instead of following the established and practised emergency procedures for a tank rescue. It was later concluded that the atmosphere was not only deficient in oxygen but contained quantities of other gases generated by the residue. Despite a determined rescue attempt by the remaining crew members wearing breathing apparatus, all seven men lost their lives.

3. Two other incidents occurred on bulk carriers. In the first incident a crew member unsuspectingly entered an unventilated cargo hold that contained various quantities of timber, steel and general cargo loaded some two months earlier. He was seen to collapse and the three men who rushed in to help also got into difficulties because the atmosphere was deficient in oxygen. A rescue attempt was mounted by crew members wearing breathing apparatus but only one of the casualties survived. In the second incident a shore official and four crew members entered a hold containing pig iron loaded three weeks earlier. The ventilators for the hold had been kept closed during the voyage in anticipation of rough weather and the hold had not been ventilated prior to entry. The men were well down into the hold when they experienced difficulties due to the oxygen deficient atmosphere. Although every effort to rescue them was made by crew members using breathing apparatus only one of the five who entered the hold survived. Fortunately no additional lives were lost in this case due to reckless entry by unprotected personnel.

4. In another incident four senior crew members on board a liquefied gas carrier entered one of the double bottom tanks from the duct keel. While they were in the tank one of the men collapsed. Two men remained to help him while the other went to summon assistance. Because no one had been instructed to stand by at the tank entrance and because no safety equipment

was kept ready for immediate use in the event of a situation of this type developing, it proved difficult to mount a rescue attempt and the three men in the tank all lost their lives. Subsequent investigation showed that the tank had not been properly ventilated and that inert gas had leaked into the double bottom tank from a known defect in the bulkhead separating the tank from an adjacent void space.

5. All the above incidents have been described in detail to illustrate the following points.

(*a*) The atmosphere in any enclosed space may be incapable of supporting life. It may be lacking in oxygen content and/or contain flammable or toxic gases and should be considered unsafe unless it has been thoroughly ventilated and properly tested.

(*b*) An unsafe atmosphere may be present in any enclosed or confined space including cargo holds, cargo tanks, pump rooms, fuel tanks, ballast tanks, fresh water tanks, cofferdams and duct keels. Furthermore, it should never be assumed that precautions need not be taken for holds or tanks containing apparently innocuous cargoes.

(*c*) An enclosed or confined space should not be entered unless a "permit-to-work" or similar authority has been obtained.

(*d*) Any one who enters an enclosed or confined space to attempt to rescue a person without first taking suitable precautions not only unnecessarily risks his own life but will almost certainly prevent his colleague being brought out alive.

6. The "Code of safe working practices for merchant seaman" copies of which should be on .board all ships, contains detailed advice on entering enclosed or confined spaces. The warnings contained in the Code should be heeded and the recommended procedures followed.

7. It is essential that there should be clearly laid down procedures for entering enclosed or confined spaces—preferably in the form of a "permit-to-work"—to ensure that all the necessary safety measures and precautions are taken.

8. The Code recommends that oxygen testing equipment should be carried on board all ships. Its use, maintenance and regular calibration in accordance with the manufacturer's instructions is strongly emphasised. Additional information on entry into tanks and enclosed spaces on ships carrying dangerous chemicals in bulk is contained in Notice No. M.576.

9. Investigations into incidents involving loss of life have shown that in some of the cases there were no established rescue procedures for dealing with accidents in enclosed or confined spaces. Procedures for dealing with such incidents should be formulated where they do not already exist. Regular drills should be conducted to simulate the rescue of a crew member or life sized dummy from an enclosed or confined space—the space having been proven safe for the exercise. These drills would bring all the emergency procedures into use including, where appropriate, the use of breathing apparatus and lifelines by the rescuers, the control of their air supplies and the provision of replacement air supplies, the lowering of a resuscitator and a stretcher, the rigging of portable hoisting equipment over suitable openings, and the recovery of the "unconscious person" to prove and practise the formulated emergency procedure.

10. When breathing apparatus is being used difficulty is sometimes experienced in gaining entry into enclosed or confined spaces due to the restricted size of the openings. Similar difficulties are experienced in recovering an injured or unconscious person from such spaces, or from a space with restricted access leading to another enclosed space. It is recommended therefore that with new tonnage, access hatches to or manholes or openings in enclosed or confined spaces should be of a suitable size to permit entry by a person wearing breathing apparatus and to allow the recovery of an injured or unconscious person. Furthermore the access hatch, manhole or other opening should be positioned, whenever possible, to enable an unobstructed recovery of the injured or unconscious person from the lowest part of the space.

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DEPARTMENT OF TRADE MERCHANT SHIPPING NOTICE No. **M.946**

FIRES INVOLVING ELECTRIC HEATING OR DRYING EQUIPMENT

Notice to Owners, Masters, Officers and Crew Members of Merchant Ships, Owners, Skippers and Crew Members of Fishing Vessels, Shipbuilders and to the Builders of Fishing Vessels

This Notice supersedes Notice M.570

1. In recent years there have been a number of fires involving electric heaters or drying equipment incorporating an electric heater.

2. In a number of cases fires have resulted from items of clothing, bedding or other objects being placed too close to, or inadvertently falling onto, unguarded electric heaters. In another incident a drying cabinet was overfilled thereby blocking the ventilation apertures with the result that the contents overheated and caught fire. Other incidents have involved portable electric heaters installed as temporary heating during very cold weather or for use in cold climates when insufficient attention was given to the positioning of the heaters so that they were too close, or immediately below, flammable objects.

3. It is important that all fixed electric heaters are fitted with suitable guards securely attached to the heater and that the guards are maintained in position at all times. Temporary arrangements to hang clothing above the heaters or to dry clothing on the heaters should not be permitted and drying of clothing should only be carried out by using suitably designed equipment.

4. When using drying cabinets or similar appliances care should be taken so that the ventilation apertures are not obscured by overfilling of the drying space. As the ventilation apertures of drying appliances may become blocked due to accumulations of fluff from clothing any screens or fine mesh covers associated with the ventilation apertures should be regularly inspected and cleaned.

5. The use of portable heaters should be avoided. However, if they are used with the ship in port as temporary heating during repairs and as additional heating during inclement weather, the heaters should not be positioned on wooden floors or bulkheads, carpets or linoleum without the provision of a protective sheet of a non-combustible material. Portable heaters should be provided with suitable guards and care should be exercised when positioning the heater in relation to furniture and other fittings in the cabin or other space. Again, drying arrangements in relation to these heaters should not be permitted.

6. The construction and installation of electric heaters in merchant ships and fishing vessels should take due account, as appropriate, of the requirements of Regulation 47(6) of the Merchant Shipping (Passenger Ship Construction) Regulations 1980, Regulation 10(11) of the Merchant Shipping (Cargo Ship Construction and Survey) Regulations 1980, Regulation 14(5) and Schedule 6, paragraph 7(3) of the Merchant Shipping (Crew Accommodation) Regulations 1978, Regulation 14(5) of the Merchant Shipping (Crew Accommodation) (Fishing Vessels) Regulations 1975 as supplemented by paragraph 2.10.1 of the Survey of crew accommodation in merchant ships —Instructions for the guidance of surveyors and paragraph 2.10 of the Survey of crew accommodation in fishing vessels—Instructions for the guidance of surveyors.

7. Permanent electric heaters are normally supplied with installation instructions by the manufacturers and these should be carefully complied with.

8. Attention is also drawn to chapter 2 and chapter 26 of the Code of safe working practices for merchant seamen.

Department of Trade
Marine Division
London WC1V 6LP
September 1980

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DEPARTMENT OF TRADE MERCHANT SHIPPING NOTICE No. **M.971**

THE SAFE CARRIAGE OF COAL CARGOES
EMISSION OF FLAMMABLE GASES AND SPONTANEOUS COMBUSTION

Notice to Shipowners, Shipbuilders, Masters and Officers

Superseding M Notices M106 and M682

1. **Introduction** (See also Merchant Shipping Notice M970)

1.1 The principal aims of this Notice are to remind those engaged in the carriage of coal of the dangers associated with the emission of flammable gases and spontaneous combustion and to provide advice on means to reduce the risk of such dangers.

1.2 The recommendations in Section 3.3 of this Notice do not accord with those dealing with spontaneous combustion found in Appendix B of the IMCO Code of Safe Practice for Solid Bulk Cargoes (1980 Edition). After consideration of casualty experience and in consultation with industry it was agreed that the main emphasis should be placed on the precautions against explosion due to methane emission and the recommendation in this Notice should be followed in preference to that given in the above IMCO Code.

1.3 It is recommended that the provisions contained in this Notice are complied with in all ships carrying coal cargoes.

2. **Dangers which can arise**

2.1 **Emission of flammable gases**

All grades of coal will emit methane, an odourless flammable gas which is less dense than air. A methane/air mixture containing between 5 per cent and 15 per cent methane constitutes an atmosphere which can be readily ignited by sparks or naked flames (eg electrical or frictional sparks, a match, or lighted cigarette etc) to produce a highly dangerous and potentially lethal explosion. In recent years such explosions have resulted in a number of deaths and serious injuries.

Although a methane/air mixture containing more than 15 per cent methane is not explosive itself it could, after dilution with air, become explosive and therefore should also be regarded as hazardous.

2.2 **Spontaneous combustion**

Spontaneous combustion can occur with certain types of coal. Reaction with oxygen causes the temperature of the coal to rise to a point at which self ignition occurs and burning commences. Should spontaneous combustion occur, a deep seated fire may develop and a very difficult and dangerous situation can arise.

3. **Precautionary measures**

The dangers outlined above can be minimised and possibly eliminated if the following safeguards are carefully observed.

3.1 **Safeguards applicable to the ship**

3.1.1 bulkheads and decks forming the boundaries between the cargo compartments and any accommodation space, any other enclosed space which can be used by the crew or shore personnel (eg deck store rooms, work shops, pumprooms, cofferdams, duct keels, forecastle, tweens etc) or any machinery space, shaft tunnel, chain locker, or similar space, should be gas-tight;

3.1.2 all reasonable measures should be taken to prevent gases emitted from the cargo accumulating in the adjacent enclosed spaces referred to above (eg avoid placing access hatches or other openings to cargo compartments in such spaces, ensure that ventilation trunks from the cargo compartments are in a sound structural condition and gas-tight whenever they pass through any enclosed space, etc).Where for sound practical reasons this cannot be done special arrangements should be made, eg hold access from within a mast house or deckhouse should be in a separate space with its own ventilation. In all such cases warning Notices should be prominently displayed on the entry door;

3.1.3 all the enclosed spaces referred to in 3.1.1 above should be provided with efficient means of ventilation; which in the case of such spaces as cofferdams, chain lockers, etc, may be by means of access openings;

3.1.4 steps should be taken to prevent any gases which may be emitted from the coal cargo from entering any other cargo compartment not being used for the carriage of coal;

3.1.5 all coal cargo compartments should be provided with effective ventilation to remove any explosive or flammable gas which might accumulate above the surface of the coal cargo. Ventilation may be by natural or mechanical means and when conditions permit, assisted by the partial opening of hatch covers. On no account should the arrangements be such that air can be directed into the body of the coal

as this could promote spontaneous combustion. The arrangements should provide only for surface ventilation and any openings which provide ventilation to the lower parts of the cargo space should be blanked off before loading commences. Whilst there are no statutory requirements for surface ventilation the Department, on receipt of the appropriate fee, will examine the arrangements proposed for a particular ship against the recommendations, where appropriate of Circular 1641;

3.1.6 new ships intended for coal cargoes and similar existing ships undergoing substantial repairs or modifications should comply with the following:

3.1.6.1 electrical equipment and associated wiring other than that referred to in the footnote below should not be fitted in any cargo space or adjacent enclosed spaces, or deck house, or ventilation system to such a space where flammable gases may accumulate. In such spaces through runs of cables should be suitably mechanically protected, have no joints and be of a type approved for use in tankers or be enclosed in heavy gauge screwed steel conduit;

3.1.6.2 points of entry and exit of any electric cables should be suitably sealed to prevent the passage of gas into any adjacent spaces or contiguous enclosures such as contactor boxes, or switch gear, or cubicles;

3.1.6.3 other existing ships should comply with the requirements for new ships except that:

(i) electrical equipment which is "certified safe" to an acceptable standard and which is essential for operational and safety purposes may be fitted in all spaces described in 3.1.6.1 above except in cargo spaces;

(ii) junction boxes which are "certified safe" to an acceptable standard may be permitted in runs of cable which may be of standard shipboard type;

(iii) equipment and cables which do not comply with these requirements should be positively isolated either by the removal of suitable links; or the disconnection of the supply cables; or locking the isolation device in the "off" position with the locking device held by a responsible officer. A warning notice should be posted at the point of isolation; and

FOOTNOTE

There is no restriction on the installation of Intrinsically Safe electrical equipment which is certified to an acceptable standard and associated cables, if properly installed and maintained. Megger testing of such equipment should not normally be undertaken.

3.1.7 whilst compliance with the recommendations of this Notice should reduce considerably the risk of a methane explosion the Department recognises that circumstances could arise when it may be prudent to test an atmosphere for the presence of methane. This can be done using a methanometer; or a gas detector or an explosimeter suitably calibrated for use in a methane atmosphere. However, it should be appreciated that in order to give reliable results such an instrument must be regularly serviced and calibrated; and whilst on board properly maintained.

The Department recommends that a suitable instrument is kept on board.

3.2 **General safeguards applicable to the carriage of all types of coal cargoes to be undertaken by the Master**

3.2.1 **Prior to loading the cargo the Master should:**

3.2.1.1 be satisfied that an inspection of the electrical equipment and wiring which is permitted to remain alive in accordance with 3.1.6 has been carried out to ensure that there are no obvious faults. In addition an insulation resistance (megger) test* should be made of all electric circuits except that for ships regularly carrying coal this need not be done for every loading provided a test is carried out at regular intervals to prove that the electric circuits are satisfactory; and

3.2.1.2 ensure that all cargo compartments have been inspected to establish that;

(i) any significant quantities of previous coal cargoes and all residues of other cargoes have been removed;

(ii) the bilge wells are free of water and waste material, strum boxes clear and that limber boards where fitted are intact; and

(iii) the bilge pumping system is in efficient working order.

3.2.2 **During the loading of the cargo the Master should ensure:**

3.2.2.1 that the cargo is not stowed adjacent to any hot areas; and

3.2.2.2 that as loading is nearing completion the cargo is stowed and trimmed in all directions as level as is reasonably practicable to promote ventilation above the surface of the cargo to prevent the formation of pockets of flammable gases.

FOOTNOTE

*There is no restriction on the installation of Intrinsically Safe electrical equipment which is certified to an acceptable standard and associated cables, if properly installed and maintained. Megger testing of such equipment should not normally be undertaken.

3.2.3 On completion of the voyage the Master should:

3.2.3.1 ensure that there are no naked flames or equipment liable to spark in the vicinity when removing hatch covers and that those electrical circuits which had been positively isolated are not re-connected until the hatch covers have been removed and all spaces where flammable gases may accumulate have been properly ventilated. This action is particularly important, where, for any reason it had not been possible during the voyage to provide effective ventilation of the spaces above the cargo.

3.2.4 **At all times the Master should:**

3.2.4.1 prohibit smoking, the use of naked flames or welding in the cargo and adjacent areas unless satisfied that all spaces where flammable gases may accumulate have been properly ventilated;

3.2.4.2 ensure that, weather permitting, all cargo spaces are effectively ventilated; and

3.2.4.3 prevent personnel from entering any enclosed space in which methane might accumulate eg via a non-gastight access hatch or doorway etc until it has been thoroughly ventilated. The guidance given in Chapter 10 of the Code of Safe Working Practices for Merchant Seamen should be followed.

3.3 Spontaneous combustion

3.3.1 it may be possible to detect the development of spontaneous combustion by regularly taking temperatures in the cargo compartments on longer voyages (say 5 days or more). However coal is a bad conductor of heat and the failure to detect any hot areas in the stow should not be taken as a sign that spontaneous combustion is not taking place in areas not accessible for the taking of temperatures. Use should be made of any suitable pipes or trunks passing down through the holds from the deck to take temperatures, but digging into the body of the coal is not recommended.

