The Care and Maintenance of Watertube Boilers*

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The paper attempts to highlight the problems arising in the care and maintenance of boiler units in a modern steamship, and is not intended to include all details of the various operations such as expanding tubes, setting safety valves, replacing parts, etc., which are already adequately dealt with in instructional manuals supplied by manufacturers.

Design is only included where, in the author's opinion, it has a definite bearing on maintenance, and where some guiding principle can be given to reduce the cost.

An endeavour has been made to give the basic reason for a given trouble and the means to cure and if possible avoid repetition.

A TYPICAL BOILER UNIT

Fig. 1 shows a typical arrangement of a boiler unit and indicates by arrows the sequence followed in discussing the various parts comprising a complete installation, from the flow of air from the fans to the boiler fronts and the combustion gas from the furnace to the funnel, and considers the internal parts from the feed to the steam outlet of the superheater. To avoid repetition it will be necessary at times to deal with the internal parts out of sequence.

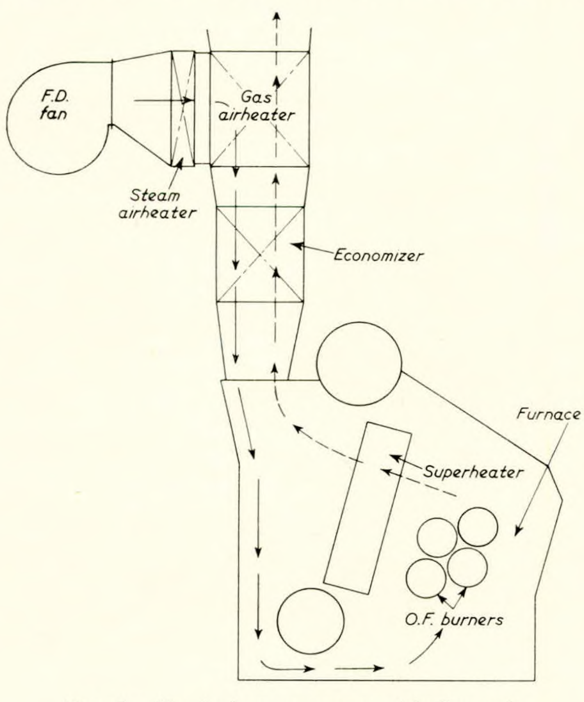

FIG. 1—*Typical arrangement of boiler unit*

N.B. This paper expresses the personal views of the author.

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FORCED DRAUGHT FAN

This item, with the possible exception of the electrical contacts in the starting and regulating gear, probably requires the least maintenance. Except for small units where reciprocating engines are the most suitable drive, and in special cases, say, for naval use, for very large boilers and sometimes to provide for high overload conditions, the standard merchant practice is to use electrically driven fans. Alternating current is becoming more and more commonly adopted, and it is general practice to use two-speed fans, this being thought the best compromise between the multiple speed d.c. fan for ease of control and the excessive cost of an a.c. fan to give the same speed range. Recently, however, owing to the high maintenance cost on the electrical side, there has been a tendency to go forward on a vane controlled single-speed fan. This would not only reduce maintenance but would also considerably reduce the initial cost. It must however be remembered that a boiler has to operate through a very wide range, and for this reason, if a single-speed fan is to be used, careful consideration has to be given to the outputs required and the margins over and above actual requirements which should be provided, as undoubtedly these will have to be cut to a minimum if the fan is to be suitable for all conditions of steaming.

For reasons which will be apparent later in this paper it is desirable that the fan itself shall be situated above the boilers in the boiler room fidley, whereas the motor should be in a separate fan room. This, however, does not present any technical difficulty and it is the arrangement obtaining on many ships at present at sea.

One further word about the fan arrangement: it is of the utmost importance that ample room be provided around the fan intake, as any restriction at this point will seriously affect the fan performance. The added resistance in the use of high velocity funnel, grit arresters, etc., must not be forgotten in specifying the fan capacity.

FAN DISCHARGE DUCTING

The lead of the ducting should be as direct and simple as possible, and where cross-over ducting is required care should be taken to ensure that the shut-off damper is a good fit, and consideration should be given to pinning jointing material on the landing edges so as to ensure that the damper is tight when shut. Leakage past this damper has in many cases seriously affected the combustion conditions, particularly with automatic control.

The damper control should be led to a convenient position and suitably geared to avoid undue force being necessary to operate the dampers. Whilst an indicator should be provided giving the open and shut position, it is most important that in addition a groove is machined on the end of the damper spindle indicating the position of the damper blade relative to the spindle. This grooving should be deep to avoid it, being obliterated by painting, and is much more important than would appear at first sight as it is the only sure means of checking the damper position when the boilers are steaming.

The importance of having the operating gear in a convenient position is obvious, but nevertheless is not provided on many installations. These remarks also apply to bypass dampers.

STEAM AIR HEATERS

There are two reasons for using steam air heaters:

a) As a means of heating the combustion air where no gas air heater is provided.

b) As a means of heating the inlet air to a gas air heater in order to increase the metal temperature of the air heater tubes.

Steam air heaters are simple in construction and require little attention, but the following comments are important. Normally, the steam supply to the heater will be bled steam at a pressure between 35/50lb. per sq. in. abs. There should however be an alternative steam supply from the auxiliary range of approximately 150lb. per sq. in. gauge which can be used when manœuvring and under harbour conditions when bled steam is not available. The importance of this will be seen later in this paper.

Care must be taken in arranging the drains from the steam coils to ensure that recirculation cannot take place, as this will seriously affect the efficiency of the heater and the makers take care of this by supplying a seal pot with the drain fittings.

The heaters should be periodically examined at least once every six months on the air side to make sure no fouling or choking has taken place. This can occur either by fibrous matter being entrained in the air supply to the fans or, more likely, from soot emission from the uptakes through an expansion joint leaking or an access door not being properly replaced.

GAS AIR HEATER

For convenience it has been assumed that the boiler unit under discussion is fitted with an economizer and gas air heater, and therefore the next section through which the air passes is the gas air heater. Such a fitting has today gone out of favour with certain owners, but it must be recognized that this is the cheapest form of heat recovery available, and permits of the highest feed temperature, which gives the best overall steam cycle efficiency, and there are a large number of ships operating without trouble. On the other hand, it is recognized that the vertical tube gas air heater (Fig. 2) has been a source of considerable worry and expense in maintenance on certain classes of ships, mostly oil tankers, possibly because the oil burnt is not of such high quality.

The primary cause of the trouble is the increase in the sulphur content of the average fuel oil bunkered, and the length of time it has taken designers to appreciate the mechanics involved.

The trouble consists of two complementary effects—choking and corrosion—and the common reason for both is that the metal temperature of the air heater tubes is sufficiently below the dew point of the combustion gases to allow a dilute solution of sulphuric acid to accumulate. If the accumulation is so small that concentrated sulphuric acid forms, no corrosion will take place, and it is doubtful if choking will take place, but with the dilute acid the quantity of liquid is such that it runs down the surface of the tube, collecting ash on the way, gradually building up until the tube is completely choked, and underneath the deposit the acid corrodes the tube surface. It is very rare that a horizontal tube air heater (Fig. 3) chokes, for the obvious reason that the gas passage is much freer, but this does not prevent corrosion taking place, and in fact, in practice the damage caused by corrosion in this design of air heater is more rapid, possibly because of the thinner tubes used in the construction. The form of attack was recognized soon after the troubles occurred, but unfortunately it was not then appreciated that the tube metal temperature was too low in service. Originally it was considered only

