BOILERS

NOTES ON CURRENT PROBLEMS AND DEVELOPMENT

BY

LIEUTENANT-COMMANDER R. N. LANGMAN, R.N., B.SC.(ENG.), C.ENG., A.M.I.MAR.E.

(*Boiler Section, D.G. Ships*)

Introduction

This article is a very brief outline of some of the current problems and developments in the boiler field. In many cases, the subjects covered here also formed part of the agenda of the conference on 'Boiler Maintenance, Repair and Operation' held at the Admiralty Marine Engineering Establishment on the 21st/22nd May, 1969.

This conference was called by DG Ships and was attended by representatives of Western Fleet Technical Staff, the Home Dockyards, Ship Maintenance Authority, Director General Dockyards and Maintenance, Admiralty Marine Engineering Establishment and the Central Boiler Inspection Authority. Its aim was to range the problems of boiler maintenance, repair and operation, and by so doing, to provide Headquarters with a better appreciation of those areas where efforts may best be directed towards:

(*a*) Improving the availability, through improved reliability, of those designs of boilers which have a significant remaining service life.

(*b*) Reducing the boiler maintenance load imposed upon ships staff and repair authorities.

A report on the conference, which includes detailed papers on all the subjects in this article except 'Furnace Explosions', was produced by DG Ships and circulated in August, 1969. The distribution covered the participants, the Admiralty Marine Engineering Establishment, and the Marine Engineer Officers of ships administered by C.-in-C., Western Fleet.

Furnace Explosions

A review of boiler furnace explosions in H.M. ships showed that 14 such explosions are on record for the period 1959–1968. The distribution between ship classes was:

Class	*No. of Explosions*
County class DLG (Y.102)	8
Tribal Class Frigate (Y.111)	1
Blackwood Frigate (Y.101)	2
Whitby (Y.100) *Rothesay* (Y.136) *Leander* ,,	1 (at AMEE, none in ships)
Leander Frigate (Y.160)	1
Admiralty 3-drum Boiler	1

Six of the fourteen explosions occurred during lighting up, and six while steaming auxiliary. In the latter case the auxiliary load was low, and in most of these only one main register was in use. In two cases the circumstances leading up to the explosions were not recorded in detail. No furnace explosion occurred in a boiler while main steaming.

Dieso only was being burnt in ten cases, and FFO on the main registers with dieso on the pilot in two cases. Here it should be noted that dieso has been used for lighting up in many FFO-burning ships for a number of years.

In these explosions, the extent of the damage was severe in only one case outside the County Class (Y.102), namely H.M.S. *Hermione* (Y.160 *Leander*). An analysis of the records has shown that the causes of the explosions were as follows:

No. of Explosions	*Environment leading to explosion*	*Final cause of explosion*
5	Involuntary flame out	Relighting without purging furnace
3	Involuntary flame out	Continuing to admit fuel to a hot furnace (above 260°C) after a flame-out
3	Partial flame out	Ignition of unburnt fuel vapour by a flame or hot spots in the furnace
1	Fuel admitted to furnace before torch igniter was alight	Ignition of torch igniter
2	Insufficient details recorded	

Since the majority of explosions occurred in Y.102 boilers, in the first instance attention was directed towards this class. The relative hazards associated with dieso and FFO firing were also investigated.

The prime conclusions drawn from these analyses and investigations were:

(*a*) With dieso firing, there is somewhat less margin for operator error or equipment malfunction than exists with FFO firing. However, from investigations, backed by experience, it is clear that present systems can achieve a system reliability such that for the average operator following the system operating instructions, the hazard associated with dieso burning is well within acceptable limits.

(*b*) The principal cause of furnace explosions is the failure to adequately purge the furnace with air after a flame out.

(*c*) In the County Class DLGs, the guided missile trough cooling fans are used to provide combustion air for the Y.102 boilers during lighting up if steam is not available to run a main blower. The extensive air trunking system has been found to have a large air leakage area, particularly in older ships, and this, combined with a marginal design capacity of the fan, has meant that in many cases the air supply has not been sufficient to ensure efficient combustion with a 400 lb/hr burner.

(*d*) In the Y.102 installation the minimum air flow delivered by the main blower running at its lowest speed, as defined by its lubricating oil requirements, is greater than that required for combustion in one register. It is also considerably greater than the quantity of air that the lighting-up fan can effectively deliver to the registers. This situation leads to a large step change in the air supply during lighting up when the main blower takes over from the lighting-up fan, so increasing the risk of a flame out.

The following action has been taken by DG Ships as a result of these investigations:

(*a*) To redefine the existing instructions issued on purging and sighting of boilers before lighting, or relighting after a flame out. In this context, flame out includes the deliberate extinction of all flame in a furnace.