3.3.2 To minimise the risk of explosion due to methane emission even when spontaneous heating is suspected, ventilation of the spaces above the cargo, which might include limited opening of hatch covers, should continue until there is clear evidence that the cargo is burning as the result of spontaneous combustion. At this stage the aim would be to contain the fire in the cargo hold and to achieve this the Master should:

3.3.2.1 ensure that the cargo compartment is completely closed down against the entry of air;

3.3.2.2 apply carbon dioxide, inert gas or high expansion foam into the hold if these are available;

3.3.2.3 if necessary, use water to cool the boundaries of the cargo space but water or steam should never be applied directly to the burning coal; and

3.3.2.4 ensure that the space remains sealed until the ship reaches port and specialist advice followed concerning the precautions necessary, including the time when it would be safe to open hatch covers and work the cargo.

4. Cargo stability

The danger of the cargo shifting will be minimised provided that it is stowed and trimmed in all directions as reasonably level as is practicable (see Section 3.2.2.2). During shipment some coal cargoes, eg slurries, duffs, etc might liquefy and shift. Merchant Shipping Notice M970 which deals with these types should also be consulted.

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USE OF LIQUEFIED PETROLEUM GAS (LPG) IN DOMESTIC INSTALLATIONS AND APPLIANCES ON SHIPS, FISHING VESSELS, BARGES, LAUNCHES, AND PLEASURE CRAFT

EXPLOSIONS, FIRES AND ACCIDENTS RESULTING FROM LEAKAGE OF GAS

Notice to Shipbuilders, Owners, Masters, Skippers, Officers and Seamen of Merchant Ships and Fishing Vessels, Owners and Builders of pleasure craft and to other users of marine craft

This notice supersedes Notice No. M.603

In view of the considerable use on smaller cargo ships, fishing vessels, tugs, barges, launches and pleasure craft of bottled hydrocarbon gases for cooking, water and space heating, refrigerators, etc., the Department wishes to draw attention to the possible dangers which may accompany their use and to the need for installations to comply at least with the requirements of British Standard Institution publication BS 5482: Part 3: 1979—The code of practice for domestic butane and propane gas-burning installations; Part 3—Installations in boats, yachts and other vessels. Individual appliances and fittings should comply with the relevant British Standard Specifications listed in BS 5482: Part 3: 1979, some of which are given at Appendix 1.

2. The possible dangers associated with the misuse of such installations include fire, explosion and asphyxiation due to the leakage of gas from appliances, storage containers or defective fittings or due to an accumulation of gas following flame failure. Incidents may result in loss of life and sometimes cause serious material damage. The siting of gas consuming appliances and storage containers and the provision of adequate ventilation of the spaces containing them are *consequently most important.*

3. In addition to the risk of asphyxiation should the leakage or accumulation of gas occur in an enclosed space, there is also the risk of carbon monoxide poisoning when the appliance is in use. It is dangerous to sleep in spaces where gas-consuming open-flame appliances are left burning and it follows that heaters without flues should not be sited in areas designed as sleeping quarters or in unventilated spaces communicating directly with such areas.

4. Furthermore, open-flame heaters and gas refrigerators with non-enclosed burners may present a serious hazard from the fire and explosion aspects and if possible, their use should be avoided.

5. In the United Kingdom the gases most commonly used for domestic Liquefied Petroleum Gas (LPG) installations in ships are butane or propane conforming to BS 4250—Commercial butane and propane. A stenching agent is added to enable the presence of gas to be detected by smell even when its concentration in air is below its lower limit of flammability. Trade names and the suppliers of some of these gases are given in Appendix 3.

6. It is important to remember with LPG installations that the gases, although heavier than air, if released, may travel some distance tending to fall to the bottom of a compartment. Here they diffuse and may form an explosive mixture with air, as in the case of petrol vapours.

7. A frequent cause of incidents involving LPG Installations is the use of unsuitable fittings or the replacement of items such as flexible hoses with temporary rubber or plastic tubing. It is essential that any repair or replacement part is in accordance with the original specification of the equipment as detailed in BS 5482: Part 3: 1979.

8. In view of the elements of danger in the use of LPG installations a warning notice in red should be displayed adjacent to each appliance to read as follows:

WARNING

1. **DO NOT LIGHT IF LEAKAGE IS SUSPECTED.**
2. **BEWARE OF ANY UNUSUAL SMELL AS THIS MAY INDICATE LEAKAGE FROM THE APPLIANCE.**
3. **DO NOT CHECK FOR LEAKS WITH A NAKED FLAME.**
4. **MAINTAIN GOOD VENTILATION AT ALL TIMES.**

9. In conjunction with any LPG Installation the provision of an automatic gas detection and alarm system of a reliable type is strongly recommended and is absolutely necessary when a cooking or other gas consuming appliance is fitted in sleeping or other spaces below decks. It is essential that any electrical equipment associated with the gas detection and alarm system should be certified as being flame-proof or intrinsically safe for the gas being used.

10. As expressed above LPG installations should at least comply with the requirements of BS 5482: Part 3: 1979 but the Department also wishes to stress the importance of obtaining expert advice regarding the fitting of LPG Installations and of the need to ensure that such installations and associated alarm systems receive adequate (and expert) maintenance in service.

11. BS 5482: Part 3: 1979 deals very fully with all aspects of LPG Installations but some general comments are made in Appendix 2 as all users of such installations may not have access to this publication or to the selection of individual specifications listed at Appendix 1.

12. LPG Installations in mechanically propelled sea-going fishing vessels registered in the United Kingdom need to comply, as appropriate, with the requirements of Rules 34 and 61 of the Fishing Vessels (Safety Provisions) Rules 1975. However the warnings detailed above are applicable to all fishing vessels and such installations not directly covered by the Fishing Vessel Rules should be in accordance with the recommendations of this Notice.

13. Attention is also drawn to the requirements of Regulation 6(6) of the Merchant Shipping (Crew Accommodation) Regulations 1978.

Department of Trade
Marine Division
London WC1V 6LP
August 1981

APPENDIX 1

SELECTION OF RELEVANT BRITISH STANDARD SPECIFICATIONS

BS 2491	Domestic cooking appliances for use with liquefied petroleum gases.
BS 2773	Domestic single room space heating appliances for use with liquefied petroleum gases.
BS 2871	Copper and copper alloys. Tubes. Part 1. Copper tubes for water, gas and sanitation. Part 2. Tubes for general purposes.
BS 2883	Domestic instantaneous and storage water heaters for use with liquefied petroleum gases.
BS 3016	Pressure regulators and automatic change over devices for use with liquefied petroleum gases.
BS 3212	Flexible rubber tubing and hose (including connections where fitted and safety recommendations) for use in LPG vapour phase and LPG/air installations.
BS 3605	Seamless and welded austenitic stainless steel pipes and tubes for pressure purposes.
BS 4104	Catering equipment burning liquefied petroleum gases.
BS 4368	Carbon and stainless steel compression couplings for tubes. Part 1. Heavy series. Part 3. Light series (metric).
BS 5045	Transportable gas containers. Part 2. Steel containers up to 130 litres water capacity with welded seams.
BS 5314	Specification for gas heater catering equipment.
BS 5386	Specification for gas heating appliances. Part 1. Gas burning appliances for instantaneous production of hot water for domestic use.

APPENDIX 2

GENERAL COMMENTS ON LPG INSTALLATIONS

1. **Stowage of gas containers**

Wherever possible gas containers should be stowed on the open deck or in a well-ventilated compartment on deck so that any gas which may leak can disperse rapidly. Where deck stowage is impracticable and the containers have to be stowed in a compartment below deck, such a space should be adequately ventilated to a safe place and any electrical equipment in the space should be of flame-proof construction. In all cases stowage should be such that the containers are positively restrained against movement, preferably in secure mountings specially designed for the purpose. On multiple container installations a non-return valve should be placed in the supply line near to the stop valve on each container. If a change-over device is used it must be provided with non-return valves to isolate any depleted container. Where more than one container can supply a system it should not be put into use with a container removed. Where stowage below deck or use of appliances in accommodation is unavoidable, an added precaution is the provision of remote closure of the main gas supply from the containers. Containers not in use or not being fitted into an installation should always have the protecting cap in place over the container valve. Containers should never be lifted by means of a rope around the valve.

2. **Stowage of spare and empty gas containers**

It is important that the stowage of spare and empty gas containers receive the same consideration as the positioning of operating containers, particularly with regard to ventilation and electrical equipment should the spare containers be stowed below decks.

3. **Automatic Safety Gas Cut-off Devices**

A device should be fitted in the supply pipe from the gas container to the consuming appliances which will shut off the gas automatically in the event of loss of pressure in the supply line, e.g. should a connecting pipe fracture. The device should be of a type which requires deliberate manual operation to re-set it to restore the gas supply. It is strongly recommended that all gas consuming devices should be fitted, where practicable, with an automatic shut-off device which operates in the event of flame failure.

4. **Open-flame heaters and gas refrigerators**

Where such appliances are installed, they should be well secured so as to avoid movement and be preferably of a type where the gas flames are isolated in a totally enclosed shield, arranged in such a way that the air supply and combustion gas outlets are piped to the open air. However, in the case of refrigerators where the burners are fitted with flame arrestor gauzes, shielding of the gas flame may be an optional feature. Refrigerators

should be fitted with a flame failure device and flueless heaters should be selected only if fitted with atmosphere-sensitive cut-off devices to shut-off the gas supply at a CO_2 concentration of not more than 1·5 per cent by volume. Heaters of the catalytic type should not be used.

5. **Fittings and Pipework**

Solid drawn copper alloy fittings or stainless steel tube with appropriate compression or screwed fittings are recommended for general use for pipework for LPG installations. Aluminium or steel tubing and any materials having a low melting point such as rubber or plastic should not be used. Lengths of flexible piping (if required for flexible connections) should be kept as short as possible, be protected from inadvertent damage and comply with the appropriate British Standard.

6. **Ventilating Arrangements**

(*a*) It is highly desirable that compartments containing a gas-consuming appliance should not have access doors or openings direct to accommodation spaces or their passageways, but where this is impracticable it is advisable that mechanical exhaust ventilation trunked to within 12 in. of the floor adjacent to the appliances and adequate inlet ventilation be provided.

(*b*) Compartments containing a gas-consuming appliance which are situated upon an open deck with direct access to the adjacent deck and with no opening direct to accommodation spaces or their passageways should also be adequately ventilated, preferably by mechanical means.

(*c*) In pleasure craft and in some small ships where it may be impracticable to provide the mechanical ventilation referred to in sub-paragraphs (*a*) and (*b*) above, all compartments where gas-consuming devices are used should have adequate natural ventilation of a type which cannot readily be closed and which will prevent a dangerous accumulation of gas. The ventilation should provide for extraction of any gas which might leak from the system, as well as providing a fresh air supply. Since the gas which is heavier than air, tends to fall to the lowest level, exhaust ventilation openings should be led from a position low in the space. Such ventilation might be provided by wind-actuated self-trimming cowls or rotary exhauster heads.

(*d*) When mechanical ventilation is fitted to any space in which gas containers or gas-consuming appliances are situated, the materials and design should be such as will eliminate incendive sparking due to friction or impact of the fan impeller with its casing. Electric motors driving fans should be situated outside the space and also, whenever practicable, outside the ventilation trunking and clear of outlets, but suitably certified flame-proof motors should be used if this cannot be achieved. Ventilator outlets should be in a safe area free from ignition hazard. Ventilation systems serving spaces containing storage containers or gas-consuming appliances should be separate from any other ventilation system. Mechanical exhaust ventilation trunking should be led down to the lower part of the space adjacent to the appliance.

(*e*) Notwithstanding (*b*) above, Regulation 32(11) of Part I of the Merchant Shipping (Crew Accommodation) Regulations 1978 requires mechanical exhaust ventilation to be provided for galleys in any ship over 1,000 tons gross and Regulation 25(9) of Schedule 6 to the same Regulations (existing ships) requires mechanical exhaust ventilation in any galley.

(*f*) In cases where loss of life has occurred due to asphyxiation or carbon monoxide poisoning the ventilation system has been found to be deficient because ventilators have been interfered with or neglected. It is not unusual to find ventilators deliberately blocked, and butterfly and sliding ventilators have been found to be in the closed position and immovable. The importance of adequate ventilation of spaces containing gas consuming appliances cannot be too strongly emphasised and on no account must a ventilation system be interfered with so as to prevent it functioning correctly.

(*g*) Whilst adequate ventilation is a prerequisite for safety, consideration should be given to the siting of gas-consuming appliances in relation to the ventilating system such that air turbulence does not bring about the extinction of unshielded gas flames and thus permit the escape of gas.

7. **Gas Detection**

Suitable means of detecting the leakage of gas should preferably be provided in each compartment containing a gas-consuming appliance and where this is a detector, it should generally be securely fixed in the lower part of the compartment in the vicinity of the gas-consuming appliance. Any gas detector should preferably be of a type which will be actuated promptly and automatically by the presence of a gas concentration in air not greater than 0·5 per cent (representing approximately 25 per cent of the lower explosive limit) and should incorporate an audible and a visible alarm, although on small craft a portable manually operated detector may be used. Where electrical detection equipment is fitted it is essential that it should be certified as being flame-proof or intrinsically safe for the gas being used. In all cases where detection and alarm equipment are used, the alarm unit and indicating panel should be situated outside the space containing the gas storage and consuming appliances.

Similar provision for automatic gas detection and alarm should also be made in small vessels, such as pleasure craft and barges, if a cooking or other gas-consuming appliance is fitted in sleeping or messing spaces below deck.

Detectors can be rendered unsafe for use in explosive atmospheres by inexpert servicing, particularly in respect of arrangements for sealing off the detection chamber. Any maintenance should therefore be carried out by persons competent to do so or by replacement of the detection unit.

In all cases the arrangements should be such that detection devices can be tested frequently whilst the craft is in service.

8. **Emergency Action**

A suitable notice detailing action to be taken when an alarm is given by the gas detection system should be displayed on board the craft. In addition, the information given should include the following:

(*a*) the need to be always alert for gas leakage;

(*b*) when leakage is suspected all gas-consuming appliances should be shut off at the main supply from the container and no smoking should be permitted until it is safe to do so. **NAKED LIGHTS SHOULD NEVER BE USED AS A MEANS OF LOCATING LEAKS;**

(*c*) the correct use and maintenance of fire extinguishing appliances of which an adequate number should always be carried;

(*d*) the need for users to be fully aware of the contents of the consumer instructions and emergency procedures issued in accordance with clause 22 of BS 5482: Part 3: 1979.

APPENDIX 3

SUPPLIERS OF LPG GASES USED IN THE SHIPPING INDUSTRY

Supplier	*Gas*
1. **Propane**	
Air Products Ltd.	Propane
British Oxygen Co. Ltd.	Propane
BP Oil Ltd.	BP Gas—Propane
Calor Gas Ltd.	Calor Propane
Calor Kosangas (Northern Ireland) Ltd.	Propane
Shell UK Oil	Propagas
2. **Butane**	
BP Oil Ltd.	BP Gas—Butane
Calor Gas Ltd.	Calor Gas
Calor Kosangas (Northern Ireland) Ltd.	Butane
Shell UK Oil	Butagas

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IMPLEMENTATION OF UNITED KINGDOM REQUIREMENTS FOR INERT GAS SYSTEMS

Notice to Masters, Owners and Shipbuilders of Merchant Ships, the Designers and Constructors of Inert Gas Systems, Classification Societies, and Port Authorities

Introduction

1. The purpose of the Notice is to elucidate recent United Kingdom legislation concerning inert gas systems and describes how the Guidelines on such systems developed at the Inter-Governmental Maritime Consultative Organisation (IMCO) are to be treated. The Notice introduces a log book for inert gas systems and covers general survey procedures. Finally reference is made to procedures to be adopted should an inert gas system be defective whilst the ship is in a port in the United Kingdom.

Legislation—General

2. For United Kingdom registered ships the new requirements for inert gas systems are detailed in the following Statutory Instruments that came into force on 25 May 1980:

For ships where the keel was laid on or after 25 May 1980, SI 1980 No. 544—The Merchant Shipping (Fire Appliances) Regulations 1980.