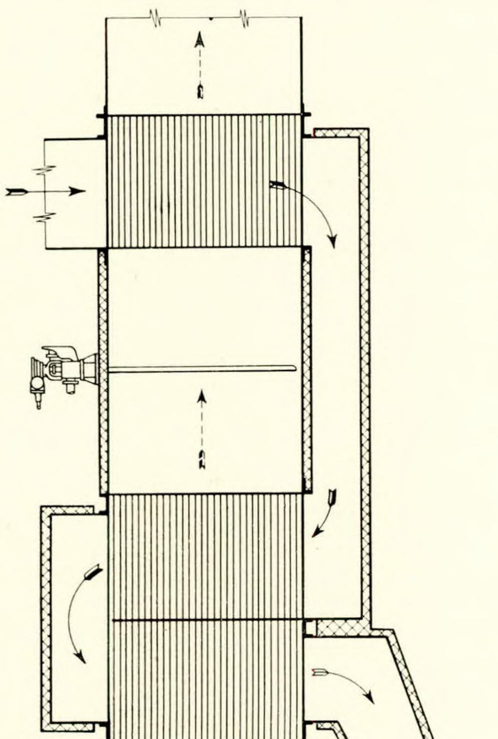

FIG. 2—*Vertical tube air heater*

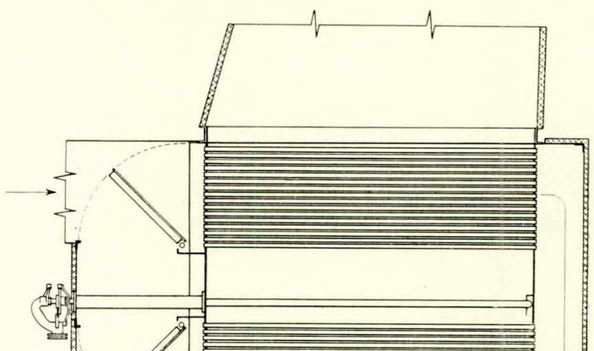

FIG. 3—*Horizontal tube air heater*

necessary to bypass the air heater during lighting-up, but experience proved that this was not sufficient and it was extended to manœuvring and light load conditions in harbour. Subsequent tests carried out under service conditions indicated that even with an air entering temperature of 100 deg. F., the tube metal temperature was still too low and this was only rectified by fitting steam air heaters before the gas air heater, coupled with improvements in the design of the latter.

It will be appreciated that the physical limitations in designing an air heater result in the metal temperature of the air heater tube being influenced primarily by the air temperature entering the heater irrespective, or practically irrespective, of the gas temperature leaving the air heater, whether this be either on the inside or outside of the tubes. Modern designs therefore now include steam air heaters in front of the gas air heater of such a capacity that the air temperature will be raised sufficiently to ensure a metal temperature of the gas air heater tube of approximately 260/280 deg. F. under all conditions of steaming which will give protection when burning fuel containing 5 per cent sulphur. It is recognized that this lowers the maximum overall efficiency of the boiler unit obtainable, but there is a small gain on the steam cycle efficiency from the bled steam air heater. With this arrangement it is not necessary to bypass air during light loads, but it is essential that the steam air heater be kept in use even when the turbines are stopped, and therefore an auxiliary steam supply is required and this should be approximately 150lb. per sq. in. gauge so that the air temperature from the steam air heater can be increased during these periods to counteract the smaller quantity of combustion air required. With such a steam supply, as the quantity of air decreases the temperature increases and there should be no difficulty in obtaining an air temperature at the inlet to the gas air heater sufficient to maintain a safe metal temperature.

Air heaters should be inspected on the gas side at least once every three months, and if the deposits are heavy the air heater should be water washed as this will remove the hard scale deposits as well as the loose soot, and if arrangements are provided in the uptake below the gas air heater to attach a sheet of "Neoprene" coated nylon with the necessary drain pipe in the side of the uptake, there is no reason why the air heaters should not be water washed without affecting any other part of the boiler unit. This means that the operation will take only a few hours from shut-down. Water washing is discussed in more detail later in the paper.

Because of the construction of the vertical air heater, hard deposits on the inside of the tube are more difficult to remove because the water cannot come in contact with the bulk of the deposit. Under these circumstances a steam jet has been found to be effective, particularly if the tube can be attacked while the deposit is still relatively hot. Failing this, the deposit will have to be drilled out, but this is a difficult and lengthy procedure and cannot readily be done except during the lay-off of boilers for survey.

Corrosion of air heater tubes is naturally greatest at the air inlet, and in the horizontal type takes place usually about 3in. to 9in. from the tube plate and extends from 3in. to 6in. An effective way of dealing with this situation without renewing a tube is to insert a ferrule on the inside; such a repair has extended the life of a tube by as much as two years. The reason the corrosion takes place in this position is the turbulence created by the air entering a tube increasing the heat transfer in this vicinity many times greater than the average over the length of the tube. Fig. 4 illustrates the detail of the ferrules.

An alternative means of reducing the damage caused by turbulence is to extend the air heater tubes some 12in. to 15in. beyond the tube plate. This method has been adopted on contracts but it is too early yet to know if it is completely effective.

A further alternative is to make the tubes from corrosion resisting material. Stainless steel gives very little protection from sulphuric acid attack, but certain copper bearing nickel steels have been found to double the life of the tube. Whilst

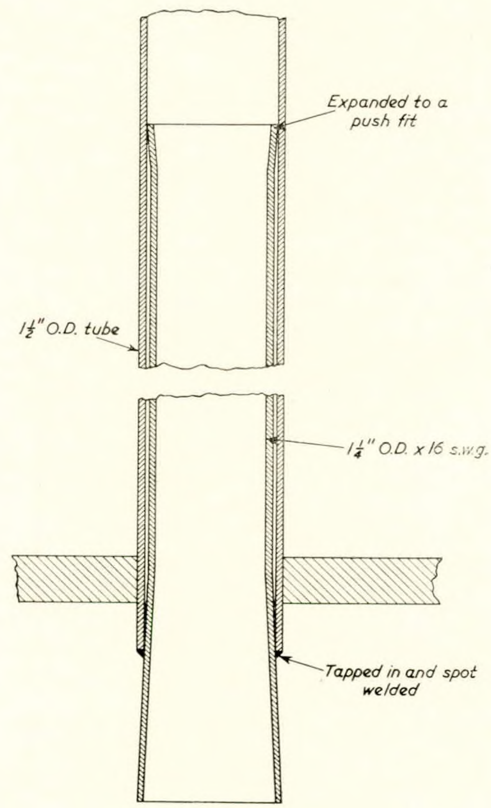

FIG. 4—*Air heater tube ferrule*

this is an appreciable advantage it must be remembered that the initial cost is greater. Other methods tried have been to coat a tube with vitreous enamel, but this is not only an expensive process but makes the attachment of the tube to the tube plate complicated and expensive, and should the enamel crack the attack will be concentrated and probably more rapid than on an unprotected tube.

In certain cases it has been considered desirable to protect the tube plate itself from corrosion, and this has been done by insulation around the tubes. In the author's experience this is a refinement, as the corrosion of tube plates has been negligible.

Another form of air heater is the plate type rotary heater which does not suffer to any degree from choking of the elements, but does suffer from corrosion, and this has been tackled by making the section most liable to corrosion in corrosion resisting steels and easily renewable, and the author can see no reason why a steam air heater should not be used before the gas air heater, as is done with tubular air heaters.

Cast iron plate type air heaters have been proposed and fitted in at least one vessel, but it is too early to say whether this type of heater will in the long run reduce maintenance to any appreciable extent, because if the conditions obtain when dilute acid is formed on the plates, choking will take place and renewal due to corrosion is only a matter of time. Whether or not this type of air heater is warranted for other reasons, such as reduction in weight and space, is beyond the scope of this paper. Generally, the author is of the opinion that the correct method of dealing with this part of the boiler unit is to ensure that the acid does not form even if this means some small loss in the boiler efficiency.

A point which cannot be ignored is that of fires occurring in air heaters. These are not so numerous as might at first be thought. The author's company has since the war supplied boiler units with air heaters for over 340 ships, and during that time they have been notified of fires occurring in only eight ships. Nevertheless, the disorganization of the ship's routine when such a fire occurs is so serious that a considerable amount of research has taken place to ascertain the cause, and although it is not pretended that all the answers are known it is felt that the main reasons are now appreciated.