(*b*) To institute action to fit larger capacity lighting-up fans to the Y.102 boilers. The first one from the manufacturers will be installed at the AMEE to be proved in advance of the first ship installation.

(*c*) To fit motor-driven lubricating oil pumps to the main FD blowers of the Y.102 boilers, to reduce the minimum safe running speed, so providing an overlap between the outputs of the two systems.

(*d*) To carry out trials on the Y.102 boiler at the AMEE, Haslar, to develop an improved lighting-up procedure, using the existing equipment.

(*e*) To analyse boiler installations in all classes of ships, paying particular regard to the matching of air and fuel supplies and demands under all boiler load conditions. The acceptability for dieso firing was also reassessed.

The analysis has shown that shortcomings in air and fuel supplies and demands that exist in the Y.102 installation are confined to that class. It was also concluded that for all classes burning dieso it was safe to do so with the systems and equipment fitted and using extant instructions.

Dieso Firing

DCI (RN) 1084/69 was issued as a guidance to ships which have changed over to dieso firing or are in the process of so doing. The principle points which have arisen are:

(*a*) In conditions under which FFO would produce black smoke, dieso will produce carbon monoxide which, with the addition of air from gas casing leakage, can lead to after burning with its characteristic high gas temperatures, particularly below the economizer, the funnel remaining clear. In the absence of the definitive and narrow range black and white smoke limits produced with FFO firing, adherence to the operating instructions is essential. The need for additional or modified instrumentation to enable the watchkeeper to adhere positively to these instructions has been reviewed and, where necessary, corrective action is in hand.

(*b*) Sea water readily separates out from dieso. While one can 'burn' FFO containing up to 40 per cent sea water as an emulsion, only 1 per cent sea water in dieso may arrive at the boiler as a 'slug' of water, resulting in a flame out.

(*c*) Brickwork does not become so glazed when fired only with dieso, and may be absorbent to fuel. Hence the absence of visible fuel on a furnace floor is not a 100 per cent guarantee that it is free from fuel. The correct continuous sequence of sighting, purging and lighting up is therefore essential.

Boiler Casings

In the past, boiler casings have often been the 'poor relation' of the boiler world. It is now becoming obvious that casing air leakage, which may have been allowed to get progressively worse as the ship got older, can lead to a limitation on boiler power. Previously this had often been accepted as one of the signs of a ship 'growing old', but with the change to dieso firing, gas casing leakage is more detrimental due to the part it plays in promoting after burning, and it is essential that it is kept to a minimum.

Pre and post-refit casing leakage tests are being instituted, and work is in hand to devise a 'simple' in-service test which would allow an estimate to be made of the air leakage without the extensive preparations which are needed for the present full test.

Soot-blowers

This is another poor relation which will continue to be required even when a boiler has been changed over to dieso burning. The principle causes of failure would appear to be:

(*a*) Inadequate lubrication.

(*b*) Incorrect blowing arcs.

(*c*) Incorrect cams.

(*d*) Damage to cams, either by the follower running off the cam, or by attempts to turn the handwheel in the wrong direction—usually with a large wheelspanner! The lack of direction arrows in some cases does not help.

(*e*) Failure of cooling air either due to jammed air ball valves or blocked air passages.

(*f*) Incorrect blowing pressure due to incorrect or missing orifice plates.

(*g*) Boiler casings which are weak in the vicinity of the soot-blowers causing malalignment.

Part of the problem is due to the inaccessability of the soot-blowers and the inhabitability of their immediate environment, which invariably means that their maintenance is poor. Little can be done to improve the siting on existing designs of boiler, as this is a function of the boiler configuration, but the detailed design will be improved where this is possible.

Brickwork and Insulation

The main problem areas here have been the rear walls in the frigates, and the castable insulation and the front walls in the area of the quarl in most types of boilers.

In the Y.100 boiler, the insulating bricks behind the rear water walls are laid at an angle and are unkeyed. This has given two problems, the first is that a temporary distortion of the gas casing, due to pulsation for example, may allow a brick to drop down behind the course below it. This then produces permanent distortion leading to further overlapping and also allows hot gases from the furnace to circulate behind the water wall, damaging the insulating slabs. The second problem is that if the refractory part of the rear wall is removed for renewal, the bricks behind the water wall tend to slide out of place, producing gaps in the insulation which can lead to casing hot spots.

The modifications which are being considered in this case involve stiffening the casings, keying the brickwork or the use of high temperature castable insulation.

Renewal of the castable insulation in way of the saturated and superheated passes on the latter classes of boilers has frequently involved large scale tube removal. Trials have been arranged using a single castable material over the full depth in place of the two layers of different material now in use. This improves the life of the castable insulation and also allows a different casting technique to be used which reduces the tube removal required. It is hoped that a method of this type will be in general use soon, and will reduce the amount of work involved in this repair.