For ships where the keel was laid before 25 May 1980, SI 1980 No. 541—The Merchant Shipping (Fire Appliances) (Amendment) Rules 1980.

Similarly, for ships not registered in the United Kingdom but when in a port in the United Kingdom the appropriate requirements are detailed in the following Statutory Instrument that came into force on 1 July 1980:

SI 1980 No. 687—The Merchant Shipping (Fire Appliances—Application to Other Ships) Rules 1980.

3. A feature of the above legislation is the requirement for either the fitting of inert gas systems retrospectively to certain existing tankers already in service or the modification of inert gas systems already fitted to such tankers which do not meet the latest requirements. For United Kingdom registered ships the Merchant Shipping (Fire Appliances) (Amendment) Rules 1980 further amend the Merchant Shipping (Fire Appliances) Rules 1965 (SI 1965 No. 1106) as previously amended by the Merchant Shipping (Fire Appliances) (Amendment) Rules 1974 (SI 1974 No. 2185) and a collective reference is made in this Notice to the "1965 Rules as amended". For ships not registered in the United Kingdom reference is made to the "1980 Application to Other Ships Rules".

Legislation—UK Registered Ships

4. For existing United Kingdom registered ships, Rules 38A to 38D of the 1965 Rules as amended indicate the date on which the tanker is required to comply with the inert gas requirements. In respect of ships to which Rule 38B and 38C apply attention is drawn to Rule 60B(*v*)(ii) that permits certain relaxations dependent on the date when the inert gas system is fitted.

5. It will be noted that in Rule 38D(2) of the 1965 Rules as amended the inert gas system is to be to the satisfaction of the Secretary of State and here the system should comply in general with Rule 60A until the date when Rule 60B becomes applicable in accordance with Rules 38B and 38C.

6. Owners and operators of tankers should submit their proposals to the Department for either the fitting or modification of inert gas systems well before the ships are required to comply and where exemptions are requested under Rule 38C(3) of the 1965 Rules as amended the design features of the ship and its equipment which are considered grounds for the exemption should be fully stated.

7. In order to illustrate the requirements for inert gas systems appropriate to the various conditions an algorithm for United Kingdom registered ships where the keel was laid before 25 May 1980 has been developed and is attached as appendix 1 to this Notice.

Legislation—Ships not Registered in the UK

8. The 1980 Application to Other Ships Rules extend requirements for inert gas systems to ships of other flags when visiting United Kingdom ports by applying the detailed requirements of the International Convention on Safety of Life at Sea 1974 (SOLAS 1974) at identical operative dates to those for United Kingdom registered ships, again dependent on size and whether a crude oil washing system is employed. It should be noted that the operative dates are in advance of the dates required by the 1978 Protocol to SOLAS 1974.

IMCO Guidelines—UK Registered Ships

9. IMCO has developed Guidelines to supplement its revised inert gas system requirements and the approved text has been published by IMCO in a booklet entitled "Inert Gas Systems for Oil Tankers". The status of these Guidelines is advisory.

10. With inert gas systems for new buildings the Department expects Owners, Designers and Shipbuilders to take account of the advice contained

in the Guidelines. Strict adherence to the Guidelines is not intended to prevent the development of alternative systems or procedures or the use of materials other than those specified but where the advice of the Guidelines is not followed the Owner, Designer or Shipbuilder will need to demonstrate that the objectives of the Guidelines have been achieved.

11. Where a ship is already fitted with an inert gas system the Department does not expect designs and materials to be modified to conform with the Guidelines. However the operational procedures contained in the Guidelines should be followed on such ships to the extent that it is practical having regard to the existing arrangements.

Emergency Procedures

12. An important aspect of the Guidelines (see paragraph 9) is section 8 relating to emergency procedures. In the event that the inert gas system is unable to meet the operational requirements and it is assessed that it is totally impracticable to effect a repair, the cargo discharge, deballasting and necessary tank cleaning should only be resumed when the requirements of this section are complied with. Particular reference is made to these emergency procedures in paragraph 23 relating to operations in United Kingdom ports.

Instruction Manual—UK Registered Ships

13. The Instruction Manual for the inert gas system required by the Rules and Regulations listed in paragraph 2 should be in accordance with section 11 of the Guidelines (see paragraph 9). In some instances it may be necessary to revise the Instruction Manuals already on board to take account of the detailed operational procedures, the emergency procedures, precautions, etc, contained in the Guidelines.

IGS Log Book—UK Registered Ships

14. Whilst inert gas systems will be subject to initial, annual and renewal surveys in conjunction with the Safety Equipment Certificate, including possible spot checks with the ship in service, the Department places considerable emphasis on the need to keep a comprehensive log to record the operation and maintenance of the inert gas system.

15. The format of an inert gas system log book may vary dependent upon the ship owner and manufacturer of the system but the log book should generally contain three sections. The first section should be arranged to record the oxygen level and the various pressures and temperatures normally checked during the operation of the system. The second should be arranged to record the routine tests of the safety features of the system, such as the tests on the alarm and shut-down facilities and pressure/vacuum relief arrangements. The final section should be arranged to record the maintenance and survey of individual items of the system.

16. For guidance, a model for an inert gas system log book is given at appendix 2 to this Notice. This model is intended to illustrate the information that should be recorded in the inert gas system log book and it is not intended that the format need be strictly followed.

Surveys—UK Registered Ships

17. Inert gas systems will be subject to initial, annual and renewal surveys. For United Kingdom registered ships, when the drawings for the inert gas system have been approved and the installation completed, a full scale test will be required to demonstrate that:

(1) a positive pressure can be maintained in all cargo and slop tanks during maximum discharge conditions;

(2) the O_2 content is acceptable during maximum discharge and also during a topping up phase when no cargo is being discharged;

(3) all alarms operate at the stipulated pressures, temperatures, levels and flow rates as applicable;

(4) all required shut-down facilities are activated at the stipulated temperatures, pressures, levels and flow rates as applicable;

(5) the instrumentation is effective, including the recorders for the O_2 content and the pressure in the cargo tanks.

18. During renewal surveys, internal inspection of the scrubber, deck water seal, pressure vacuum release arrangements, etc. may be impracticable at the time of the survey. Furthermore, it is not usually possible to test the "backflow prevention" function of the deck water seal during the time when the cargo tanks require to be kept inerted. The integrity of the deck water seal can then only be established by a thorough internal examination for corrosion and erosion particularly of those dimensions in the structure necessary to form the required levels in the seal. Thus the survey of the deck water seal can only be undertaken when the ship is gas free, or when it can be established with confidence that the deck isolating valve and non-return valve are sufficiently gas tight to enable such an examination to be conducted in safety.

19. The owners' attention is drawn to the above constraints when requesting a survey for the renewal of the Safety Equipment Certificate but where it is not possible for the above items to be examined then it will be in order for the Surveyor to accept an inspection by the ship's Chief Engineer Officer, provided that the inspection and the operation of the inert gas system are fully documented. It will be conditional on accepting such an inspection that the Surveyor is satisfied with the external condition of those items he is not able to inspect internally together with the entries in the inert gas system log book relating to the operation of the system.

20. Whilst it will be in order for the Surveyor to accept the inspection of the Chief Engineer Officer referred to in paragraph 19, arrangements should be made for all such items to be surveyed internally by an Independent Surveyor at least once within a five year period. The Independent Surveyor, who may be a Marine Surveyor of the Department of Trade or a Surveyor from the Classification Society with which the ship is classed, will then complete for record purposes the appropriate part of the maintenance and survey section of the inert gas system log book.

Reporting Defects in IGS

21. The Master's attention is drawn to Regulation 11(*c*) of Chapter I of the International Convention on Safety of Life at Sea 1974 as modified by its 1978 Protocol which requires the Master or Owner to report to the Flag Administration at the earliest opportunity any defect which affects the safety of the ship or the efficiency or the completeness of its equipment. When the ship is in port, the Master or Owner is also required to report such a defect to the appropriate authorities of the Port State, which is the Department of Trade in the United Kingdom. For inert gas systems, a defect which should be reported is one which prevents either the required quality of gas being delivered or a positive pressure being maintained in the cargo tanks.

Operations in UK Ports

22. The Merchant Shipping (Tankers) (EEC Requirements) Regulations 1981 (SI 1981 No. 1077) requires Masters to report certain information to harbour authorities before arrival at a United Kingdom port. Included in this information is whether a tanker has an inert gas system and whether or not the system is operational. Should there be any recorded defect associated with the inert gas system and the Harbour Authority or Terminal Operator concerned still wish the ship to enter their area then they should, when possible, first contact the local marine office of the Department of Trade.

23. Should the inert gas system break down during the period in port, it is the responsibility of the Master to immediately suspend cargo or deballasting operations and notify the Harbour Authority, the Terminal Operator and, when possible, the local marine office of the Department of Trade. Before it is permitted to resume operations by implementing the emergency procedures given in the Guidelines (see paragraph 12) all concerned should be satisfied that it is either totally impracticable to effect a repair of the inert gas system or that continued operations are necessary in the interests of the safety of the ship. Where it has not been possible to consult the local marine office of the Department of Trade then the relevant office should be informed of developments at the first opportunity.

24. Any inspection that a Harbour Authority or Terminal operator institutes for the purpose of verifying that an inert gas system is in order

before or during cargo or deballasting operations will usually be restricted to a check that the system is functioning by a reference to the instruments provided on board for the purpose. This check should show that a pressure above atmospheric pressure and an oxygen content of below 8 per cent is maintained in the cargo tanks at all times, the figure of 8 per cent being the interpretation of Rule 7(*b*) of the Merchant Shipping (Fire Appliances—Application to Other Ship) Rules 1980 in respect of ships not registered in the United Kingdom.

Detention

25. It will be noted from the statutory instruments listed in paragraph 2 or in the related Merchant Shipping Acts that ships that do not comply with the appropriate requirements shall be liable to be detained. Detention action and possible prosecutions in such cases will normally be the responsibility of the Department of Trade.

Department of Trade
Marine Division
London WC1V 6LP
September 1981

APPENDIX 1

IGS for Ships with Keels Laid Before 25 May 1980

1. Tankers

What is the DWT?	When was the Keel Laid? (See Note 1)	Does the Ship Carry Crude Oil or Other Cargoes with a Similar Fire Hazard?	Is a C.O.W. System Fitted?	Is an Inert Gas System Required?	If an Inert Gas System is Required then:	
					Statutory Instrument and Rule	Operative Date
Less than 20000	before 5/80	NO	NO	NO (see Note 2)	—	—
	before 5/80	YES	NO	NO	—	—
	before 5/80	YES	YES	YES	SI 1980 No. 541—Rule 38D (See Note 3)	25.5.80
From 20000 up to but not including 40000	before 1/80	NO	NO	NO (see Note 2)	—	—
	before 1/80	YES	NO	YES	SI 1980 No. 541—Rule 38C (See Note 4)	1.6.83
	before 1/80	YES	YES	YES	SI 1980 No. 541—Rule 38D (See Note 5) SI 1980 No. 541—Rule 38C	25.5.80 1.6.83
	1/80 to 5/80	NO	NO	NO (see Note 2)		
	1/80 to 5/80	YES	NO	YES	SI 1980 No. 541—Rule 38A	25.5.80
	1/80 to 5/80	YES	YES	YES		
From 40000 up to but not including 70000	before 1/80	NO	NO	NO (see Note 2)	—	—
	before 1/80	YES	NO	YES	SI 1980 No. 541—Rule 38C	1.6.83
	before 1/80	YES	YES	YES	SI 1980 No. 541—Rule 38D (see Note 5) SI 1980 No. 541—Rule 38C	25.5.80 1.6.83
	1/80 to 5/80	NO	NO	NO (see Note 2)		
	1/80 to 5/80	YES	NO	YES	SI 1980 No. 541—Rule 38A	25.5.80
	1/80 to 5/80	YES	YES	YES		

What is the DWT?	When was the Keel Laid? (See Note 1)	Does the Ship Carry Crude Oil or Other Cargoes with a Similar Fire Hazard?	Is a C.O.W. System Fitted?	Is an Inert Gas System Required?	If an Inert Gas System is Required then:	
					Statutory Instrument and Rule	Operative Date
From 70000 up to but not including 100000	before 1/80	NO	NO	NO (see Note 2)	—	—
	before 1/80	YES	NO	YES	SI 1980 No. 541—Rule 38B	1.6.81
	before 1/80	YES	YES	YES	SI 1980 No. 541—Rule 38D (see Note 5) SI 1980 No. 541—Rule 38B	25.5.80 1.6.81
	1/80 to 5/80	NO	NO	NO (see Note 2)	—	—
	1/80 to 5/80	YES	NO	YES	SI 1980 No. 541—Rule 38A	25.5.80
	1/80 to 5/80	YES	YES	YES		
From 100000 upward	before 2/75	NO	NO	NO (see Note 2)	—	—
	before 2/75	YES	NO	YES	SI 1980 No. 541—Rule 38B	1.6.81
	before 2/75	YES	YES	YES	SI 1980 No. 541—Rule 38D (see Note 5) SI 1980 No. 541—Rule 38B	25.5.80 1.6.81
	2/75 to 1/80	NO	NO	NO (see Note 2)	—	—
	2/75 to 1/80	YES	NO	YES	SI 1974 No. 2185—Rule 32A SI 1980 No. 541—Rule 38B	1.2.75 1.6.81
	2/75 to 1/80	YES	YES	YES	SI 1974 No. 2185—Rule 32A SI 1980 No. 541—Rule 38B	1.2.75 1.6.81
	1/80 to 5/80	NO	NO	NO (see Note 2)	—	—
	1/80 to 5/80	YES	NO	YES	SI 1980 No. 541—Rule 38A	25.5.80
	1/80 to 5/80	YES	YES	YES		

2. Combination Carriers

What is the DWT?	When was the Keel Laid? (See Note 1)	Does the Ship Carry Crude Oil or Other Cargoes with a Similar Fire Hazard?	Is a C.O.W. System Fitted?	Is an Inert Gas System Required?	If an Inert Gas System is Required then:	
					Statutory Instrument and Rule	Operative Date
Less than 50000	Treated as a Tanker of the Same DWT					
From 50000 up to but not including 70000	before 2/75	NO	NO	NO (see Note 2)	—	—
	before 2/75	YES	NO	YES	SI 1980 No. 541—Rule 38C	1.6.83
	before 2/75	YES	YES	YES	SI 1980 No. 541—Rule 38D (see Note 5) SI 1980 No. 541—Rule 38C	25.5.80 1.6.83
	2/75 to 1/80	NO	NO	NO (see Note 2)	—	—
	2/75 to 1/80	YES	NO	YES	SI 1974 No. 2185—Rule 32A SI 1980 No. 541—Rule 38C	1.2.75 1.6.83
	2/75 to 1/80	YES	YES	YES	SI 1974 No. 2185—Rule 32A SI 1980 No. 541—Rule 38C	1.2.75 1.6.83
	1/80 to 5/80	NO	NO	NO (see Note 2)	—	—
	1/80 to 5/80	YES	NO	YES	SI 1980 No. 541—Rule 38A	25.5.80
	1/80 to 5/80	YES	YES	YES		
From 70000 upward	Treated as a Tanker of the Same DWT					

Notes:

1. See also date on which building contract was placed and date of delivery as appropriate.
2. In such tankers Rule 32 of SI 1965 No. 1106 is applicable which requires a smothering gas system but permits the use of a deck foam system in lieu of a smothering gas system.
3. The inert gas system should be to the satisfaction of the Secretary of State (see paragraph 5).
4. Where crude oil or other petroleum products or liquids having a similar fire hazard are carried and high capacity tank washing machines (ie machines having a throughput greater than 60 m³h) are fitted, no exemption from an inert gas system is permitted.

   Where crude oil is carried and low capacity tank washing machines are used, an exemption may be permitted (see paragraph 6).

   Where liquid cargoes other than crude oil but having a similar fire hazard (see Rule 38A of SI 1980 No. 541) are carried and only low capacity tank washing machines are used, no inert gas system is required.
5. The inert gas system should be to the satisfaction of the Secretary of State (see paragraph 5) until such time as either Rule 38B or Rule 38C of SI 1980 No. 541 is applicable.