Fires occurred with some frequency during the war in American-built ships, but the reason was not far to seek. These vessels were capable of from 15 to 17 knots, steaming in convoys at from 10 to 12 knots. Automatic combustion control was fitted to practically 100 per cent but was not adjusted or even capable of adjustment down to such low loads; the consequence was that the combustion was far from perfect, and it was not permitted to use the soot blowers. The result was that at the end of the voyage the air heaters were badly fouled and the fires almost universally occurred when the burners had been relighted after standing idle for some 12 to 24 hours, during which time the carbonaceous matter on the air heater tubes was absorbing residual heat from the furnace brickwork, etc., and in a reducing atmosphere was glowing. The admission of air under these conditions resulted in a fierce burning of the deposits. These conditions do not obtain today but it is still the author's experience that fires occur principally after a shut-down period, sometimes after the air heaters have been hand cleaned, the boilers having been lit up and perhaps intermittently steamed for some 12 to 24 hours. The reason here is more difficult to appreciate, but laboratory experiments have shown that if the carbon deposits contain a small proportion of ferrous sulphide which readily oxidizes in air with the separation of sulphur, the heat generated may be great enough to give incandescence and the deposit will burst into flame at as low a temperature as between 400/600 deg. F. This means that great care has to be taken to obtain better combustion when lighting up, particularly in avoiding the dangers of white smoke, which indicates too much combustion air, and it is here that some attention has to be paid to the minimum output of the forced draught fan, particularly if of the single-speed variety, and additional dampers on the discharge side of the fan will probably be required to reduce the quantity of air to that necessary for very low loads. It may even be an advantage on certain installations to provide a small fan for lighting-up purposes only.

It also seems most desirable not to bypass the air heater on the air side, thus keeping the temperature of the tubes always below 400 deg. F., but the possibility of corrosion must not be overlooked.

One point of interest to note in the construction of an air heater is that at one time it was thought necessary in order to provide for expansion of the tubes that they should be completely rolled into the tube plate at one end and only lightly rolled at the other end. This has not been found necessary in practice and has been the cause of air leakage. The tubes should therefore be completely expanded at both ends. Precautionary measures to prevent fires in air heaters and the action to be taken should a fire occur are briefly described as follows.

General Precautions

Maintenance of Good Combustion

Oil burning and draught equipment should always be properly operated to assure good combustion. This will prevent smoking or diluting the combustion gases with too much excess air, particularly under low load operation conditions. It will materially assist in preventing the deposition and accumulation of unburned combustible material, either on the external heating surfaces or in the gas passages.

Operation of Sootblowers

Under all conditions of operation, sootblowers should be used at frequent intervals. The time interval between sootblowing periods should be determined by the individual requirements of each installation, as observed under actual service conditions. Generally, sootblowing once per day, revolving each unit three or four times, should be sufficient.

Prior to using the sootblowers, the gas velocity through the boiler unit should be materially increased, by increasing the speed of the forced or induced draught fans, or by further opening the fan dampers.

Sootblowers should be operated, starting at the air heater or economizer blowers, and then in order from furnace through the boiler to the outlet and finishing again with the air heater or economizer sootblowers.

The stop valve in the steam supply line to the sootblowers must seat tightly. Any leakage through this valve, in combination with an open or leaky sootblower head valve, will result in the introduction of vapour or moisture into the gas passages, causing soot to cake on the adjacent surfaces and make removal difficult.

Inspection for Obstructions, and Hand Cleaning

All external heating surfaces and gas passages should be frequently and periodically examined. If it is noted from such examinations that deposits tend to accumulate at any particular location, despite the periodic sootblowing, it will then be necessary to arrange for periodic hand cleaning of such portions of the boiler unit.

While a boiler unit is in operation, screen meshers or other obstructions that would in any way interfere with the removal of the products of combustion must not be placed across the top of the stack opening or in the boiler breechings or uptakes.

Checking of Gas Temperatures

The uptake gas temperature should be checked at frequent regular intervals during each watch, and any sudden or inexplicable rise or reduction in this gas temperature should be investigated immediately.

Precautions—Port Load and Low Load Operation

It is under port and low load rates of operation that most air heater fires are apt to occur. Operators should therefore note particularly, and become familiar with, the following precautionary measures.

Care in Changing Load

Generally, under port operating conditions, load changes are frequently experienced, thus necessitating the cutting in and out of burners as required. When operating under such conditions the fuel oil pressure, fuel oil temperature, quantity of air supplied and the flame appearance should be kept under close observation, so as to assure the proper atomization and burning of the fuel oil.

Whenever a burner is cut in, *always use a torch.* Do not attempt to light the burner from an adjacent burner or from the hot brickwork. Before lighting the burner make sure that properly heated oil for this burner is available. The recirculating line should be used for this purpose.

Loss of Burner Ignition

Whenever it becomes necessary, regardless of duration, to shut off all burners under a boiler, or should the burners be extinguished (ignition lost due to low oil pressure, water in the fuel oil, cold fuel oil, etc.), *the furnace and the gas passages of the boiler unit must be thoroughly purged before any attempt is made again to light a burner.*

In the case of ignition loss the valves leading to the individual burners should be closed immediately, then the purging operation started.

Purging Operation

Purging of the gas passages can be accomplished by opening the air register doors on all oil burners and operating the fan at a moderate speed for a period of five minutes.

Relighting Burner

On completion of the purging operation, as many burners as are required may be put into service. When lighting each burner, and with the lighting torch in proper position, the last valve in the branch connexion leading from the fuel oil heater to the burner should be slightly opened. If the first burner fails to ignite in a period of five seconds, the valve should be closed and an investigation made. The fault should then be corrected, and the gas passages purged before another attempt is made to light the burner. Once the first burner is ignited, additional burners may be lighted to satisfy load requirements —*use a torch to light each burner.*

Careful attention to the above precautionary measures will eliminate the possibility of delayed or accidental burner ignition and furnace explosions—which latter, while generally of a minor character, may be of sufficient magnitude to shoot flame up into the gas passages and cause ignition of any accumulated combustible material.

Use of Proper Sprayer Plate

Under steady and very light port load conditions, such as might prevail at night when cargo is not being worked, a sprayer plate should be selected of a size that will allow operation with one or more burners in continuous service, while maintaining the proper oil pressure. Thus, a better regulation of proper combustion conditions can be obtained.

If, after operating as already described for any appreciable length of time, an increase in load necessitates cutting in an additional burner, it is particularly necessary to determine that hot oil is available for this additional burner before any attempt is made to light the burner.

Precautions—Hand Cleaning

Whenever a boiler unit is taken out of service for periodic inspection and routine cleaning, sufficient access doors and casing panels should be opened, or removed, to assure that all essential parts are accessible.

Prior to cleaning, the air heater surfaces should be thoroughly examined, to ensure that all deposits and accumulations of combustible material are located. Whilst such concentrations constitute a greater hazard than the lighter and more uniformly distributed combustible matter, extreme care must be exercised in locating, and then removing, both such light and heavy deposits, especially where concentrated in corners, etc.

The cleaning operation should start at the top of the air heater and progress towards the furnace. As the latter is reached, all loose accumulations which have fallen on the floor should be removed by a vacuum cleaner or some manual method. This must be done immediately in order to prevent any fine soot from being picked up by the draught or suction in the furnace and redeposited on the cleaned heating surface.

Precautions—Placing of Unit in Service Following Hand Cleaning

Replace all casing and access panels which were opened or removed during the cleaning operation.

Open wide all burner register doors, and start forced or induced draught fans. Operate these fans at a speed corresponding approximately to that used during full power rating.

After observation reveals a clear funnel and no further ejection of soot particles, the forced or induced draught fans should be continued in service at approximately their full power speed for an additional 15 minutes, following which these fans can be slowed down, the first burner ignited and the boiler placed in service.

Action in Case of an Air Heater Fire

In the event of an air heater fire the following action should be taken immediately to minimize the damage that may occur.

a) Shut off the oil supply to all oil burners.
b) Close the air registers on all air burners.
c) Secure the forced or induced draught fans of the affected unit and close the inlet air damper.
d) Raise the water in the steam drum so that the level is just in sight at the top of the gauge glass.
e) By means of the access door in the boiler uptake, proceed to flood the uptake area over the air heater with a carbon dioxide (CO_2) or other suitable fire extinguisher.
f) Do not use sootblowers as such action at this time may cause a serious gas explosion.