It has been shown that the performance of a register is adversely affected by misalignment and inaccuracies in the quarl. The Dockyards have been asked to work to tighter tolerances when building quarls, and, on the whole, these are being met. One method is to use a cast and accurately machined alloy former, positioned by a jig mounted on the register plate, not on the inner brick plate as was frequently done before.

Chrome ore still gives some problems, but improved techniques have reduced the number of defects arising. The use of of the correct pneumatic tools for removing the ore is essential. When replacing it, the ends of the outer row of studs should be just visible, if these are covered the additional ore will fall off very quickly in service. The exposed ends may burn slightly, but as they are water cooled they will soon establish a position of equilibrium.

Boiler Fuel Sprayer Hoses

The position of the development programme aimed at reducing and, we hope, eliminating the burst hose problem in ships, was briefly described in the last issue of the *Journal.*†

Two types of PTFE hoses have been tested, in H.M.S. *Sirius* and H.M.S. *Dundas*. One type failed and the trial was stopped, while the other developed end fitting problems. These have been modified and a further ship trial is planned. An all nitrite rubber hose, with a single carbon steel braiding, similar to that used successfully in H.M.C.S. *Restigouche*, is now manufactured in this country, and is on trial in H.M.S. *Charybdis*.

To date, no failures have been reported from ships burning dieso using the existing pattern of hose, which would appear to confirm the opinion that the previous failures were accelerated by the high FFO temperatures being used.

The Plessiflex W2 hoses used in the DLGs and GP frigates are going out of production as a result of a product rationalization by the firm. The W3 hose which is being offered in its place is now on trial at the AMEE. Other alternative hoses have completed trials and will be tried at sea.

It is considered that the installation and handling of the hoses in ships plays a large part in determining their life. Provision of improved handrails to boiler room ladders, to prevent 'swinging off' on a handy hose, is a point worth considering.

†*Journal of Naval Engineering*, Vol. 18, No. 2, Page 175.

Superheaters

BR 3000 requires that the superheaters in Babcock and Wilcox controlled superheat boilers are to be renewed at the first opportunity after six years from first raising steam, and that the life remaining in the tubes removed is to be assessed and reported as for a Wear and Waste test. This requirement arose due to the extreme difficulty—or impossibility—of carrying out a Wear and Waste test on the superheaters of these boilers, and the desire to contain superheater renewal to long refits. The data collected from the Wear and Waste tests has been analysed and it has been concluded that:

(*a*) When using FFO, a superheater tube life of 10 years can reasonably be expected.

(*b*) When using dieso, a minimum superheater tube life of ten years can confidently be expected.

With the introduction of non-destructive examinations, superheater tube life can be assessed using improved inspection equipment which should shortly be available. Durability assessment of superheaters will then be possible and will provide a continuing check on the renewal intervals required.

In view of the above, a life of 10 years will be used for planning purposes.

The extension is also dependent on extending the life of those parts, such as steam and water drum protection plates and superheater supports, which are normally renewed while the superheater is removed. Design and material changes are being introduced in these areas, aimed at extending the life of these components.

In the Admiralty 3-drum boilers, failure of the superheater support plates is becoming a problem. A number of these have been renewed, but a large amount of work in wake is involved, as the elements have to be partly withdrawn from the boiler. The replacement supports are in an improved design and are manufactured from 'Standard Cronite' instead of 'Crown max', giving them greater strength at the high working temperatures involved.

Economizers

An analysis of the failures in economizer elements shows:

Type of Failure	*Percentage of Total*
Failure of U-bend weld	33
External wastage	33
Failure due to wedge fin	20
Other welds	14

Replacement of the wedge fin type element was announced in DCI 324/67 and is now largely complete, eliminating a cause of $\frac{1}{5}$ of the failures. A design investigation is being carried out aimed at reducing the number of U-bend welds in each element, and at improving the welding and testing techniques. Even now however, the failure rate of the U-bend welds is very low, 0·013 per cent per year, there being 380 such welds in each Y.100 type economizer.

Reducing the external wastage is a more difficult problem. One method is to cover the elements with a cermet (enamel) coat, as was tried in H.M.S. *Naiad*. It was unfortunate that one element failed, due to a defective U-bend weld, after three weeks but subsequent investigations showed that there were design problems which led to both economizers being replaced after four months' service.

Measurement of the wastage found in economizers which have been removed has shown that the wastage rate increases in the top rows, and in the areas below the rain catchments. Three actions which may be taken in a ship to reduce the external wastage rate are:

(*a*) To keep the boiler dry when shut down, by fitting the funnel cover whenever possible and using the simmering coil where this is fitted. Any suggestions for an improved version of the funnel cover would be welcome.