APPENDIX 2

Inert Gas Log

Name of Vessel

Total Cargo Discharge Capability in Cubic Meters Per Hour

A. Operational (Deck) Log
To be logged on each occasion Inert Gas Plant is used

Item	Design Value/Remarks	Value Observed		
1. In Tank Operation	eg. Loading, discharging, purging, topping up, etc.			
2. Maximum O_2 in supply	Should not exceed 5% (normally)			
3. Maximum O_2 in any Cargo Tank	Should not exceed 8%			
4. Minimum Inert Gas Pressure in any Cargo Tank	Should not fall below 100 mm Water Gauge			
5. Deck Seal Water Levels (to be checked daily when IG plant is not in use)				
Signature of Officer in Charge				
Date of Operation				

B. Routine Safety Checks before Cargo Discharge or During Ballast Voyage
(Such checks need not be done more frequently than once per month)

Item	Design/Remarks	Result of Checks and Date			
6. Blowers	For vibration levels, external corrosion, and casing drains proved clear				
7. PV Breakers	For correct liquid level and density, and correct operation				
8. Flame Screens	Inspect, clean and replace as necessary				
9. Deck Non-Return Valve	Freedom of movement				
10. Deck Isolating Valve	Freedom of movement				
11. Main PV Valve	Freedom of movement				
12. Cargo Tank Individual PV Valves	Freedom of movement				
13. High/Controlled Velocity Vent Valves	Freedom of movement				
14. Gas Pressure Regulation Valves	Test operation				
15. Soot Blower/Flue Gas Valve	Test interlocking				
16. Test Alarms For:					
(a) Low Scrubber Water Pressure/Flow	**				
(b) High Scrubber Water Level	**				
(c) High Gas Temperature	**				
(d) Blower Failure	–				
(e) High O_2 Supply	**				
(f) Power Failure to Instruments	–				
(g) Power Failure to Control Systems	–				
(h) Low Deck Seal Water Level	**				
(i) Low Inert Gas Main Pressure	**				
(j) Extra Low IG Main Pressure (if fitted)	**				
(k) High IG Pressure	**				

**Values determined by Ship Operator/Manufacturer/Designer to be inserted noting limits set by Regulations for max O_2 level in supply of inert gas and minimum positive pressure in cargo tanks.

B. Routine Safety Checks before Cargo Discharge or During Ballast Voyage
(Such checks need not be done more frequently than once per month)

Item	Design/Remarks	Result of Checks and Date			
17. Test Shut Down of IG Plant					
(a) Low Scrubber Water Level/Flow	**				
(b) High Scrubber Water Level	**				
(c) High IG Temperature	**				
(d) Failure of Blowers	–				
18. Test shut down, if fitted, of Cargo Pumps on extra low IG main pressure	– **				
Signature of Officer in Charge					

**Values determined by Ship Operator/Manufacturer/Designer to be inserted noting limits set by Regulations for max O_2 level in supply of inert gas and minimum positive pressure in cargo tanks.

C. Maintenance and Survey

Note: Items 19, 23, 24, 25, 26, 27, 28, 29, 32 and 33 must be Surveyed and the Log Sheet Signed by a Surveyor from either the Department of Trade or a Classification Society at Intervals not exceeding 5 Years

Item	Maximum Interval	Condition and Repairs as Appropriate		
19. Flame Screens	6 months			
20. Scrubber Water Level Regulators	6 months			
21. Scrubber Alarm, Floats (if fitted), Probes, Sprayers, Baffles, Inlet pipe	6 months			
22. Blowers—Impellers flushed and inspected through inspection openings	6 months			
23. Deck Water Seal Level Controls, Valves and Alarm Floats	6 months			
24. Main PV Valve	6 months			
25. Cargo Tank Individual PV Valves	6 months			
26. Deck Seal internally with particular reference to Venturis, Gas Inlet Pipe and Weirs	1 year			
27. Deck Mechanical NR Valve with particular reference to its seat, body and operating mechanism	1 year			
28. High/Controlled Velocity Vent Valves internally	1 year			
29. Inert Gas System Pipework for leakages	1 year			
30. Flue Gas Isolation Valve No. 1	2½ years			
31. Flue Gas Isolation Valve No. 2	2½ years			
32. Scrubber internally with particular reference to Packing, Weirs and any Protective Lining	2½ years			
33. Blowers dismantled for inspection of impeller, interior of casing and bearings	2½ years			
34. Liquid PV Breaker examined internally and/or Mechanical PV Breaker dismantled for examination	2½ years			
35. Cargo Tank Isolating Arrangements	2½ years			
Signature of Chief Engineer Officer				
Signature of Surveyor				
Certifying Authority				
Port/Country				
Date				

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Department of Trade Merchant Shipping Notice No. **M.1022**

FIRES INVOLVING DEEP FAT FRYERS

Notice to Owners, Masters, Officers and Crew Members of Merchant Ships and Shipbuilders; Owners, Skippers and Crew Members of Fishing Vessels and Builders of Fishing Vessels

1. Within the last few years there have been a number of fires involving electrically heated deep fat fryers.

2. In a number of cases the fires have been attributed to a failure of the thermostat fitted to control the temperature of the cooking medium. In other cases the fires have occurred due to the galley staff continuing to use fryers where it was known that the thermostat was defective. In another case it was reported that a fire resulted from the use of a fryer with an insufficient quantity of the cooking medium to permit the operation of the control thermostat.

3. In view of the serious consequences that may follow the failure of the control thermostat on a deep fat fryer, such appliances should be fitted with a second safety thermostat. This thermostat should be arranged to operate in the event of a failure of the control thermostat and should only be capable of being re-set manually. In this respect it will be noted that clause 19.17, as amended, of British Standard 4167: Part 4: 1970—Electrically-Heated Catering Equipment—Part 4—Deep Fat Fryers specifies a thermal cut-out of the non-self-resetting type or a similar device to be connected in series with the control thermostat on such appliances rated at above 6 kw.

4. It follows that any defect should be reported as soon as it occurs and the appliance either repaired or measures taken to prevent its use until the defect is rectified.

5. Whilst the temperature-sensitive elements of the thermostat and the thermal cut-out should be covered by the cooking medium in any deep fat fryer designed to comply with the above British Standard, as specified in clause 19.18, this may not be the case with older fryers or with fryers of foreign manufacture. Owners should therefore arrange for all such appliances to be examined to ensure that the cooking medium cannot be heated without this cooking medium also covering the appropriate parts of the control and safety thermostats.

6. It is also important for deep fat fryers to be provided with suitable lids and for the lids to be kept in use at all times. Furthermore, there should be an instruction for deep fat fryers to be switched off immediately after use.

7. The Merchant Shipping (Fire Appliance) Regulations 1980, as amended, and the Merchant Shipping (Fire Appliances) Rules 1965, as amended, require at least one portable extinguisher and a fire blanket to be provided in every galley on ships of Class I, II and certain ships of Class IIA with at least two such extinguishers and two such blankets being required where the deck area of any such galley exceeds 45 square metres. For ships and fishing vessels other than passenger ships the various Regulations and Rules generally require at least one portable extinguisher to be readily available for use in any part of the accommodation and service spaces. A fire blanket is an effective means of preventing the spread of fire resulting from the overheating of a deep fat fryer provided that it can be applied before the fire has had a chance to gain a hold. It is recommended, therefore, that a fire blanket should be provided in any galley containing a deep fat fryer on all other ships and fishing vessels.

Department of Trade
Marine Division
London WC1V 6LP
April 1982

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DEPARTMENT OF TRANSPORT MERCHANT SHIPPING NOTICE NO. **M.1136**

FIRES INVOLVING OIL FIRED APPLIANCES

Notice to Shipowners, Shipbuilders, Ship Managers, Masters and Crew Members of Small Cargo Ships and Similar Vessels and to Owners, Builders, Managers, Skippers and Crew of Fishing Vessels.

This Notice supersedes Notice No. M.851

1. There have recently been several accommodation fires on small fishing vessels and subsequent investigations found that the fires had been caused by oil fired appliances which had neither been installed nor operated in accordance with the manufacturers instructions. In several cases the appliance had not been fitted with any device by which the fuel supply could be shut off in the event of fire. In one particular case resulting in loss of life, in which a fire had been caused by overheating of the uptake, the safety features designed to shut down the heater in the event of fire had been removed.

2. Any oil fired appliance, whether it is an accommodation space heater, galley stove or similar appliance should be installed and operated in accordance with the manufacturers recommendations including those for siting the fuel supply and making arrangements for the flue from the appliance. In addition, the fuel shut off valve to any oil fired appliance should be readily identifiable and sufficiently remote from the appliance so as to be accessible in the event of a fire involving the appliance.

3. The appliance should be regularly and frequently examined to ensure that it is maintained in a condition that will enable it to operate properly. Particular attention should be given to the controls for regulating the oil supply, to the means fitted to shut down the heater in the event of fire and to the security of the oil connections.

4. When installing an oil fired appliance in accommodation or other enclosed spaces particular attention must be given to the provision of adequate ventilation and again the manufacturers recommendations should be followed. The ventilation arrangements should be regularly and frequently examined to ensure that they are not obstructed or have not been interfered with and that any moving parts can be operated satisfactorily. Oil fired heating boilers should operate on forced draught with suitable safety features to cater for flame failure. It is strongly recommended that such boilers should not be operated using natural draught as this may result in a blow back in variable wind conditions.

5. The attention of Shipowners and Masters of Cargo Ships is drawn to the provisions of Regulations 14(3) and 14(5) of the Merchant Shipping (Crew Accommodation) Regulations 1978 which indicate that:

(*a*) a heating appliance shall be provided with a means of turning it on or off or controlling the heat without the use of a tool or key and such means shall be, wherever reasonably practicable, within the space in which the appliance is fitted;

(*b*) the heating appliance shall not be affected by the use or non-use of the ships machinery, calorifiers or cooking appliances; and

(*c*) the heating appliance shall be constructed and installed and if necessary shielded so as to avoid risk of fire or of danger or discomfort to the crew.

Regulation 38(1) of the above Regulations requires that all equipment and installations shall be maintained in good working order, and Regulation 38(2) requires a Master to inspect crew accommodation and record defects in the Official Log Book.

6. The attention of Owners and Skippers of Fishing Vessels is drawn to the provisions of Regulations 14(3) and 14(5) and Regulations 35(1) and 35(2) of the Merchant Shipping (Crew Accommodation) (Fishing Vessels) Regulations 1975 which are similar to those of the Regulations referred to in Paragraph 5 above.

7. The Owners and Skippers of Fishing Vessels are reminded that where the Fishing Vessels (Safety Provisions) Rules 1975 apply, the installation of space heaters and cooking stoves shall be in accordance with Rules 32 and 61(2) of these Rules. The relevant requirements of these Rules are as follows:

(*a*) Where a heating or cooking appliance is supplied with fuel from an oil tank, the tank shall be situated outside the space containing the appliance and the oil supply shall be capable of being controlled from outside that space.

(*b*) Appliances using oil fuel having a flash point of less than 60°C (Closed Test) shall not be fitted.

(*c*) Means shall be provided to shut off the fuel supply automatically at the appliance in the event of a fire or failure of the air supply. The means shall require manual resetting in order to restore the fuel supply.

(*d*) The oil tank supplying the appliance shall be provided with an air pipe leading to a position in the open air where there is no danger of fire or explosion from the oil vapours. The open end of the pipe shall be fitted with a detachable wire gauze diaphragm.

(*e*) Means shall be provided for filling the oil tank and for preventing overpressure.

(*f*) Appliances shall be secured in position and their exhausts and the surrounding structure shall be adequately protected against fire. Exhausts shall be provided with ready means of cleaning. Dampers fitted in exhausts shall provide an adequate flow of air when in the closed position.

(*g*) Ventilators which are used to provide an adequate supply of air to a heating or cooking appliance shall not be capable of being closed.

8. It is strongly recommended that the installation of space heaters and cooking stoves in Fishing Vessels of less than 12 metres in length to which Rules 32 and 61(2) of the Fishing Vessels (Safety Provisions) Rules 1975 do not apply should be generally in accordance with the requirements of these Rules indicated in Paragraph 7 above.

9. Combustible bulkheads, ceilings, linings and furniture should be protected from adjacent oil fired appliances such as galley ranges, space heaters etc by non-combustible board type materials not containing asbestos.

10. Oil fired appliances such as galley ranges, space heaters etc should not be used for drying clothing, linen etc because of the danger that such clothing, linen etc may interfere with the ventilation arrangements of the appliance or fall onto the appliance and catch fire. Curtains and other hanging textile materials should not overhang or be fitted sufficiently close to an oil fired appliance where there is any danger of them coming into contact with the appliance.

Department of Transport
Marine Directorate
London WC1V 6LP
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Discussion

P. J. HAMBLING (DTp Marine Directorate): The authors are to be congratulated on their presentation of a very interesting and informative paper which will be well received by those engaged in the design, installation, operation and survey of marine machinery. No doubt they would have liked to include mention of other notable machinery failures, such as those that have occurred on steering gears, but as they point out it was not possible to catalogue all incidents in this paper and the cases chosen clearly illustrate the serious damage to marine machinery that can result from poor design or maloperation.

The Marine Directorate of the Department of Transport has itself investigated many incidents relating to machinery failures on UK ships and has on record cases similar to those contained in this paper. The value of such investigations is that the knowledge gained can be used to improve the design and operation of machinery and thereby the safety of life at sea. This can be achieved in a number of ways, depending on the nature of the machinery failure and the urgency of the need for follow-up action. Sometimes it is necessary to take unilateral action and make amendments to merchant shipping legislation. At other times it is more appropriate to go to IMO with recommendations for changes to the SOLAS Convention and then implement such changes when they are agreed internationally. Another means of bringing the specific problem to the attention of those concerned is by the use of Merchant Shipping Notices, some of which are appended to this paper. Perhaps the authors could give us some examples of where their investigations have resulted in changes to Lloyd's rules and also advise on whether, in view of the fact that they deal with foreign as well as UK ships, they pool their information with the other major classification societies so that the more predominant failures can be identified.

Mention is made in the paper of operational irregularities being one of the causes of machinery failure. There is little doubt that the human element in the operation of ship's machinery plays an important role, even where technical factors predominate. The DTp is currently engaged in research, with the co-operation of the shipowners' and seafarers' unions, in an attempt to identify the human element in shipping casualties and develop preventative measures. The research utilises the Department's casualty records and looks at the human factors such as skill, experience, fatigue and onboard organisation. It does of course go much further than machinery failures and covers collisions, grounding and heavy-weather damage. Apart from ongoing research, the training and certification standards of UK engineer officers are under constant review and it is hoped that the coming into force of the Convention on Standards of Training and Watchkeeping will lead to an improvement in standards internationally.

Reference is made to corrosion resulting from microbiological attack in lubricating oils. This, of course, is not confined to motor ships and there are cases on record of corrosion in the thrust pads of steam turbines. The problem is, however, well understood by the shipping industry and appropriate measures have been taken to counteract the effect.

The engine referred to in section 4.10 is probably the Stork-Werkspoor TM410. In our experience with these engines the cracks in the grey cast-iron bedplates started at the roots of the serrations in way of the main-bearing keeps. Whilst changing to nodular cast iron eliminated the problem, it is interesting to note that some original bedplates are still operating with the serrations suitably modified to reduce stress concentrations. Could the authors comment further on the use of grey cast iron in situations where high stress fluctuations can be anticipated? Could they also amplify their comments on the use of nodular graphite cast iron, since there are two grades in BS 2789:1973 (Iron Castings with Spheroidal or Nodular Graphite) whose elongation is only 2%. The superior grades have elongations of 17% and 12% and it is agreed that these are comparable with steels but the inferior grades are not.

It is also our experience that these engines suffered a number of main-bearing and bottom-end-bearing failures, some of which resulted in the crankshafts being written off. There was often dispute as to whether the failure was due to incorrect grip on the bearing shells or some other factor, such as loss of lubricating oil or overloading. Could the authors provide any further information on the outcome of this particular problem?

With regard to the section on screwshafts, it is noted that the keyway shown in Fig. 34 is of the sled-runner type but is not spooned out at the forward end as is present practice. If it had been spooned out, the crack might not have occurred.