Repairs

Temporary Repairs

If the air heater is damaged on an installation fitted with an air heater bypass damper, the bypass may be opened and the air heater closed off completely.

Permanent Repairs

On the basis of the inspection, damaged material should be repaired or replaced at the first opportunity. Where the air heater sootblowing system has been damaged, immediate repairs are advisable to permit the proper cleaning of the unit.

ECONOMIZERS

Marine economizers fall generally into two types—the mild steel stud tube extended surface and the mild steel with cast iron or aluminium extended surface, and in many installations there is a combination of both.

The size of the economizer is governed by the feed temperature. If the feed temperature exceeds 300 deg. F., a relatively small economizer will be needed and the ultimate efficiency of the boiler unit will be obtained by fitting a gas air heater after the economizer. If the feed temperature is between 260 and 280 deg. F. it will probably be decided to dispense with the gas air heater, and in this case the economizer will be larger because it has to do more work, and either of the above mentioned types is suitable because the risk of corrosion or choking is negligible. If the feed temperature is 240 deg. F., the economizer must be either entirely of the cast iron extended surface design or a combination of the two. The ultimate decision will be made probably from space, weight and cost considerations. In both cases a steam air heater will be provided, usually of a size to heat the combustion air to approximately 250 deg. F., although it will be appreciated that should the overall design of the machinery warrant it this temperature could be considerably increased. The difference in the overall efficiency of the boiler unit with 280 deg. F. feed to 240 deg. F. feed would be approximately 0·4 per cent, the advantage lying with the lower feed temperature.

As with gas air heaters so with economizers; a trouble-free job will depend on the metal temperature of the economizer elements. Unless this surface can be maintained at a sufficiently high temperature to avoid the deposit of dilute acid, choking and corrosion will occur, and it must be recognized that this is a fundamental fact and cannot be avoided. Further, the metal temperature of an economizer element is a factor of the feed temperature and is usually some 10 deg. F. higher.

The importance therefore of maintaining the feed temperature under all conditions of steaming will at once become apparent. If the normal feed temperature is 280 deg. F., there is a margin of some 30/40 deg. F. by which the feed could drop under light load or harbour conditions without causing either choking or corrosion, but a feed temperature of 240 deg. F. is so close to the minimum required that under no circumstances whatever should this feed temperature be allowed to fall any lower, and not only must means be provided to maintain this feed temperature, such as the use of live steam in the deaerator feed heater, but it is essential that the operating staffs ensure that this alternative means be used and see that any automatic valve fitted is always in perfect working condition.

These points cannot be too strongly emphasized because the gas temperature leaving the economizer has for all practical purposes nothing to do with choking or corrosion. If the feed temperature falls to, say, 200 deg. F. the gas leaving temperature can be as high as 600 deg. F., and still choking and corrosion will take place, and it is the author's experience that this point is very often overlooked. Should choking take place the only effective means of removal is by water washing. Details of this will be found later in this paper, but by the use of a "Neoprene" coated nylon screen under the economizer this part of the unit can be water washed without interference with the remainder of the boiler, and it should be emphasized here that there is everything to be gained by using this method as otherwise there is the danger of washing the heavy deposits from a choked economizer down into either a lower section of the economizer or on to the boiler generating surfaces, which can be overlooked and cause trouble at a later date.

Carbonaceous deposits in economizers have also caused fires, and it is therefore equally important that care be taken to maintain combustion as near perfect as possible when lighting up and under very light load conditions, and to ensure this the author would again refer to the importance of studying the fan characteristics to make sure that the right quantity of air is supplied, particularly in avoiding white smoke.

Economizers are a pressure part and must be treated as such, but if care is taken in operating the boilers, both on the gas and water side, little trouble will be experienced in maintenance. More and more economizers of all-welded construction are being fitted with only sufficient access doors for inspection during survey, therefore joints are reduced to the absolute minimum, and to enable a surveyor to assess the internal condition of the elements, designs provide for certain elements to be extended at the return bend so that the bend can be cut off, inspection of the tube made, and after the ends have been dressed the bend rewelded into position. Should an element leak in service there are usually two ways of continuing steaming of that unit:

a) Interconnecting piping is provided on the feed side to bypass entirely the economizer, which must be drained and left empty, the gas temperature in this part of the boiler unit not being such that any permanent damage will occur.
b) That particular section of the economizer can be plugged either through the access door in the economizer box with the normal tube plug or by cutting through the element in proximity to the box and sealing by means of a special plug, types of which are illustrated in Figs. 5 and 6.

One trouble which does occur is leaking of handhole door joints, with the result that the faces become scored and have to be remachined. The reason is probably due to fluctuation of feed temperature during manœuvring.

Many types of joints have been tried and in the author's opinion the most effective is the reinforced "C.A.F." joint, double dipped in graphite. Here it might be of interest to give a brief history of experience with various types of joints. When high steam pressures and temperatures were first introduced for marine service, the "C.A.F." type of joint was almost universally used, with excellent results as far as steam tightness was concerned, but it was found that there was one great disadvantage—the joint invariably carbonized on the face of the box and was very difficult to remove, and if small portions were left on the surface it was impossible to remake the joint satisfactorily. Other types were then used, first the plain metal sheathed asbestos filled, and later the spirally wound with asbestos insert. These gave results varying from job to job, but could not be considered wholly satisfactory.

The improved technique which enabled a reinforcing wire mattress embedded in a 1/32-in. thick "C.A.F." joint and the process of dipping twice in a solution of graphite has greatly strengthened the joint and avoided carbonization, with the result that experience over the last two years has been most satisfactory.

Care in applying the joint is of the utmost importance as the least carelessness in boxing up a job can lead to untold trouble when the vessel goes back into service. Great care is taken in the design and machining of the faces on the boxes and the door clamps to fine tolerances, and too often this is not appreciated by people handling the doors which are often taken off, thrown in a heap and replaced without the slightest inspection to see if the door has been damaged in any way. This also occurs when new doors are used which might have suffered in transport. Care must be taken to see that the joint is a perfect fit over the spigot of the door and that the door is carefully inserted into the box and seats properly before being tightened. It is also very good practice to smear the threads with molybdenum disulphide grease before running down the nut. This lubricant is expensive but very little is