(*b*) Keep the funnel rain catchments and drains in working order.

(*c*) Maintain the feed inlet temperature to the economizer as high as possible. In most cases, ships systems are designed to give a feed inlet temperature of 220 to 240 degrees F at full power. Modern practice is to design for a minimum of 280 degrees F, and merchant ships often use complex feed heating systems to achieve temperatures well above this.

The use of dieso will not change the conditions in the economizer, except possibly to reduce the amount of soot deposited in it. Although dieso contains less sulphur than FFO (1 per cent max to 3·5 per cent max) the conversion rate for SO_2 to SO_3 varies with the sulphur content in such a way that the amount of SO_3 formed will remain sensibly the same.

Internal Cleaning and Internal Gear

DCI 522/69 changed the administrative procedure for controlling internal cleaning of boilers, and gave more latitude for extending the cleaning interval beyond the basic 2 years to 2 years 8 months. The aim is to achieve the maximum possible interval and this depends on three points:

(*a*) Use of effective internal cleaning methods

(*b*) Regular and detailed internal inspections, with accurate reports

(*c*) Strict control of boiler water and feed water purity.

The bullet brush removes light deposits, but it is prone to misuse and its general standard of cleaning is often low. This is becoming more noticeable now that endoscopes are being increasingly used for internal inspections. Trials are being carried out with an air driven rotary brush gear now manufactured under licence in this country, with the aim of replacing the now obsolete flexitube gear, and possibly the bullet brush.

Chemical cleaning by the inhibited citric acid process is now standard for all new boilers, but it is not used for 'in service' cleaning. The process produces sludge which must be completely flushed out and therefore the internal gear must be removed during the process, which also requires specialist equipment and personnel. There is thus no gain in time or cost compared to mechanical cleaning which, if carried out properly, achieves a satisfactory standard. However, trials are in hand of an alternative chemical cleaning process which holds the deposits removed in solution and can therefore be used with internal gear in place. This could give a worthwhile saving in the time and effort required for internal cleaning.

Current design investigations are also aimed at simplifying the steam drum internal gear securing arrangements, and possibly the internal gear itself, with the aim of making internal inspections easier and quicker, and reducing the likelihood that the same area will be examined at each inspection.

Boiler Water Treatment and Testing

It has already been pointed out that increased intervals between internal cleans depend in a large part on the maintenance of a high standard of boiler water purity. The limits laid down in BR 3000 are the maximum limits, and in the case of salinity, the normal level should be well below this.

It has been reported that the alkalinity of a boiler may tend to fall after it has been at WW for a period of three weeks or more. This is acceptable, but it is essential that the salinity be kept below the correct limit. The use of the simmering coil, when fitted, will keep the boiler compound in solution and will reduce the fall-off in alkalinity. It will also keep the external surfaces dry and help to maintain a slight internal pressure in the boiler, which will prevent the ingress of air and oxygen.

Silver nitrate, pattern No. 0473/114 strength N/24·8, has now been withdrawn and only pattern 0473/220–3040, strength N/35·5, should be used in the boiler water test set. With a 50 cc sample, 1 cc of N/35·5 silver nitrate represents a salinity of 20 ppm. On the subject of ppm, Form S1189 provides a useful conversion chart between ppm, micromhos and grains/gall.

Boiler Preservation during Refits, etc.

Recent experience has shown that the standard of preservation of boilers during extended repairs is not always as high as it should be, leading to unnecessary deterioration of the pressure parts.

It is essential that the time taken to carry out repairs on the pressure parts of a boiler be kept to a minimum so that the boiler may be returned to WW, ECL or a similar state. This means that at the planning stage, the boiler work must be concentrated into the minimum reasonable period.

Improved methods of preserving boilers are being investigated. The use of hydrazine to scavenge the oxygen in the water when at WW is one method, used already by the Netherlands Navy. Another is to fill the boiler with nitrogen when it is standing empty but closed.

It is also essential that the external surfaces are kept dry, and cutting access routes where they will allow rainwater to percolate down into the boiler should be avoided. Some ships have reported that the simmering coil can be effective in keeping an empty boiler dry, instead of airing stoves or electric heaters.

Non-Destructive Examination of Boilers

DCI 931/69 introduced the use of non-destructive techniques for determining the durability of boiler pressure parts. These methods will come into general use in 1970 and should give a clearer picture of the condition of a boiler, while reducing the work involved. It must be remembered however, that with the present equipment a destructive wear and waste test must still be carried out in cases where the non-destructive methods have indicated a durability of less than four years.