Investigations into machinery failures do not always result in more stringent regulations and the case of propeller shafts is a good example. It was as a result of discussions with Lloyd's Register of Shipping, and information provided by them of numerous propeller-shaft surveys, that the Merchant Shipping (Cargo Ship Construction and Survey) Regulations 1981 were amended in relation to the periodic survey of propeller shafts. The good record of certain designs of propeller shaft has made it possible to extend the period between withdrawals to 7½ years and, in some cases, to 10 years, subject to satisfactory examination after 5 years. This is of obvious benefit to shipowners. In a similar manner it has been possible to extend the time interval between surveys of auxiliary water-tube boilers to two years, provided that the certifying authority is satisfied with the feed-water treatment and boiler-water analysis.

With reference to section 4.6, could the authors give some further information on the procedure at Lloyd's for controlling the quality of spare parts? Presumably, large components such as cylinder liners are required to be surveyed at the manufacturers' works and suitably identified, a procedure which should prevent the supply of 'pirate spares'.

Section 8 of the paper deals with engine-room fires and quite rightly draws attention to the hazards caused by overflow from sounding pipes to fuel-oil tanks. The positioning of such sounding pipes, in relation to potential ignition sources, often leaves a lot to be desired. The problem has received attention at IMO and the first set of amendments to SOLAS 1974, which came into force on 1 September 1984, prohibit the termination of oil-fuel-tank sounding pipes in any space where the risk of igniting spillage from the sounding pipe might arise. This requirement is also in the Merchant Shipping (Cargo Ship Construction and Survey) Regulations 1984 and (Passenger Ship Construction and Survey) Regulations 1984.

A number of engine-room fires have, unfortunately, occurred in the last few years as a result of the spillage or leakage of fuel oil, lubricating oil and hydraulic oil on to heated surfaces. Merchant Shipping Notice No. 750, which warns the industry of these dangers, is currently being revised and will be reissued in the near future to reflect lessons learnt from recent incidents. It is already a statutory requirement for oil-fuel injection pipes in machinery spaces that are periodically unattended to be screened. The revised M Notice will recommend screening even in machinery spaces that are continuously manned.

A recent article in a shipping periodical suggested that no action has been taken by any classification society or governmental regulatory authority to prevent accidents involving the failure of oil-fuel pipes and consequent leakage on to hot surfaces. It went on to suggest that flexible fuel-line piping, currently in use in jet aircraft engines, is suitable for use in marine engines because of its resistance to vibration. The source of the majority of fires caused by oil leaking on to hot surfaces is, however, the failure of the pipe system between the fuel-oil booster-pump discharge and the suction of the fuel pumps serving individual cylinders on medium-speed diesel engines. Although the nominal pressure is relatively low, the fluctuating pressures that result from fuel-pump action can lead to fatigue failure. It has been shown that the flexible pipes designed for aircraft fuel systems are inadequate for use on medium-speed diesels. Considerable attention is in fact paid to the design and construction of flexible pipes by classification societies and the Department of Transport to ensure that they are not only fire-resistant but capable of withstanding service conditions. Perhaps the authors could give us some examples of the standards set by Lloyd's for flexible pipes.

With regard to M 984, the Department of Transport has remained active in attempting to reduce the dangers of LPG leakage on all types of vessel. To this end a draft specification for flammable-gas detectors has been produced.

J. L. BUXTON (Lloyd's Register of Shipping): It is understandable that, when dealing with a subject as far-reaching as marine machinery failures, the authors have had to limit the content to those instances from which they consider the most pertinent lessons can be learned. However, on the highly automated ships now in service, consideration has to be given to the effect of control-system failure on the power plant and the interaction of the crew with the controls.

The authors point out that crew negligence and ignorance are often seen as contributory factors to machinery failures and suggest that, given a sufficiently high level of training and personnel education, this contribution could be expected to be reduced dramatically. While this is a perfectly reasonable observation, the situation is perhaps not so simple, particularly when one considers unattended machinery space where a great deal of reliance is placed on the control and instrumentation for correct operation of the plant. In this situation the causes of human error are rather more complicated.

Research carried out in the nuclear power industry led to estimates that human error contributes about 10% to all general failures of control systems and associated plant but, more importantly, contributes between 50% and 80% to all major accidents causing extensive plant damage or loss of life.

Some of the main causes of human error besides downright negligence and ignorance are:

- Complexity of system design which leads to a lack of understanding of the system and a longer time for fault finding, with a subsequent longer down-time of the associated plant.
- Confusing information presented to the engineer. This can be seen where alarm panels are used for status information and command signals are accepted as actual position indication.
- Faults in design logic where systems react to inputs which were never thought of at the design stage. In these circumstances control systems react in a manner alien to that expected and operators have difficulty in adjusting to the unusual situation arising.
- Poor documentation and insufficient instructions to the operator.
- Obviously human nature also plays its part. Man has a tendency to go for the optimistic solution and take a chance on beating the odds. Testing the cause of a fault tends to take an illogical pattern and different causes can be tested at random. Stress and panic in emergency situations compound the problem and in these situations the error rate for performing a simple corrective task is estimated to be between 0.2 and 0.3.

High standards of education and training can reduce the errors due to human nature but there is also a great deal that can be done at the design stage to improve the man/machine interface and give the engineer a fairer crack of the whip.

With regard to the sort of failures discussed in the paper, surely good planned maintenance procedures can go a long way toward their prevention.

Lloyd's Register of Shipping has recognised the importance of planned maintenance for many years; first with the introduction of the continuous survey of machinery (CSM) and later the survey of machinery by the ship's chief engineer. In an endeavour to make good planned maintenance play an even greater role in ship operation, the Society has recently introduced a new survey procedure whereby 'approved planned maintenance schemes' may be accepted as an alternative to CSM.

Planned maintenance schemes which would be acceptable to the Society have to be based on either preventative or condition maintenance or a combination of the two methods. Where this is the case there are advantages to both the shipowner and the Society. From the owner's point of view there is greater flexibility as to where and when the Chief Engineer carries out his machinery examinations; the number of surveys can be reduced to one a year with a consequent reduction in expenses; and items can be accepted for survey without unnecessary opening up when their condition is shown to be good.

In terms of classification, Lloyd's Register of Shipping expects planned maintenance to provide an improvement in machinery operation and a reduction in defects. It should also produce better reliability and defect data than can be achieved with present survey methods.

T. W. BUNYAN, FEng (Pilgrim Eng. Developments): The author's dramatic and compelling reporting of so many different examples of machinery disasters tempts one to believe that they have been borrowing freely from the classic 'Pandora's Box of Horrible Delights!'. A 'Pandora' lecture every five years or so would remind us of the fragile nature of our calling and stir the ingenuity of inventiveness in most of us. It would also be of absorbing interest for so many of our retired members who all have favourite disasters of their own, reported from time to time in these Transactions.

For most of a 20 year career at LR, trouble-shooting on ships was my meat and drink, so to speak. This experience gave me a unique opportunity of finding simple, practical solutions to some of the recurring problems.

Fatigue failures in tailshafts: In 1958 there was a failure epidemic among keyed tailshafts. The average life of all tailshafts above 16 in diameter was four years. The larger the shaft, the greater was the chance of failure. Tests done on a 40 000 dwt bulker indicated that flogging-up propellers with box wedges and a 28 lb hammer in the UK climate (16°C) achieved a grip on a 1/12 taper keyed shaft which was almost entirely lost in the temperature of the Red Sea (35°C) because of differential expansion of the bronze propeller hub on the steel shaft. The hydraulic propeller nut ('P' nut in Japanese) provided the precise solution of adequate, yet precisely controlled, push-up load.

Elimination of key and keyway: Keyless propellers were emerging in the early 1960s. LR statistics for the period from January 1968 to September 1982 showed that such propellers had a shaft failure rate of 0.33 per 100 years of service. This is a success story which has been recognised by classification societies world-wide by extension of the period between tailshaft-cone inspections to 10 years, with certain interim safeguards. Smaller versions of the 'P' nut are extensively used in many industrial and marine applications. These include high-precision (±2%) remotely controlled simultaneous tensioning of closure studs in nuclear pressure vessels operating at about 400°C, and many other applications involving high levels of vibratory torque in reciprocating machinery.

Drive-fitted coupling bolts: Another recurrent problem which has been satisfactorily solved was the high potential of damage to coupling bolts and bolt holes which had to be drive-fitted to achieve adequate frettage-free performance. This was particularly the case with large, directly coupled diesel-engine drives. Every four years or less, shipowners were faced with the pantomime of driving out the tailshaft coupling bolts, which often fired-up, reducing the ship's stock of over-size bolts and necessitating the coupling-bolt holes to be bored out and reamed. The self-straining bolt was the perfect answer as it provided the only truly fitted-bolt performance with a tensioning load more than 25 times as much as was obtained with drive-fitting. Further, the bolt fitted the bolt holes with a radial contact pressure of about 1.5 t/in^2. Although the self-straining bolt is more expenisve than the conventional solid bolt, only one hydraulic head is required per ship. The saving in time and effort and the removal of risk of delay due to bolt and bolt-hole damage, make it a wise investment with a rapid pay-off. So far over £6M worth of self-straining bolts for line-shaft couplings and for securing the blades of large CP propellers have been sold for naval applications.

Eccentric loading in bolted assemblies: Because of large errors in the squareness of spot facings on the first intermediate shaft coupling, heavy eccentric loading and yielding of the threads of the coupling bolts occurred. This was found to be so severe that nuts became slack with rapid generation of frettage. The spot-facing errors were gauged and split shims were ground to have the same declivity and alignment as the spot facings. The split shims were fitted under the hydraulic 'P' nuts used to tension the bolts to about 12 t/in^2 residual stress, as shown by the normal strain-indicator rods. It took a few voyages for the bolted connections to settle down on the fretted surface of the spot-facings. Six-monthly checks of strain were made and re-tensioning carried out as necessary.

Periodic checking of transducer performance: It is hardly necessary to emphasise that blind faith must never be placed in displays at the control console, without occasional independent checks being made on transducer performance. In the case of a twin-screw ship, one of the stern-bearing header tanks showed the usual 2 to 3 gallon daily loss of oil, whereas the other one showed no loss. This continued to be the case for half the voyage. Suddenly, the bearing-temperature alarm operated and subsequent inspection of the gauge glass showed the tank to be empty. The report indicated that the transducer float had hung up on a stiffening bracket within the tank.

J. CRAWFORD (Lloyd's Register of Shipping): The authors are to be congratulated on producing such an interesting and provocative paper. I would offer the following comments.

Self-closing cocks on short sounding pipes. These have been in use for a long time and, subject to proper usage, have given satisfactory service. Some incorporate a small pet-cock on the sounding pipe which would allow testing before opening. The case reported was obviously due to maloperation and I can only refer back to the old adage. You can, to an extent, cater for fools but not bloody fools. However, having regard to current attitudes, I have no doubt UMS incorporating central control stations will be overtaken by remote sounding arrangements; but not, I hope, incorporating a type of penetration shown in Fig. 53.

Thermometer pockets. I must confess some surprise in reading that this type of fitting, relying solely on a gland for securing, was ever installed. I had always understood that glands were considered as a pressure-retaining item, not a means of securing a piece of equipment. Whilst dealing with lubricating oil systems, I would comment on a mild encounter experienced at sea. While I was serving on a particular ship a heavy loss of lubricating oil was evident. All the usual possible sources of leakage were examined and dealt with as necessary, but still the loss continued, reaching, if I recall correctly, up to 20 gallons (90.0 l) per day. Tracing the leak path back to its source indicated the leakage was from the engine sump itself in way of the drain pipe from the engine sump to the double-bottom service tank. Examination of the crankcase at our next port (Manaus up the Amazon) indicated what at the time was thought to be small crack. This was patched up in the manner shown in Fig. D1 and proved successful in that the leak was

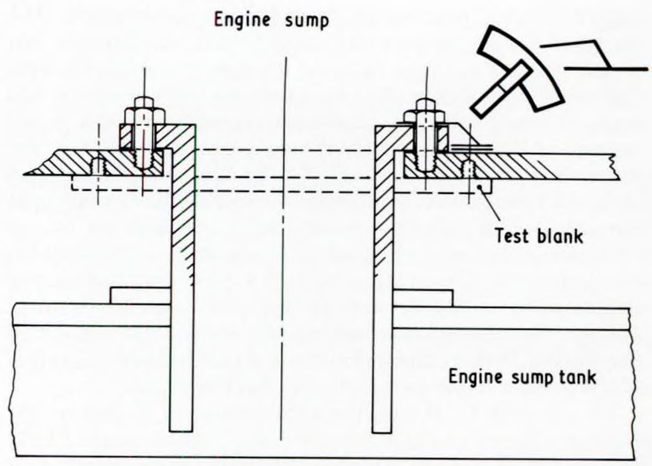

FIG. D1 Repair of engine sump to stop leakage

arrested. Further examinations in New York indicated that the fault was not a crack, but a stud hole in the crankcase base which had been drilled that little too deep and, over the period of penetration, had been gradually increased, causing the heavy loss of oil previously indicated.

Flooding of machinery space via sea-inlet piping: I was involved in a similar case of flooding but it was the standard reinforced-rubber bellows unit located on the discharge side of the sea-water cooling pump. The bellows piece split circumferentially for about 12 in (300 mm) and it was amazing how fast the water flooded into the engine room. Fortunately we were able to shut the shipside valve but this took time (no remotely operated butterfly valves on that ship). Even with all direct and branch bilge suctions going full blast the water was just under the floor plates before being brought under control. Meanwhile the turbines were shut down and the turning gear inserted and the engine turned to prevent damage to the turbines. The cause of the failure was bacterial attack on the fabric reinforcement of the bellows unit. The outer surface, at some time having been scored, allowed contaminated sea water to enter the crack from which the bacterial attack started.

I feel sure other members present will have had their own experiences and may wish to comment. Indeed I feel the authors may well have opened Pandora's box when presenting their very interesting and provocative paper.

G. VICTORY (FIMarE): This is a very useful paper in that it passes on to the marine engineers, who have to operate and maintain machinery, vital information on the problems which have been encountered by others employed at sea. As such it might awaken them to the failures which could occur on their ships and, perhaps, result in some avoidance of similar failures in the future. Every failure or casualty has a lesson, which if not used to avoid similar failures, represents so much wasted time, money and opportunity. The authors and Lloyd's Register are to be congratulated for issuing and setting out the information in a constructive way.

Unfortunately, too few owners, classification societies and authorities are willing to draw attention to the problems they have experienced. Perhaps this paper may lead the way to others being more forthcoming and result in a number of papers being presented on similar lines for I am sure that these are the sort of papers which will be welcomed by all members of the Institute, whether they be seagoing or land based.

However, I wish to draw attention to one or two statements with which I am not in agreement and to extend the scope of some of the examples.

On page 2 the authors state, without apparently producing any data in evidence, that 'very few cases of metallurgical faults have been found responsible for failures investigated in the laboratory in the last 30 years'. I, in common with many others, could enlighten them on failures due to metallurgical faults. In fact, I am of the opinion that at least six of the examples given were due to, or compounded by, metallurgical faults. I would also have been happier had category 1.2 been headed 'Design and manufacture', for a number of the examples given were relevant to manufacturing processes rather than to design.

According to my breakdown, the examples given would fall as follows: Design and manufacture, 17; Operational, 7; Metallurgical, 6; with some having two or more possible contributory factors. For this reason I cannot accept the statement 'Since it has been shown that machinery failures are not generally due to metallurgical matters the cause must lie mainly in 1.1 Operational; 1.2 Design'.

I am a little surprised, therefore, that more emphasis has been given to 'operational failure' than 'metallurgical failure' and that this has been rather arbitrarily divided into crew negligence (carelessness) and crew ignorance (insufficient training). The external pressure upon the seagoing staff to keep the ship on a very tight schedule, in my experience the cause of many casualties, has been ignored. Even some of our more prestigious ships appear to be suffering from the competitive urge to get 'a quart out of a pint pot'.