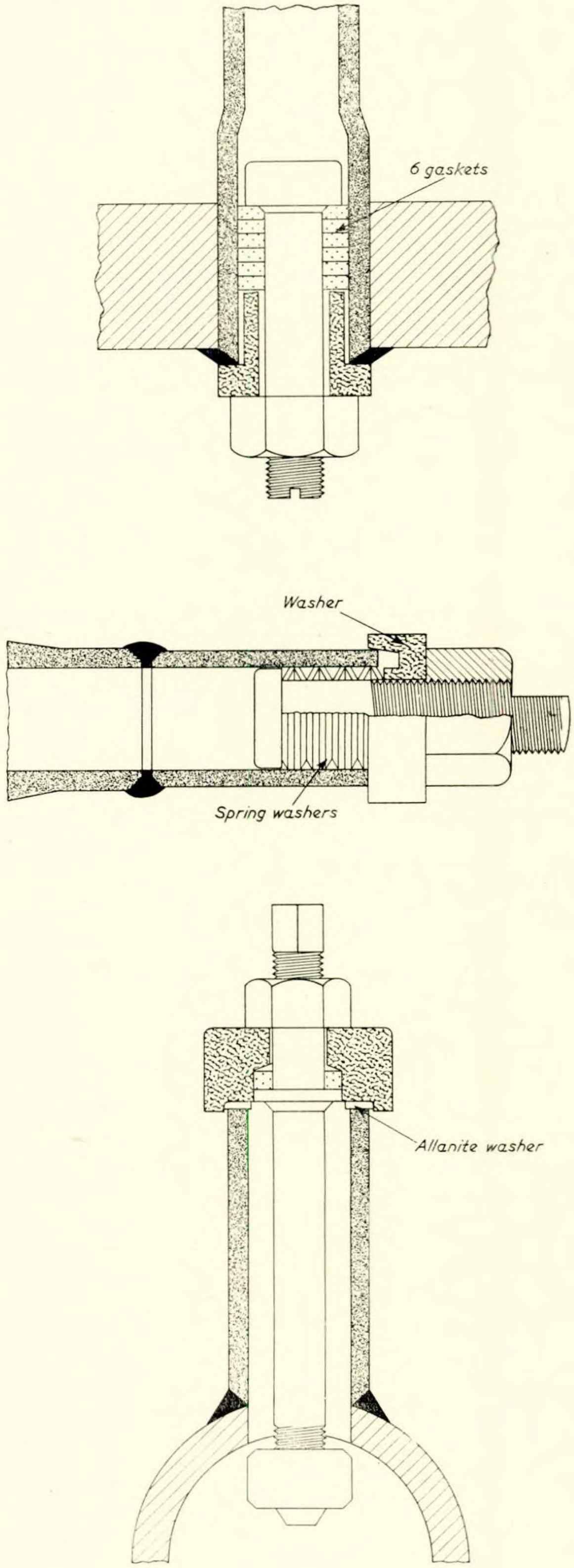

FIG. 5—*Typical economizer tube plug*

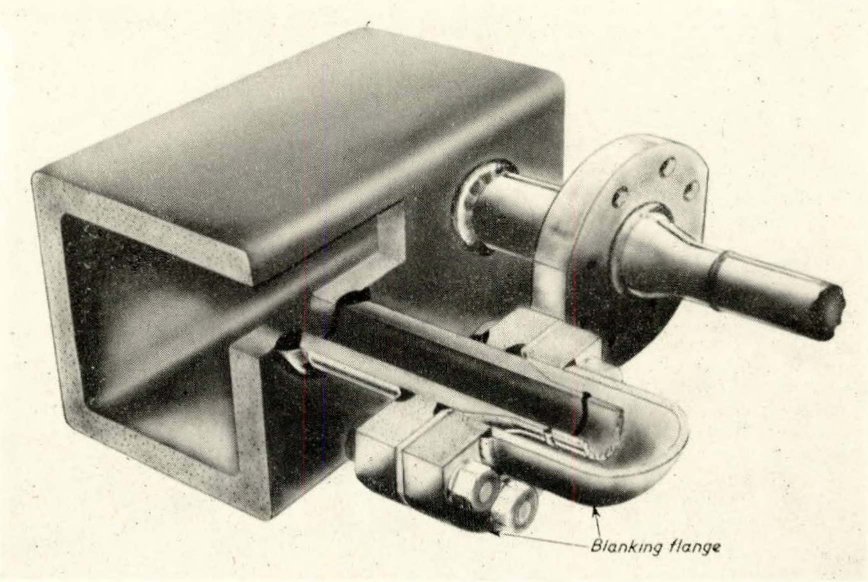

FIG. 6—*Typical economizer tube plug*

required and the cost is saved several times over when next the door is removed.

It should now be placed on record that the length of the spanner used in tightening the doors is no criterion whatever as to the steam tightness of the finished job; in fact, quite the reverse, as invariably when a long spanner is used, operated by two lusty men, distortion of the box takes place and no amount of force will make a badly fitted door tight. All doors up to 5-in. square need a spanner only 14-in. long, and to make sure that there are no leaks in service all doors must be followed up whilst steam is being raised after fitting new joints. It is recognized that in a modern double cased boiler the work involved is considerable, as outer casing doors have to be replaced to permit the fans to be in operation when raising steam, then removed to retighten the doors, and again replaced. However, the pressure of air required to raise steam is small and for this purpose one or two clamps on each side are all that is necessary to secure the access plates. This permits of easy removal and the plates can be permanently fitted after the doors have been followed up. The result of this procedure will repay many times over the inconvenience of carrying it out.

Can a plea be made at this stage that when finally replacing a casing access door, the door be examined to see that the joint on the landing edges is in perfect order and that the clamps bear evenly on the door when pulled up? This will prevent air leakage and the economy gained in service will more than repay the care taken.

AIR CASINGS

Following the flow of air we now come to the boiler casings. Due to added resistance to the gas flow by the addition of economizers and the reduction in size of boilers, air heaters, etc., resulting in generally high ratings, the resistance through the boiler unit has increased and requires either the use of an induced draught fan or a pressure carried in the furnace, and in order to maintain simplicity in design and operation the more common practice today is to allow a pressure in the furnace. Because of this it is imperative that the whole boiler unit be double cased, i.e. an air jacket around the whole of the boiler unit. This prevents gas leakage into the boiler room space, and if there is any resistance to the gas flow after the boiler unit by grit arresters and high velocity funnels, it is recommended that the air jacketing be carried right up to the top of the funnel. This jacket should be insulated and has the advantage of reducing radiation losses and maintains the uptake plates at as high a temperature as possible, thus reducing the deposits on these parts and the risk of corrosion, and what is perhaps more important, of deposits accumulating and falling down on to either the air heater or the economizer and causing or aggravating choking.

To reduce radiation loss from the boiler unit it is advantageous to lead the air in a positive direction from the air heater down the back of the boiler underneath and along the sides to the oil burners at the boiler fronts. It is now also common practice to take a tapping from the cold air discharge from the fan to provide a small proportion of cold air to flow down the double casing at the sides of the unit, thus materially reducing the temperature of the casings and improving the habitability of the boiler room. The air casings require little attention but it is important that these be inspected periodically to make sure that there is no accumulation of foreign deposits that might enter with the air flow, particularly carbon deposits from a regenerative type air heater, and what is even more important, and unfortunately is overlooked on too many occasions, cotton waste, wood blocks, planks, sacks, etc., are not left in these spaces after a refit has taken place. The number of fires in the boiler casings from this cause are, regrettably, much too frequent and it is respectfully suggested that a senior member of the operating staff be held responsible for inspection of the closing up of a boiler after refit, for it is the operating staff which suffers if any trouble does occur.

The sight doors are an important feature in the furnace side walls, as they provide for inspection of combustion conditions. These usually take the form of a window in the outer casing and a flap on the inner casing operated by a lever on the outside. Unfortunately, with the use of water cooled furnaces the size of inspection holes is restricted, and it is most important that the maximum use be made of what is provided. The windows therefore should always be kept clean and the flap on the inside free to operate, and it is more important for the flap to be a loose fit than that it should form a perfect air seal when closed. The amount of air leakage from a loose fitting will in any case not affect either combustion conditions or boiler efficiency.

OIL BURNERS

The air now flows into the air registers and oil burners. These are certainly one of the most important items of a boiler unit. An enormous amount of thought and experimentation has gone into the design and development of oil burning equipment and it can be said that the choice of a particular make today is very similar to the purchase of a motor car, where the shape of the body and the colour of the upholstery is the final deciding factor rather than whether or not one particular unit is slightly more efficient than another. On the other hand, like the motor car, the oil burning equipment will only give of its best if maintained in a proper condition, and it is to be regretted that even today in many cases the oil burners are only looked on as a boiler maker's job which can be treated as roughly as possible, whereas the oil burner itself, and particularly the burner tips, are a precision job and can be damaged very easily. A complete paper could be read on this subject and the present paper only aspires to generally useful comments which will amply repay the operator if carefully followed.

Great care is taken in the manufacture and inspection of the parts. The sprayer plates are machined to a tolerance of 0·001in. and are then encased in "Crocell" for protection before use. Is it therefore unreasonable to expect special treatment in cleaning during service? The burners should be changed after four to eight hours' use, and on removal the end of the burner should be immersed in a solvent oil for some thirty minutes, when any carbon deposit can be wiped off with a soft rag. On no account should wire be used to prick out the slot or orifice holes; if this is done the fineness of the spray will be destroyed. It is also important that the sprayer plates be correctly seated on the end of the burner, and the end caps or nuts tightened with care to avoid distorting the plates.

To obtain good atomization, use the size of sprayer to give the required output with a pressure at the burner fronts within 20lb. per sq. in. of the maximum pressure recommended. Filters must be kept clean and the oil to the burners maintained at the correct viscosity. This requires regulation of the temperature of the oil both in the daily service tank and when leaving the oil fuel heaters. The oil fuel pumps are usually ordered to handle 2,000-sec. oil and if the oil bunkered is above this figure the temperature to the pump should be kept a little higher than stipulated in the charts provided to give a viscosity of 2,000 sec., always remembering that the maximum temperature permissible is 150 deg. F. Opinion differs as to the best viscosity for burning but today it is generally accepted as between 80/100 sec., and strict attention should be paid to seeing that the necessary temperature to give this viscosity is carried at the oil heater outlet. With oil bunkered today this may be as high as 275 deg. F., and as a general statement experience has shown there is a tendency on the part of the operators to keep a lower temperature than is really required.