On page 3 the authors refer to the 'surveillance by instruments' as 'a major step forward' based 'upon confidence in the reliability of the machines and the instruments watching over them'. I would agree that this move was forced on many owners by foreign competition, drastically reducing their manning levels, and with the statement that 'we must not become too complacent'. But the delay between the initiation of a fault condition, the alarm functioning and the arrival of engineers on the spot can be crucial for breakdowns other than fire in the engine room. Incidents which perhaps could have been anticipated by good manual watchkeeping can become major breakdowns before the alarm condition can be detected and isolated. At best, unattended machinery spaces should be considered as a necessary evil. Then, perhaps, the blind reliance on instruments and alarms on one hand, and ignoring them because of frequent false alarms on the other, could be avoided.

Many of the examples given, it seems, merely go to show that we never learn from experience. I am surprised that the classic example of the *QE2* is not mentioned under 'turbines'. Certainly the lesson of that case should have helped to avert the mistake shown in Fig. 6 and elsewhere, and alerted the designers to the perils of stress concentrations resulting from sharp edges, especially in cut-away sections; similarly, as regards propeller shafts and liners, we have seen them all before and all too often!

In section 4.6, the danger of buying 'pirate' spares whose scantlings may not be up to standard is highlighted. Perhaps it would have been right at the same time to warn designers of the perils of a gradual reduction in scantlings on the assumption that if it has not failed it is too strong! Or even that in making adjustments to avoid a known fault it is easy to introduce an even greater hazard.

During the war a well known British engine was subject to a certain amount of piston-crown cracking, which was not a really serious fault in itself so long as a good watch was kept on the piston cooling temperatures and the water in the open piston-cooling-water tank. The problem was considered to be due to locked-up temperature stresses in the crowns which, it was thought, could be avoided by allowing the upper part of the piston walls to flex a bit. Therefore the upper walls were thinned down to absorb some stresses from the crowns. The result was that, after a period of satisfactory running, cracks would appear, progressing from the lower ring-groove recess into the piston wall. The danger was that a complete failure of a top piston crown would separate the crown from the piston and rod with disastrous results.

On one ship, to my knowledge, six pistons cracked in an identical manner in one month. As it was war time and only one new piston was available, the ship was run with all the cracked pistons as bottom pistons, at reduced speed of course, on the assumption that there would be less chance of the crown becoming completely detached. Incidentally, the makers said that the cracking was due to the vessel being operated without piston-cooling water; an excuse to which I, as Chief Engineer, objected strongly, but it remained a case of 'negligence' on their books!

Later pistons were altered to stiffen up the section behind the ring grooves when the same faults occurred on a number of ships, all of which could not, presumably, be put down to 'negligence'. But the reason for the alteration was never publicised!

Under section 8.5, where a fuel pipe broke at the cylinder tops and a severe fire took place, the comment is made that a stand-by signal should not be accepted until all pipe clips and shields have been replaced. This again is on the assumption that all pipes are suitably clipped and supported when the ship leaves the builders yard, an assumption to which few would agree, I think!

All too often the fracture of an injection pipe is due to vibrations of the pipes because a single clip allows nodal vibrations between the clip and the end connections.

Sections 8.5 and 8.6 refer to fires due to fracture of a work-hardened copper pipe and blowing out of a thermometer pocket which was retained in place only by the friction of the gland. Both these show the need for attention to detail. Many fires have been caused by the failure, in one way or another, of small pipe connections, copper or steel, for pressure gauges and other services necessary in pressurised-oil systems, particularly on or near boiler fronts. I am surprised that, in mentioning the possibility of blow-out of a thermometer pocket by pressure in the pipe, attention was not drawn to the ever-increasing use of 'compression' fittings of one kind or another where blow-out is just as possible. This is particularly true in the higher-pressure systems now used, where the force pushing the pipe out of the union can be considerable. In the case of the thermometer fitting no collar or restraining arrangement was provided on the pipe. On the *Amoco Cadiz,* where one such union blew out, the pressure could rise to 220 bar before the relief valve opened (and it could well have been higher), so the parting force would be in excess of one ton! The tightening of the union on assembly is therefore vital: too little and it will blow out, too much and necking of the pipe will lead to failure. In fact to get proper security, some necking of the pipe is essential yet the margin is so critical that surely this also is an example where a retaining collar or other effective securing device is necessary.

Finally, it was very gratifying to see the reproductions of several DTp M Notices in the Appendix. These are the means by which the Department endeavours to pass on to those concerned the lessons which can be learned from casualties to British ships, although the ships cannot be named. There are many more than those quoted and all seafarers should be familiar with them. There will be, or should be, a copy of every one on every British ship: so ask for them!

J. K. ROBINSON (Lloyd's Register of Shipping): Failures in prime movers for generating sets can of course originate at the electrical end, e.g. incorrect installation of pipework across bearing insulation may result in stray shaft currents with consequent pitting of bearing surfaces.

Should a vessel's electrical installation have experienced a major short circuit, what checks would the authors consider prudent on the engine(s) of the generating sets that had been running at time of fault, considering that the transient peak torques involved can be more than ten times normal running?

J. L. SNOWDON (FIMarE): First may I thank Messrs Munro and Haynes for their most interesting paper.

I would like to take this opportunity, when we have two very experienced engineers present, to ask a couple of questions which are not directly on the paper but are of a similar nature; and make a few comments.

Could our speakers suggest a simple method of determining if such items as steel tap bolts are made from ordinary carbon steel or stainless steel, in the field?

My reason for making this request is as follows. About 14 years ago it was found necessary to drydock a 19 000 dwt bulk carrier within the first 12 months guarantee period, because of severe leakage of lubricating oil from the single propeller shaft after oil/sea-water seal. This was on unscheduled drydocking abroad.

It was noted, when the water fell below the after propeller-shaft seal, that the securing tap bolts had corroded away and, as a result of this, the lubricating-oil/sea-water retaining-box joint with the after end of the stern tube was no longer oil-tight, thus the lubricating oil from the head tank in the ship gravitated down the supply pipe to the stern-tube bearing and thence to the sea via the faulty joint (Fig. D2). Closer examination of the securing tap bolts revealed that they appeared to have been made of mild steel instead of stainless steel and had wasted away. Stainless-steel tap bolts were fitted to the seal box and the ship proceeded on its way without further trouble from this item.

As a result of the foregoing, all such tap bolts in future tonnage were given special attention to ensure that they were of stainless steel.

The usual test was to ascertain if they were non-magnetic, using a permanent magnet, and for several years this appeared to be satisfactory until about two years ago when some already fitted steel tap bolts, used for a similar purpose, appeared to be magnetic. Immediate enquiries were made from the suppliers who guaranteed that the bolts were of stainless steel. They further stated that there were some stainless steels that were magnetic.

My second question is do classification societies have any particular regulation or recommendation regarding steam-turbine drains?

During the preliminary trials of a single-screw passenger/cargo ship of about 9000 dwt and 8500 shp, built about 1968 (with steam conditions 450 lbf/in^2 g and 825°F), it was noted that the fuel consumption per shp measured by a shaft torsion meter was considerably more than it should have been. It was also noted that the HP astern turbine-casing temperature was much higher than anticipated. This caused some concern and one of the designers of the turbine plant stated that in his opinion there was high pressure/temperature steam leaking into the HP astern turbine casing via a hole of about 5/16 in diameter.

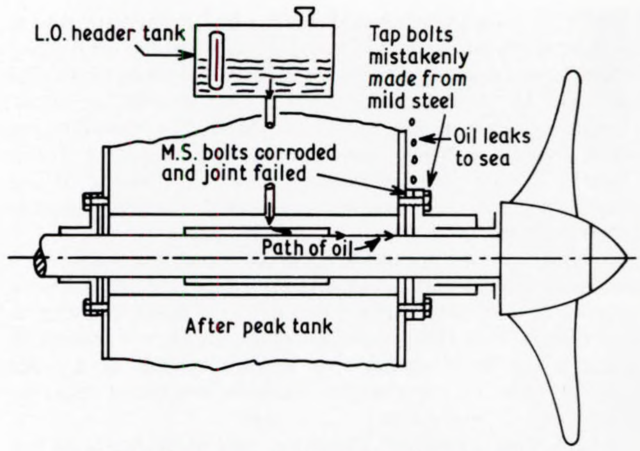

FIG. D2 Leakage of oil from head tank to the sea

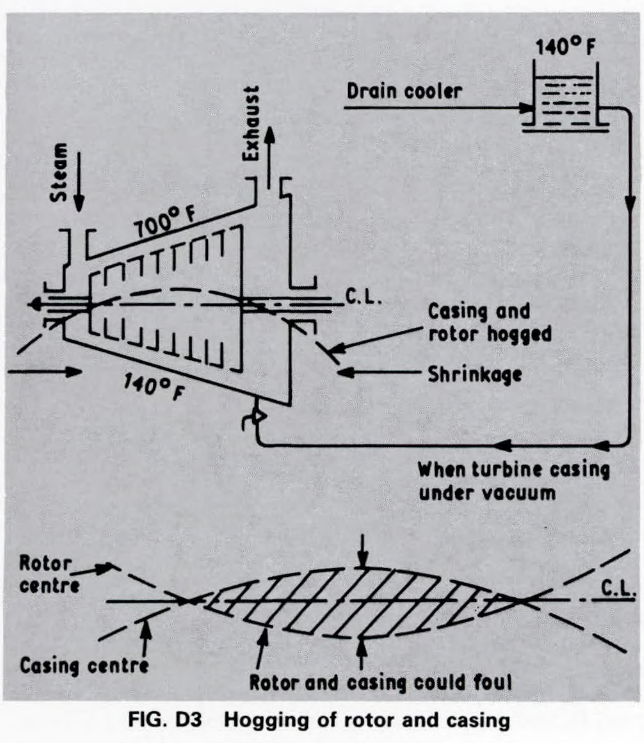

FIG. D3 Hogging of rotor and casing

This possibility was discussed and eventually the HP ahead and astern manoeuvring valves became suspect. It was suspected that the HP astern valve face had distorted and was allowing HP steam to pass into the HP astern turbine casing, thus losing steam. Further, the HP astern rotor blading was 'working' on the leaking steam, raising its temperature further and tending to reduce the ahead power available.

The plant was shut down and the ahead and astern manoeuvring valves opened up for inspection (a most hot and uncomfortable job because they had been subjected to about 750°F and were in a confined position). This examination did not reveal any positive fault.

After much discussion an attempt was made to ascertain how the steam pipe drains were run from the various turbine casings. This was difficult by reason of access and the fact that, whilst the packed drain cocks were accessible, the piping from them vanished into plastic insulation further covered with planished steel sheathing. Eventually the insulation was stripped away, when it was found that the HP ahead and astern turbine-casing drains were led to a single pipe which continued to the drain cooler. It was realised that, when both HP ahead and astern drains were open (as in manoeuvring), high-temperature steam could pass from the HP ahead casing to the HP astern casing via the drain line and this could be the cause of the trouble. Instructions were given to separate these drains. It was then believed that the drains had each been led to the condenser and the plastic lagging and planished steel replaced.

After a delay of about a day the adjustment and acceptance trials were again commenced. On the following day at about 0600 hours the manoeuvring platform began to vibrate violently, after some manoeuvring, and the complete plant was shut down, it being strongly suspected that the HP ahead turbine rotor had 'bent'. Subsequent examination proved this to be correct and the warming-up procedure was suspected, as were the turbine-casing's sliding feet, it being suspected that they were not sliding freely. The gland steam system also became suspect.

The trials were delayed about 20 days whilst a spare HP ahead rotor, already in production for a similar ship, was completed and fitted. The ship duly completed her sea trials satisfactorily and went into service for about a year. Then the

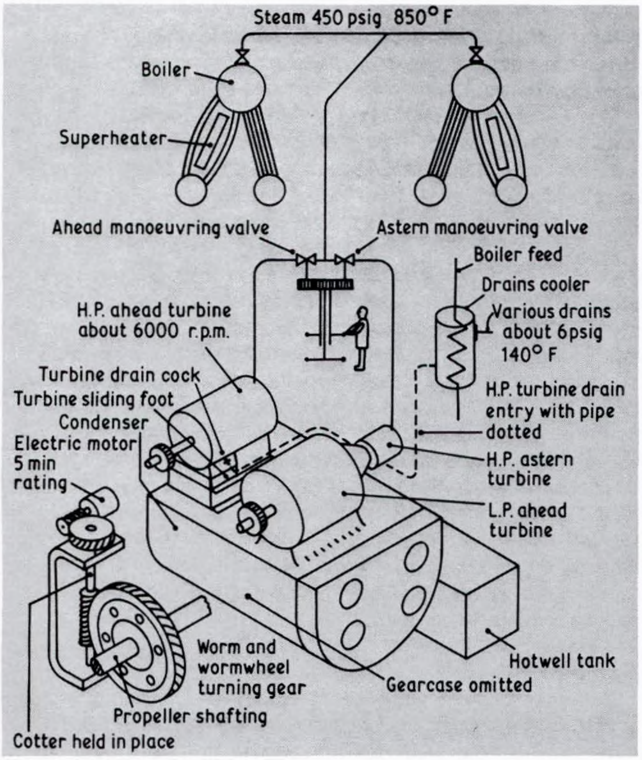

FIG. D4 General installation arrangement with offending drain pipe shown dashed

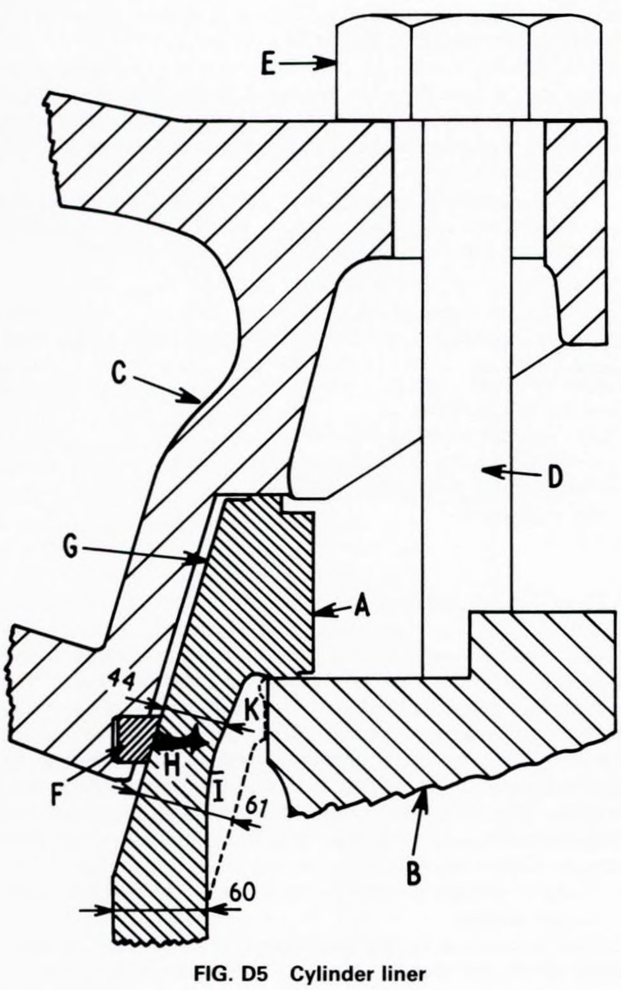

FIG. D5 Cylinder liner

HP ahead turbine again commenced to vibrate, but not as badly as previously. The rotor was removed upon arrival in the UK and was straightened by heat treatment, rebalanced and refitted, all without loss of ship's service time.

After the ship had been in service about three years and was outward bound from the UK, loaded with cargo and with passengers aboard, having passed beyond the Suez Canal, the HP turbine rotor again bent so badly that it could not be rotated in its casing. It was decided to fit the emergency steam piping, which allowed reduced-pressure HP steam by by-pass the HP ahead turbine and enter the LP casing directly. This was done and the ship proceeded at about 1.3 knots (instead of the usual 15 knots), completing the round voyage back to the UK.

Upon arrival the operating personnel were closely questioned about the installation conditions prior to the HP ahead turbine failure; whether the casing's sliding feet were free and moving, gland steam in a dry condition etc. It was learned that, immediately prior to the rotor bending, the engine had been under manoeuvring conditions, ready for almost instant movement, and was believed to have been under almost full vacuum, all drains being open.

Some of the plastic lagging and planished steel covering had been removed from under the HP ahead turbine casing when opening the HP ahead casing to allow the bent rotor to be lifted out. Further lagging was removed with the object of examining the turbine-casing drain lines. It was noted that the original HP ahead turbine-casing drain had been left leading to the drain cooler but the HP astern casing drain had been separated and led directly to the condenser.

A later similar ship had never given trouble, but there it was definitely known that all drains went directly to the condenser.

The thought then occurred that, possibly, the damaged turbine-drainage arrangement may have had something to do with the rotor bending. It then became apparent that, if the engine had been used and the HP ahead rotor and casing could be about 700°F with the engine stopped and under vacuum, it would be possible for relatively cold water (perhaps 140°F) to be drawn into the lower half of the HP ahead turbine casing from the drains cooler via the drain pipe line. This could cause the stationary rotor and casing to 'hog' and possibly permanently to distort (see Fig. D3).

If the rotor was then rotated half a revolution the casing would remain hogged whilst the rotor would appear sagged and thus fouling with permanent distortion could take place. The HP ahead turbine was fitted with a new HP ahead rotor and reassembled. The suspected drain was led directly to the condenser. The plant performed very satisfactorily for many years afterwards (as did the sister ship's plant).

Referring to the original question, it is believed that some shore-side insurance companies require steam-turbine drains to be fitted with non-return valves. If this is correct, it is suggested that in view of the above it would appear to be a good recommendation. Figure D4 describes the installation.

I thank Bibby Bros & Co for permission to publish the above.

R. APRAIZ (Naviera Artola, SA): With regard to cylinder liners, Fig. D5 shows a cylinder liner which is compressed between the upper part of cylinder block B and cylinder cover C, by means of studs D. When nuts are tightened on the upper side of studs D, ring F is firmly compressed against the cylinder liner, to prevent hot gases passing into the space G between liner and cover. These rings produce a radial force H on the liner circumference at the level of the ring.

The early liners had the external surface machined as per the dotted lines shown, and force H was taken by the protuberance K, which fitted against the cylinder block B. This arrangement corresponds to Fig. 20 of the paper and was used for many years. Later the engine was modified, eliminating the dashed line to the arrangement corresponding to Fig. 19 of the paper. The new arrangement was not satisfactory and circumferential cracks quickly developed at point I, and the designers reverted to the original design with protuberances K.

The crack shown in Fig. 34 crossing the sled-runner keyway and extending circumferentially around the body of the shaft is clearly originated by fatigue due to bending stresses and very likely would not have developed without the entry of sea water into the keyway.

Neither in the section on screwshafts nor in the section on sources of leakage is it considered that the circumferential cracks at the top of the tail-shaft cone could have been originated by bending stresses caused by the cyclic variations of torque due to the propeller blades acting in the changing velocity of the ship's wake. For without sea water making contact with the shaft through leaking joints, the actual bending stresses are practically incapable of producing circumferential fatigue cracks. In my opinion this type of failure is by far the biggest single cause of mechanical casualties in ships. Therefore it would be of the utmost interest to shipowners to know how many of these fractures have occurred in the past, according to classification societies' records; and how these failures can be avoided.

T. L. PALMER (Lloyd's Register of Shipping): I and my colleagues who attended would like to thank Messrs Munro and Haynes for presenting their paper in Liverpool. We found it of great interest.

Their slide of the damaged six-bladed propeller reminded me of a job some years ago. A general cargo steam ship's four-bladed, built-up propeller had lost a blade and came under repair. It was fitted with two spare cast-iron opposite blades and two of the original bronze blades, pending the supply of a replacement bronze blade. The ship left Karachi for Chittagong, calling at various ports before returning to Karachi some 2½ months later, when I was invited onboard.

I was informed that, on the first day out after the repairs, there had been some momentary heavy vibration but it was not until the Mate took draught marks after discharging at Chittagong that they had realised the vibration was caused by both cast-iron blades having broken off at their roots. Apparently the crew decided to say nothing and the ship continued its voyage with just two blades. On examination of the log books I found quite normal speeds and consumptions, and apparently no adverse comments were received from the several harbour pilots used. In fact the only adverse comments received were from the owner, when I insisted on a four-bladed propeller before the ship returned to service.

The problem with the cast-iron blades was traced to the fact that they had been stowed horizontally in a tween deck and supported on flange rim and blade tip, possibly aggravated by bulk cargoes in the tween deck. This had caused edge fractures. On a similar occasion later, the edges were ground clean and cracks were found.

The authors' comments on 'self-closing' sounding pipes to double bottoms also aired an age-old problem. I once spent some weeks on a grounded bulk carrier which was pounding on the rocks with the forward holds flooded. On my initial examination of the ship I found not only all the sounding pipe self-closing devices jammed open but also the watertight entrances (bolted covers) in the engine room to port and starboard pipe tunnels wide open. The following day one of the pipe tunnels flooded.

Would the authors care to comment?

Authors' Reply

The Authors would like to take this opportunity of thanking the contributors to the discussion for their interesting and valuable comments.

In reply to Mr Hambling, over the years changes in the Society's Rules have been introduced for a variety of reasons. Some have resulted from particular cases which have drawn attention to weaknesses and the need for urgent action.

One example arose when a turbine coupling failed and hot lubricating oil sprayed over hot turbine casings causing a fatal fire. This resulted in the introduction of the rule that outlets from lubricating-oil header tanks are to be operable from a remote location in the event of a fire in the engine room.

Another such case involved a fatal fire while a ship was bunkering. Long sounding pipes terminated high in the engine room and when the tank being filled came under pressure, fuel overflowed from the sounding pipe, ran along canvas which was spread on the gratings and poured over hot exhaust trunking from diesel alternator engines below. This resulted in changes in the rules to require that sounding pipes (other than short sounding pipes) are to be led outside the engine room above the bulkhead deck. Of course these locations should also be clear of accommodation spaces for obvious reasons. Our views on short sounding pipes have been made clear in the paper.

Drastic changes in the rules for starting air systems in motor ships followed a serious accident in a large twin-screw passenger ship. These included the introduction of flame guards and traps at the cylinder heads, and removal of lubricating oil from air-compressor discharges to the receivers. (Department of Transport Notice No. M474, see Appendix.)

Recently the rules for the venting of ballast tanks have been changed because there has been a number of serious tank damages through inadequate venting during discharge of ballast.

Within the structure of IACS (International Association of Classification Societies) there are a number of working parties which provide the medium for communication of information between member organisations on a case-by-case basis. On occasions when Lloyd's Register has taken immediate and unilateral action by sending a Circular to surveyors and shipowners, a copy has been sent to all member Societies of IACS.

Mr Hambling's remarks about operational irregularities are interesting, and we share the hope that the coming into force of the Convention on Standards of Training and Watchkeeping will be followed by a marked improvement in standards worldwide, as mentioned in the Introduction to the paper.

It is not irrelevant to quote from the Department of Transport Merchant Shipping Notice No. M1153: 'Accidents Reported by UK Registered Merchant Ships in 1983'.

Cause of accidents	1983 (%)	Jan–June 1984 (%)
Negligence/carelessness	32	27
Unsafe deck surfaces	18	19
'Other' unsafe working methods	12	13
Carrying/lifting too much/incorrectly	10	10
Failure to wear protective clothing and equipment	7	6
Alcohol	5	7

These figures speak for themselves and we find them disturbing.

The paper is aimed very much in the direction of the seagoing members, and no apology is made for referring to microbial infection of fluid systems, if only to provide a vehicle for the References at the end of the paper.

Figure 28 in the paper shows the striking difference in the microstructure of grey cast iron and nodular or spheroidal graphite cast iron. The flakes of graphite in grey cast iron restrict the range of properties which can be developed in the alloy no matter what form the matrix takes, i.e. ductile ferrite or a stiffer pearlitic structure; the shape of the graphite is the dominant feature.

Once a crack initiates it will readily propagate along the flakes where the bonding between the graphite and matrix is low and the tip of each flake is a significant stress raiser.

When the graphite is modified to spheroids then the graphite is not the dominant factor and the alloy may be made ductile, as in a ferritic nodular (see Fig. D6), or may be strong, tough but less ductile when a pearlitic matrix is present (see Fig. D7).

Naturally intermediate structures are possible and intermediate mechanical properties are produced.

BS 2789 (Specification for iron castings with spheroidal or nodular graphite) includes grades as described above ranging from grade SNG 24/17 with a tensile strength of 24 tsi and elongation of 17%, to grade SNG 47/2 with a tensile strength of 47 tsi and elongation of 2%.

The SG iron founder must produce a liquid iron low in sulphur, lower than when casting grey cast iron. Immediately prior to casting the melt is treated with, for example, misch metal (cigarette lighter flints, principally cerium metal) or magnesium. The cast iron will then have a nodular graphite and generally a pearlitic microstructure. Heat treating the castings will lead, under the correct conditions, to ferritic or partly ferritic microstructure. With nodular irons it is possible to adjust the mechanical properties to those required, whereas grey cast iron is not amenable to this tuning.

The cracked bedplate bearing pocket shown in Fig. 27 gives the opportunity to discuss further the courses of action available when the great extent of the damage became known. With the close co-operation of the enginebuilders sketches were produced and circulated to shipowners, making it possible for the Society to monitor every crack in the classed fleet at regular intervals. As a result of these efforts some bedplates were renewed (in SG iron), many were modified in way of the serrations and stud holes, and others were also fitted with cross-tie bolts to introduce rigidity. A number of these engines continue to operate without cracks. It is encouraging to note that as a result of the vigilance and diligence of all those concerned there were no disasters, and it should be borne in mind that a number of single-engined ships were involved, which gave us very great concern.

The Society's laboratory has investigated a number of crankpin bearing failures in recent years. The mode of failure has been found to be fatigue through the bearing keep with catastrophic resulting consequential damage. The origin of the fatigue fracture has been found to be in an area of fretting damage on the mating surfaces of the shell and keep. The fretting is due to very small oscillatory movements under high applied loads leading to localised welding of the high spots with subsequent tearing apart (microseizure).

The cause of these failures has been attributed to insufficiently tightened bolts or insufficient pinching of the shells. Unfortunately subsequent damage destroys any evidence which may be found on the shells.

This type of failure mechanism has been seen in an embryonic stage during a damage investigation associated with other parts of the engine. This form of damage is quite apart from that caused by lubrication failure and damage resulting from overheating and seizure.

While on the subject of crankshaft bearings there may be interest in a technique for the identification of debris embedded in the soft white metal which may cause scoring. The debris, if of metallic origin, is likely to be ferrous, i.e. from steels or cast irons. The production of an iron print reveals the density and distribution of embedded iron-based particles. The bearing shell should first be thoroughly degreased, without scrubbing, which would dislodge some of the debris. Then filter or blotting paper soaked in solution of 20 g potassium ferricyanide [$K_3Fe(CN)_6$] and 20 g salt (NaCl) in 500 cm^3 water is carefully laid on the bearing surface for a few minutes. The paper must be removed equally carefully to prevent smudging of the indications.

A variation is the copper print, which is useful when the bearing has wiped the steel journal or pin surface, and of course only in cases in which the shell includes a copper alloy layer. The method of production of the print is similar to that described for the iron print except that a 5% solution of ammonium persulphate [$(NH_4)_2S_2O_8$] in water is used after carefully degreasing the steel surface. Any copper embedded in the steel will stain the paper green. The prints can be dried and retained indefinitely and are suitable for photocopying for inclusion in reports.

The illustrations in Figs 34 and 35 were included to bring out the point about magnetic crack detection and it is agreed that the keyway shown is not typical of current practice.

Large cylinder liners of cast iron, a material for which the Society has no Rules, are normally subjected to hydraulic test at the manufacturers' works and accepted and stamped on that basis.

We are extremely grateful to Dr Apraiz for a full explanation of the circumstances of the strange case of the dimensions of the cylinder liners in section 4.6 of the paper, and Mr Hambling is referred to our reply to Dr Apraiz's questions.

We thank Mr Hambling for his comments on section 8 of the paper, which deals with engine-room fires, and we look forward to the forthcoming publication of the revised Merchant Shipping Notice No. 750 on this subject with considerable interest.

Flexible pipes designed for use in jet aircraft fuel systems are not subjected to pulsations of pressure as are the fuel-pipe systems in medium-speed engines, and we are completely in agreement with Mr Hambling when he says that considerable attention is paid to such pipes to ensure that they are capable of withstanding service conditions.

In this connection the Rules of Lloyd's Register have for some years required that synthetic rubber hoses for fuel systems have integral wire-braid protection, which may be single, double or multi-spiral wire layers closely bound in short

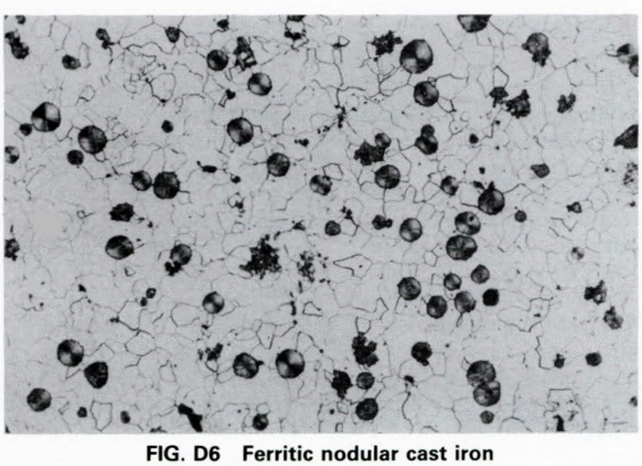

FIG. D6 Ferritic nodular cast iron

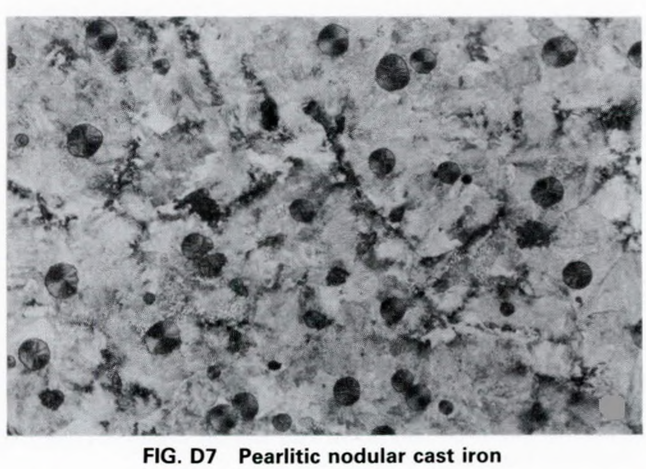

FIG. D7 Pearlitic nodular cast iron

joining lengths. For hoses at boiler burners additional external protection is required in the form of a wire braid.

The Rules also require that attention be paid to the requirements of the Statutory Authorities.

In response to Mr Buxton, we made a clear sub-division of the causes of failures of marine machinery into two categories. 'Operational' and 'Design', with 'Operational' further divided into Crew negligence (carelessness) and Crew ignorance (insufficient training). We now feel, as suggested by Mr Victory, that 'Design' should have been associated with 'Manufacture'.

If the work which is going on internationally to improve the standards of training and watchkeeping proves successful, then we can surely look forward to a reduction in failures from operational irregularities. The better-trained, higher-quality man is certainly not expected to be downright negligent.

It is intriguing to note that Mr Buxton's catalogue of alleged causes of human error lists components far removed from the man with his feet on the engine-room floorplates. Once again we are becoming trapped in the niceties of definition and of the meaning of words.

We are thoroughly in agreement with the comment that a great deal can be done at the design stage to improve the man/machine interface and give the engineer a fairer crack of the whip.

It is most appropriate that Mr Buxton should introduce planned maintenance to this discussion because we have worked closely with him for a number of years developing the Society's Planned Maintenance Scheme, and there is no doubt that this has much to offer all concerned, provided the simple rules are adhered to. At this point it is appropriate to draw attention to an article on the subject of condition monitoring by R. A. Collacott.[1]

Figure D8 shows an air compressor which was set in operation by a young engineer who failed to open the discharge valve. There was a violent explosion when the cooler casing ruptured under pressure and the young man was killed by flying pieces of iron. Surveyors of the flag State concerned subjected the relief valve to hydraulic pressure and had to change the gauge and pump because full-scale deflection was reached with no effect upon the relief valve. Eventually the valve opened violently when a pressure of 230 bar was reached.