When burners are of special design, such as spring loaded, to increase the range of output, makers supply a special testing rig such as the one illustrated in Fig. 7, and to maintain consistently good combustion burners should be tested and adjusted every time they have been dismantled. Burner control valves should be kept in perfect condition so that when shut no leakage occurs, as otherwise dripping will occur at the burner tip and carbon will form on the register. This will not only affect air distribution, but, even worse, will make the register difficult to operate, and in consequence the combustion is affected. Further, a dripping burner can cause an accumulation of oil in the air casing with the obvious risk of fire.

The oil fuel shut-off valve operated by the low water alarm is most important. The operation of this valve should be checked every time steam is raised to see that it can move freely, and especially after a refit, to make sure the spindle has not been covered with paint or the gland tightened too much, the cause too often of failure in operation when required.

As to the actual burning of the fuel, given the right temperature and pressure there should be no difficulty regulating the air supply to give good combustion. Many vessels today are provided with automatic combustion control which controls the air supply by measuring the drop in pressure over the oil fuel register and relating the drop to the quantity of fuel burnt. Once the control is properly set to maintain a given CO_2 in the combustion gases the air supply will be regulated automatically for long periods without further adjustment. It is essential however to see that the equipment is kept in good working order, and a periodic check on the CO_2 well repays the trouble involved. This should be done at

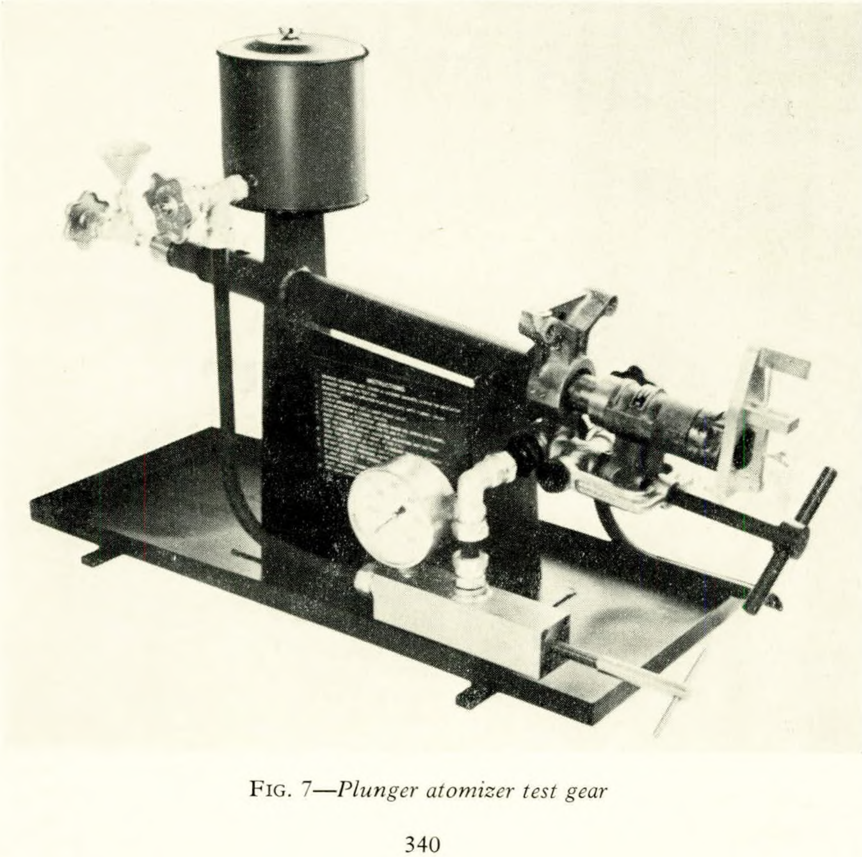

FIG. 7—*Plunger atomizer test gear*

least once every three days, but preferably once a day, the aim being to keep the CO_2 constant between 13 per cent and 14 per cent. Above this figure there is the possibility of incomplete combustion with the formation of CO, a small percentage of which will greatly reduce the boiler efficiency and is difficult to find in a normal gas analysis test. With hand control more attention has to be paid to the regulation of air and therefore more frequent gas analysis should be taken; preferably a recording instrument should be provided, but it should be noted that this will be of no use unless the instrument is kept in perfect working order, a fact too often forgotten.

People responsible for machinery layouts should see that any levers for operating control dampers are arranged in a convenient position. No one will regulate the air supply efficiently if it means running up and down ladders.

Finally, when a burner is not in use, either withdraw it completely or at least as far back as the register will allow. Remember the heat reflected from the furnace and then it is easy to imagine the effect on the end of the burner.

Check periodically the alignment of the burner, particularly if the registers have been removed for overhaul or access to the furnace. One way this can be done is by inserting a rod through the burner opening to act as a straight edge and check the dimensions from the makers' drawings. It must be remembered that in order to make the boiler as small as possible for a given evaporation, burner clearances are kept to the minimum and in consequence malalignment may result in impingement of the flame on floor or tubes which will ultimately mean additional maintenance.

BOILER AND SUPERHEATER

Furnace

A whole book could be written on the care and maintenance of the furnace, and the attempt to be made here will be to highlight what are considered to be the more important points.

If normal prefired firebricks are to be used, let it be said at once that the best quality is the cheapest in the long run. The bricks should be laid without any cement jointing, the bricks only being dipped in a cream made from grog of the same material. They must be well anchored, the anchors being of the protected type, i.e. not penetrating through to the fireside of the brick. Adequate expansion should be allowed, preferably at the sides and top of the walls, and, as an empirical figure, an allowance of ¾in. all round, with some increase at the top if the wall is very high, will be found satisfactory. The expansion gaps should be so formed to prevent the flame from penetrating to the boiler casing. A typical arrangement is shown in Fig. 8. Do not fill these gaps with broken brick or fireclay. It is not necessary to key the floor bricks but expansion gaps must be left around the floors, and the pans carrying the bricks must also be free to expand either around the perimeter or by flexible joints between the pans. In general a wash over the face of the brick is not recommended, but if a wash is used it should be applied with a brush no thicker than distemper on a wall. Walls of monolithic construction made from mouldable firebrick are today in general use, and experience has shown that this type of wall properly applied has a greater resistance to spalling than a wall built of bricks, and the most probable reason for this is somewhat surprising. Although the grog used in the manufacture of mouldable firebrick has been prefired, the wall as completed can be considered in the green state and has to rely on the furnace temperature when the boilers are lit off to complete the firing process of the clay; as it is not possible to obtain a sufficiently high temperature to completely fire the clay throughout the thickness of the wall, the material behind, say, 2in. from the face, in consequence remains flexible and can better withstand changes due to thermal shock. These changes are taken care of in the face of the wall by expansion cuts made during the construction. As spalling is probably the most usual cause of maintenance in furnaces there now seems little doubt that a monolithic wall built of mouldable firebrick has definite advantages over the normal brick, but it cannot be emphasized too strongly that this is only the case if the mouldable is of suitable quality and properly applied. In the author's opinion this is so important that the following complete instructions for application have been included in this paper.

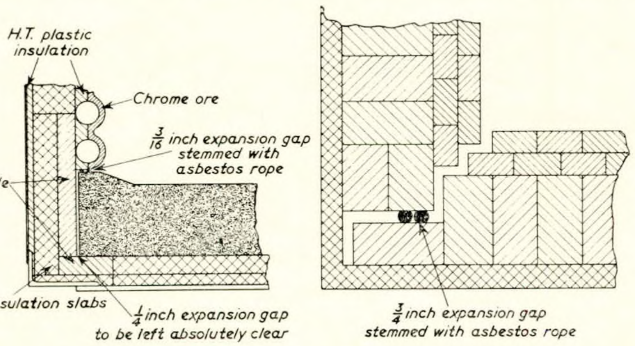

FIG. 8—*Typical arrangement of expansion gaps*

Most valuable work has been done on this subject by the British Ceramic Research Association in conjunction with the British Shipbuilding Research Association, and it is almost solely due to this work that the present conclusions have been reached.

With the exception of precast burner quarls castable refractory is not recommended for furnace walls, although this may be suitable for lining boiler casings or behind water cooled walls.

Whilst there is no doubt that the best procedure is to incorporate the burner openings in the monolithic construction of the front wall, there are those who fear that it would be difficult to rebuild or repair the burner openings with mouldable firebrick and for this reason prefer a preshaped brick which can be bolted in place, and castable refractory is a very suitable media for this; but here again the material must be of the right quality and the procedure in casting must be correct. In a modern marine watertube boiler, side and rear walls are inevitably water cooled, leaving only the front wall and floor built of refractory. The water cooled surface is of two types —the tangent wall built up of plain tubes practically touching one another, behind which is a thickness of refractory usually cast in place, followed by insulating material between the refractories and the boiler casing. The other type is a wall built with stud tubes into which is hammered chrome ore to seal the spaces between the tubes, and at the front of the furnace to cover the tube completely, so that the furnace temperature at the front shall be such as to assist the burning of poor quality oil and under low load conditions. Chrome ore has a relatively low refractoriness but is extremely resistant to slag attack and is ideal for the purpose intended, but is not suitable for building a wall on its own. Here again the correct method of application is all-important and instructions for this are included. Perhaps one of the most important points in application is the condition in which the surface of the chrome ore must be left. Under no circumstances must this be trowelled off smooth but must be stippled with a wire brush to leave the surface as rough as possible. The reason for this is that when cold the natural properties of the material form myriads of hair cracks on the surface which disappear under working conditions, and if the surface is trowelled smooth spalling will occur.

Ash will be deposited on the furnace floors, usually in a molten or semi-molten condition and will tend to accumulate at the front of the furnace. When the furnace cools down the deposit solidifies into a hard mass and must not be allowed to grow to a depth of more than 3in. as this will affect the oil burning from the lowest burners, which, to facilitate operation, are positioned as low as possible. A quick method of reducing the height is to chisel channels in the deposit about 6in. wide and down to the face of the firebricks, into which the deposits will run when they become semi-molten on refiring the boiler. This of course is only a palliative and eventually the deposit must be removed, and unfortunately this often means that in breaking up the deposit the top layer of floor bricks are destroyed and have to be renewed.

A high percentage of the deposit is silica and alumina which has come from the reaction between the constituents of the ash and the floor bricks, and a possible means of preventing this, and also the bonding of the ash to the floor, is to fit a relatively thin layer of silica carbide tiles on the top of the floor. It is too early yet to say whether this is effective or not.

It is important that drain holes covered by a refractory tile are provided in the furnace floor, or at the bottom of the vertical walls, to provide drainage from water washing.

APPLICATION OF MOULDABLE, CASTABLE AND CHROME ORE REFRACTORY

Mouldable refractory is a material which is rammed into position and is supplied in various grades, but it must be borne in mind that the mouldable refractory used must be of the right quality for the temperature conditions in the furnace, and it is essential that the correct procedure is used in applying the material if a satisfactory result is to be obtained.

Water Washing

It is essential that all boiler cleaning, especially water washing, is carried out before the application of mouldable refractory.

Consistency

Normally the ramming material will be supplied in sealed containers of the correct consistency for ready use.

The water content of a mouldable refractory varies according to the type, and must be within narrow limits to give satisfactory plasticity. If outside these limits it will be difficult, if not impossible, to erect the material to give satisfactory service.

A practical method of testing the consistency is as follows.

A handful of mouldable refractory is squeezed and kneaded in the hand to a rough ball shape. This ball, when thrown on the deck, should become a slightly deformed mass. If it flattens appreciably, or "splashes", it is too wet; if it crumbles it is too dry. *No attempt* should be made to use the mouldable refractory unless it is of the correct consistency.

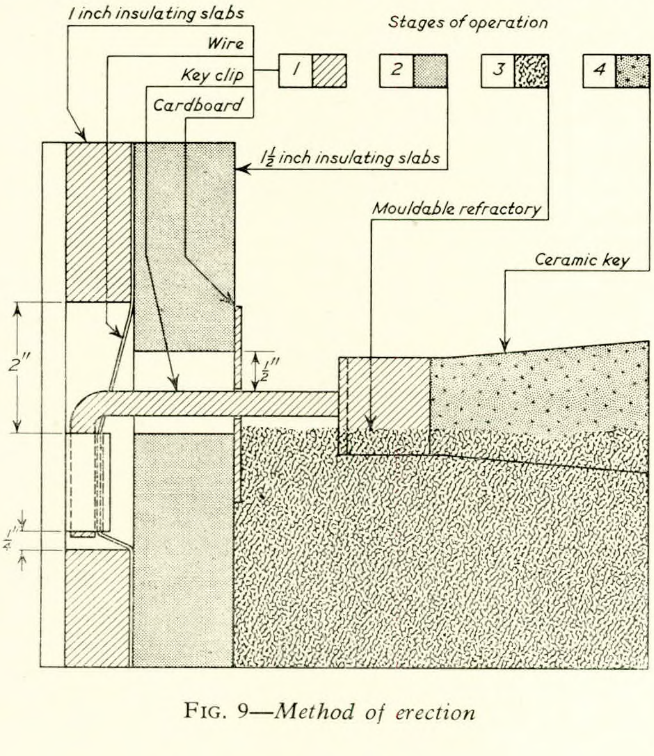

FIG. 9—*Method of erection*

Ceramic Keys and Bricks

Keys are necessary to hold the mouldable refractory, and it is strongly recommended that ceramic keys are used for this purpose, the general rule being one key to every 150 sq. in. of mouldable face, except in the overhanging portion of bowl fronts, where one key should be used every 80 sq. in. of mouldable face.

Holders are provided to give flexible attachment of the ceramic keys to the casing (Fig. 9).

Where necessary, angle section lintel supports in H.R. steel should be bolted to the casing above areas of mouldable refractory to facilitate the installation of standard furnace brickwork prior to the erection of the mouldable refractory, and also the renewal or repair of the mouldable refractory on service.

Insulation

Where practicable, insulation should consist of 1-in. thick insulation slabs which should be cut to clear the holders for at least 2in. above and ½in. below the holders and 1½-in. thick insulation slabs cut to allow expansion of the key clip shank. This will allow the ceramic keys and clips to be inserted in their holders during erection of the mouldable refractory. The 1-in. insulation slabs can be kept in position when building up, by inserting a length of wire in the holders and the 1½-in. slabs built up with the mouldable refractory.

Quarl Bricks or Formers

The quarl bricks or metal formers (where bricked burner openings are not used) should now be erected. Should insufficient formers be available for each quarl, the formers should be erected in the lower quarls and moved up as required, ensuring that when a quarl has been completed the former is not removed until adjacent quarls have been rammed. This will prevent distortion of the completed quarl during ramming of adjacent quarls.

See later instructions for method of building throats for B. and W. oil burners.

Damping

It is essential that the insulating material should not absorb water from the mouldable refractory during erection. Therefore the insulation should be thoroughly damped with water, containing a little refractory mortar, by light brushing prior to erecting the mouldable refractory.

Preparation of the Mouldable Refractory

The material should be prepared outside the furnace; the whole drum should be tipped out on to sacking, cut into small lumps approximately 2in. thick and passed into the furnace in buckets covered with damp cloths. If less than a drum of material is required, the remaining material should be covered with a damp cloth and the drum resealed.

Tools Required

The major tools required are:

a) A 2½-lb. hammer with 9in. haft length.
b) Bricklayers' trowels.
c) Wire brush.
d) ¼-in. diameter venting rods tapering to a blunt point in the last half inch.
e) Straight edges.

Levels and Thicknesses

Where shuttering is not provided, levels and thicknesses must be taken from the casing, as plumb lines will be of no value in the furnace. The thickness of mouldable refractory throughout should be checked at frequent intervals up the wall and levels should be checked with a suitable straight edge diagonally across the erected wall. It is preferable to build too much mouldable refractory and cut to the correct thickness on completion.