This is a clear case of neglect of routine duties. No responsible engineer would expect a compressor relief valve to remain efficient for the five years between surveys required for the SAFCON certificate. Had there been an effective planned maintenance scheme in operation on board that ship we are convinced the young engineer would not have lost his life.

While discussing Fig. D8 it may be of interest to mention that during final sea trials of a motor ship in the Oslo Fiord it was found that instead of 'bursting discs' the air compressors had solid metallic discs some 4.5 mm thick in that position. These had been left in place in error after hydraulic testing at the manufacturer's works. It is fortunate this had been discovered just before the ship was handed over to the owners and set out on her maiden voyage.

Mr Bunyan's long and interesting career is well known to most of us and the catalogue of successes he has submitted as his contribution fills me with awe because we know it reveals only a small part of the achievements of an outstanding engineer.

The warning of the need to check the efficiency of transducer performance is timely and is a matter which could very well find a place in comprehensive planned maintenance schemes.

Figure D9 shows the severe damage sustained by the six-bladed propeller of a large container ship when it struck the chain of a mooring buoy while passing through confined waters. As can be seen, the ship was placed in drydock and following dye-penetrant tests all potential sources of cracks were removed by chipping and grinding. Once all interested parties were satisfied that a reasonable state of balance had been achieved the ship went back into service and ran successfully between Europe and the Antipodes from December 1973 until June 1975, when the propeller was renewed.

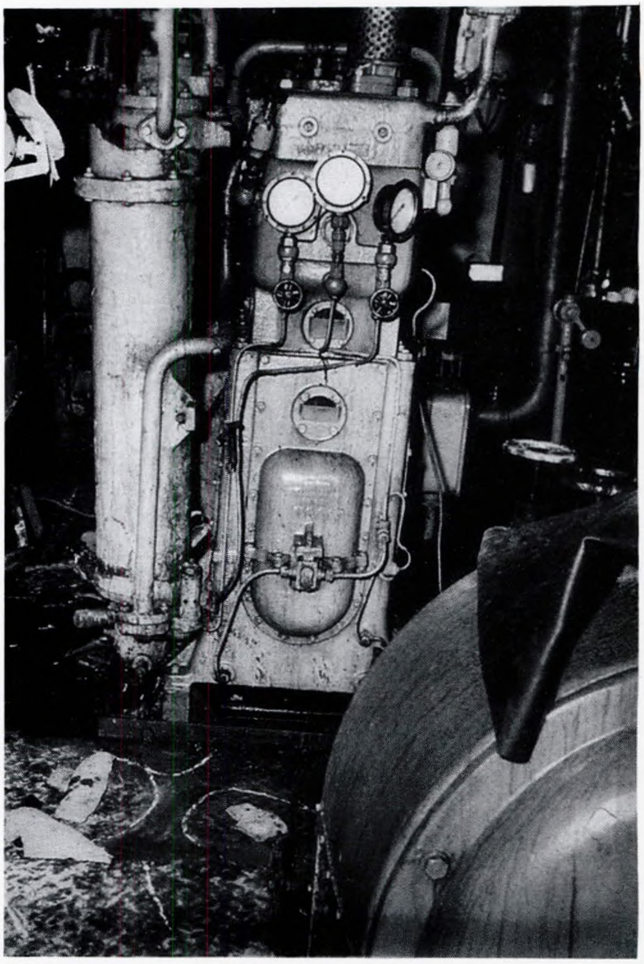

FIG. D8 Air compressor

This is a good example of calculated appreciation of an apparently very serious incident. Had the ship been put out of service a commercial crisis would have resulted with severe financial loss for the owners and many others. In the event the technical officials of the owners and the Classification Society surveyors together came to a decision which proved to be correct.

It is of great interest to note that this was a keyless bore propeller and it had not moved on the screwshaft!

In reply to Mr Crawford, there is no doubt that to put a sounding tape into a double-bottom tank through a self-closing cock requires three hands, one to hold the cock open and a pair to operate the tape. There was a time when there was no shortage of people in the engine room but in these days of reduced manning there must be a great temptation to secure self-closing cocks in the open position, and that, of course, is when they are at their most dangerous.

The ship which suffered the fire because the self-closing cock was lashed open (section 8.1) had an electric telegraph and a fluorescent lamp, which are shown in Figs D10 and D11, respectively, to emphasise the seriousness of this matter.

The thermometer pocket shown in Fig. 53 is used as a paper weight on the desk of one of the authors, when it is not being shown to students in colleges; quite the best places for it!

1. R. A. Collacott, 'Diagnostic and analytic techniques'. *Marine Engineers Review*, p. 5 (June 1985).

FIG. D9 Damaged six-bladed propeller

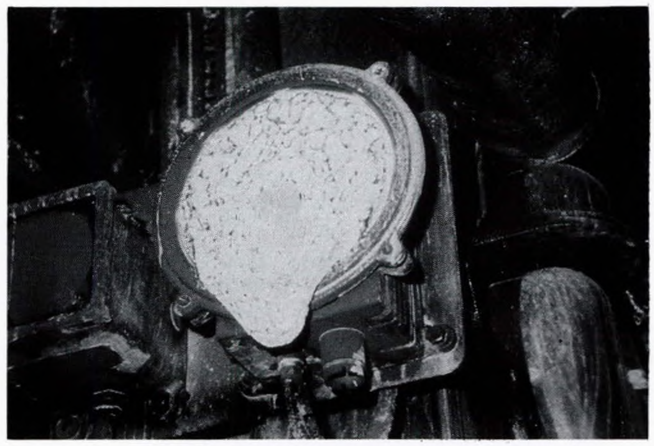

FIG. D10 Electric telegraph

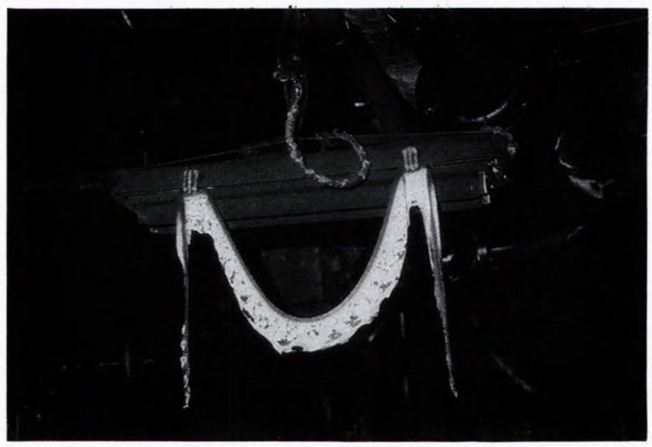

FIG. D11 Fluorescent lamp

When this paper was planned it was decided not to include boilers simply because boiler problems merit a paper on their own. However, Mr Crawford's account of the curious case of the loss of lubricating oil from an engine sump, illustrated in Fig. D1, evoked such vivid memories in one of the authors that the story will be told.

In 1954 a large Scotch boiler was undergoing internal examination by a young (!) surveyor when a tiny hole was found in the top front-end plate. Close inspection, which involved scraping the plate and introducing a piece of wire, revealed a cavity of some 4 mm depth. The cavity was the space below one of the studs in the outside of the boiler end plate, which secured the smokebox in place. The drill had just penetrated the plate with its point and the stud had not been driven to the bottom of the hole. So ended dreams of having discovered a massive plate lamination in an important boiler!

The case of microbial attack on the fabric reinforcement of a flexible bellows in a sea-water cooling system is interesting and serves to indicate that we must be aware of the possibility of this problem in unexpected places. The re-opening of this matter gives an opportunity to make reference to more recent thinking on the subject of dealing with this problem, and the suggestion is that high-temperature sterilisation and pasteurisation may prove to be more effective against attacks in fuel oil, lubricants and coolants than the use of biocides.[2,3]

In reply to Mr Victory, reference is made in the paper to establishing beyond reasonable doubt the cause of a failure; we must of course avoid latching on to a convenient scapegoat. Some precision is therefore necessary. The term 'metallurgical failure' should be defined as it is too easy to say that because a metallic component has failed we have a metallurgical failure.

A metallurgical failure is one that is caused by a metallurgical feature such as the macro- or micro-structure.

Whatever the cause of a failure the mode of failure can usually be described in metallurgical terms. A careful consideration of the cases presented in this paper will show causes ranging from inadequate design and shoddy manufacture to poor maintenance and abuse in service. No cases have been presented in which the cause of failure has been metallurgical.

We must emphasize that very few cases indeed examined by the Society's laboratory during the last 30 years have shown material significantly out of specification either chemically or mechanically, and no cases investigated have been caused by any metallurgical feature.

However, we describe the cause of a failure, and we must bear in mind that one of the purposes of the investigation is to identify the cause in order that changes made will prevent repetition. Inevitably blame is apportioned since we live in a fiercely competitive world and someone somewhere has to pay.

We agree with Mr Victory's comment that category 1.2 would have been more correctly headed 'Design and Manufacture', and thank him for the suggestion.

We are aware of the pressures on seagoing staff, but surely these have always been there. We feel the advice that a 'stand-by' signal should not be accepted until all fuel-pipe clips and shields have been replaced is sound. We have frequently referred to the vibration of these pipes as the 'dance of death'. Our remarks to Mr Hambling regarding M. Notice No. M1153 are relevant.

We are grateful to Mr Victory for having drawn particular attention to the sensitive subject of 'compression' fittings. It is hoped this will bring forward some design improvements by the manufacturers. By remarking that we never seem to learn from experience, Mr Victory has hit upon the reason the paper was compiled: the realisation that the errors of 40 years ago are still being made today. The paper is aimed very much at the seagoing members and that is the reason so many DTp 'M' notices were included in the Appendix, in order to ensure that they came into the right hands.

In reply to Mr Robinson, after a major short circuit the following checks should be carried out on the prime mover:

(i) Check coupling bolts and holding-down bolts for tightness and integrity;

(ii) Check flexible couplings for damage to fabric;

2. Alternative Strategies for Microbial Control – Oils, Coolants, Fuels and Oil Operations. Institute of Petroleum, 61 New Cavendish Street, London W1M 8AR.
3. The Commonwealth Mycological Institute, Ferry Lane, Kew, Surrey TW9 3AF, offers a range of services to industry, including consultancy and contract research.

(iii) Check PTO gear teeth for damage by distortion or fracture;
(iv) Check crankshaft alignment by web deflection;
(v) Check anti-vibration mountings for distress or damage to limit stops;
(vi) Check built or semi-built crankshafts for slipped shrinks.

These checks are relatively simple to perform, but larger-scale dismantling would be required should it be desired to check bearings for damage.

Our reply to Mr Snowdon is as follows.

Identification of Bolts: Wrought 18/8 Cr/Ni stainless steel is generally fully austenitic and therefore non-magnetic. However some stainless steels contain other alloying additions such as molybdenum, which with changes in the proportions of chromium and nickel can lead to partly ferritic structures showing varying degrees of magnetic response.

Low alloy steels such as the chrome-moly types are invariably strongly magnetic as are carbon steels. The simple magnet is therefore not very useful for sorting steel bolts where a mix-up has occurred.

The use of a magnetoscope under laboratory conditions can permit sorting of steels, even those normally considered non-magnetic. One of the authors has successfully sorted 25Cr20Ni steel from 24Cr24Ni Nb steel, both of which appear to be non-magnetic when using a magnet.

The following observations may be useful:

1. Carbon steels which are un-heat-treated will show machining marks and appear bright, unless corroded. Rust may be flaky. Heat-treated carbon steel and low-alloy steel will have a black heat-treated surface, which may obscure machining marks. Rust, particularly in low-alloy steels, may be fine and more adherent.
2. Alloy steels should not corrode to any significant extent. They tend to have a duller lustre finish compared with carbon steel. Heat-treated alloy steels may be distinguished from similarly treated carbon steels by a simple field test where filings from both types of steel are separately immersed in water. After a day or so the carbon steel filings will rust and stain the water brown.

Turbine Drains: To answer the question about Classification Society rules it has to be stated that it would be fairly easy to publish Rules and Regulations to cater for all known difficult areas and update these after every fresh incident. This attitude would, of course, result in a tome of quite impractical size and would hamper the industry rather than aid and guide it. The Classification Societies prefer to follow a policy of endeavouring to keep their recommendations as sensible and flexible as possible, while taking note of all developments, with a view to keeping abreast of the real needs of the industry.

It would seem there is little doubt that the damage suffered by the installation in the case quoted by Mr Snowdon was the result of thermal shock due to the ingress of water to the hot turbine. It is seldom we have the benefit of the presentation of such a well described case.

It is by describing such incidents that those following in the positions of designers in the industry may be made aware of some of the pitfalls which have troubled their predecessors. With this in mind it may be of interest to mention that in the 1950s a number of marine steam-turbine installations suffered serious damage by distortion of rotors, thought at the time, in many cases, to have been due to priming of the boilers, but as the cases recurred and were subjected to close analysis it eventually became apparent that these failures had common features such as would result from thermal shock due to water impingement on dummy and gland seals. This effect can be brought about when manoeuvring a hot turbine in which water has collected in the gland steam collector and the connecting piping, which is then injected into the turbine during hand adjustment of the gland steam.

It was eventually found that by the simple expedient of installing a reliable float-operated steam trap in the gland collector drain to the main condenser recurrence of this type of damage was prevented.

It may be useful to recount here some details of one such case which occurred in 1955.

The ship, having been put into service in October 1954, was of some 8825 tons gross, her machinery consisting of a triple-expansion turbine of 5500 shp, single-reduction geared to the screwshaft and taking steam at 32 bar from two water tube boilers.

Having picked up the pilot after a passage across the Atlantic Ocean, severe vibration was experienced leading to the vessel being towed into Bremen where the complete IP turbine was removed and despatched by coaster to the enginebuilders' works in Scotland for repairs. The ship meanwhile resumed her service running with the HP and LP turbines compounded.

Extensive repairs were found to be necessary, including straightening of the rotor by the thermal process, renewal of a number of rows of rotor and casing blades, and renewal of diaphragm, dummy and gland labyrinth packing throughout. A gap of some 1.5 mm between the casing joint faces was closed by the metal-spray process followed by grinding until a steam-tight joint was obtained, and by this means the time consuming and expensive major casing repair of planing the joint faces and subsequently boring out and re-blading was avoided.

On completion of these repairs the turbine was re-assembled and run under steam up to 2000 rpm, and prior to despatch to Rotterdam for re-installation on board, the dynamic balance the rotor was checked and found in order. No further difficulties were experienced with this installation.

We are grateful to Dr Apraiz for the sketch reproduced at Fig. D5 and the associated comments, which together help to make the position even more clear and emphasize the danger of dealing with component suppliers who are not *au fait* with the latest designs.

Section 7.2 and Fig. 44 were included in the paper to emphasize the acute dangers associated with keyed propeller shafts.

Since the introduction of the keyless-bore propeller the Society has not recorded a single broken keyless shaft, although there have been a very few instances of shallow corrosion grooving at the top of the tapers of these shafts. In each case the grooving was removed by grinding and the shafts were returned to service.

There is no doubt that it remains imperative to ensure the total exclusion of sea water from the top of the taper and it is hoped that this paper, and the comments of Dr Apraiz, will ensure that those concerned with the assembly of propellers on their shafts will be encouraged to pay the very closest attention to all the sealing positions indicated in Fig. 44.

In this connection it may not be amiss to remind senior officials of the danger of delegation of their duties, and the fact that when the assembly has been completed it is not likely to be re-examined for 5–7½ years, or even longer.

Mr Palmer's curious case of normal speed and fuel consumption having been recorded although two propeller blades were missing is not unique, but unfortunately not explained! It would appear that the cracks in the stored cast-iron propeller blades were yet another instance of vibration-induced fatigue.

The reference to the flooding of a bulk carrier after grounding with self-closing sounding devices jammed open brings to mind a recent case in Malta, in which, during a survey, our surveyor recommended complete overhaul of all self-closing cocks on short sounding pipes to double-bottom fuel tanks. Shortly afterwards the ship ran aground and ruptured the bottom, and was saved only because the recently overhauled self-closing cocks were absolutely tight.

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