Method of Working

Mouldable refractory should be built upwards from the floor in horizontal layers and it should not be built outwards from the casings or insulation to the face of the wall in vertical layers.

It is important to bear this in mind at all times as there is a tendency for the material to form cleavage planes along the layers and if these are vertical and parallel with the casing, sections of the wall may drop out.

To commence building the wall a layer of mouldable lumps about 2in. thick are placed on the floor to the correct width of the wall but excluding the width of the ramp at the base, and this is pounded thoroughly with a $2\frac{1}{2}$-lb. hammer in a downward direction. Layer by layer the wall should be built up using small lumps, approximately fist size, and it must be ensured that these are well pounded, as the service life will depend upon this pounding. A piece of mouldable refractory can be considered to have been correctly pounded when, on further hammering, adjacent material tends to be displaced.

It may be found convenient to hammer a piece of wood about 2in. × 2in. or larger and approximately 18in. long when the mouldable refractory is not easily accessible, but whether using the hammer on its own or with a piece of wood, the surface of each layer should be left rough and well pitted to assist in binding the next layer of mouldable refractory.

As the wall is built up the ceramic keys are built into the mouldable refractory for the purpose of holding the wall back to the casing, and these are attached to the casing by means of holders which allow the keys to rise as the wall expands.

The face of the ceramic keys can be used as a guide to maintain the correct wall thickness, as this should be flush with the finished face of the wall.

The method of building these key bricks in the wall is to build the mouldable refractory up slightly higher than the level at which the key should be positioned and the key brick is then rammed down hard into the material so that the anchor just rests on the top of the anchor holder. The next layer is then built up over the key, ensuring that a small gap is left in the $1\frac{1}{2}$-in. insulation to allow the anchor to rise when the wall expands.

In order to prevent the mouldable refractory from filling the hole in the insulation, a piece of cardboard should be slipped over the shank of the anchor so that it covers the hole in the insulation, and this will burn out when the boiler is fired.

When the wall is nearing completion it may be found that downward strokes cannot be made and it will therefore be necessary to strike from the side out, still angling the stroke slightly towards the casing, until only a small portion is left in the top left hand or right hand corner, which must of course be filled by hammering direct against the casing or insulation.

When the wall is completed it should be checked for correct thickness by plunging the venting rods through the mouldable refractory to the insulating material as necessary and it will probably be found that it has bulged slightly in places.

This should be pounded back if possible but if not a straight edge should be placed against the wall and the surplus trowelled off. Do not leave a smooth finish with the trowel but beat it flat against the wall.

When the wall has been completely built and the thickness is correct, the floor at the base of the wall should be cleaned up and the mouldable refractory cut back about 2in. into the face of the wall to form a key for the ramp, as this will remove any material which has tended to air set whilst the wall was being built.

Before commencing to build the ramp, a piece of cardboard about $\frac{1}{8}$in. thick should be placed on the floor, so that when the boiler is fired this will burn out and leave a $\frac{1}{8}$-in. gap.

The ramp is then built up in the same method as the wall but with more of a tendency to strike towards the wall, ensuring that this is well pounded and keyed into the cutaway portion of the wall.

Procedure if Wall Is Left Unfinished

If a wall has to be left before completion, the unfinished mouldable refractory surfaces must be covered with damp sacking to prevent partial drying of the exposed surface.

Expansion Cuts and Venting

This is an important part of the erection procedure. During drying and subsequent firing, a very large quantity of water in the form of water vapour is given off from the mould-

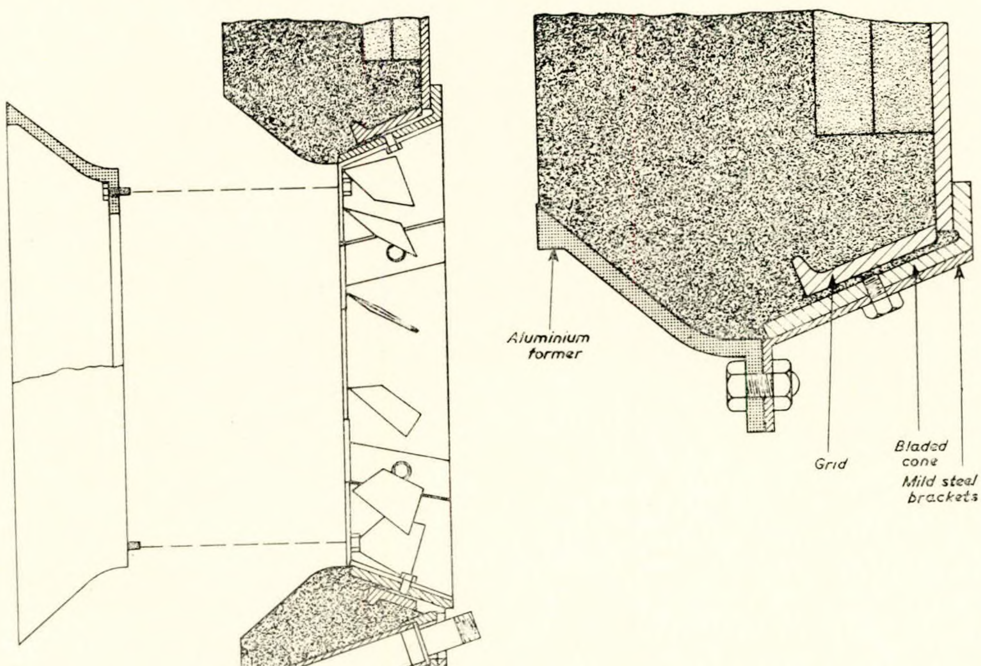

FIG. 10—*Former for Iowa burner throat*

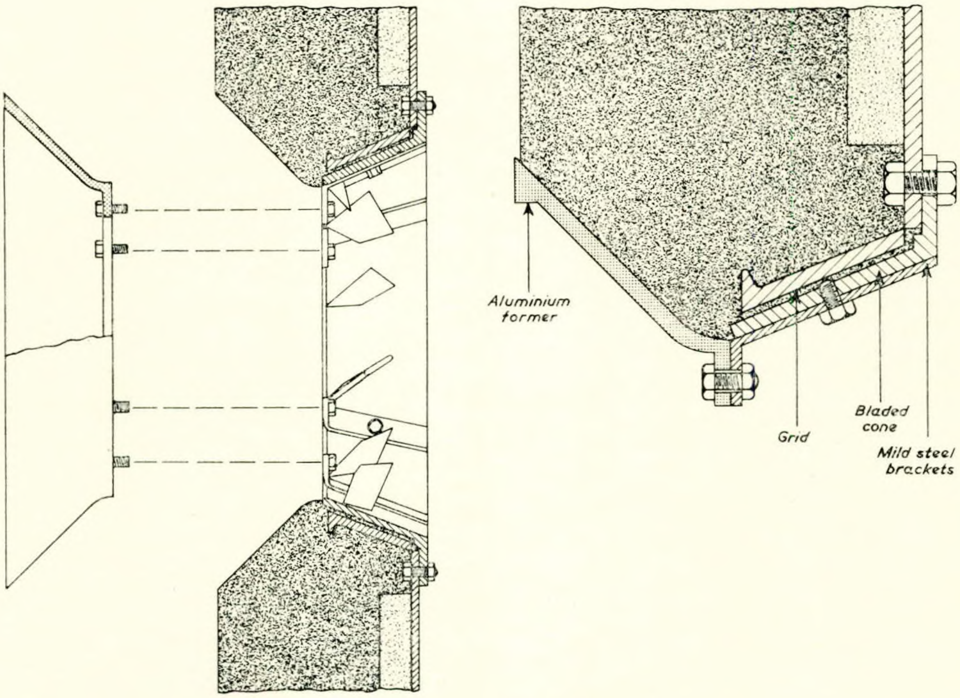

FIG. 11—*Former for decagon burner throat*

able refractory and free ventilation to the face is vital. Pockets produced in the interior of the mouldable wall by vapour which cannot escape will cause early failure. The cuts and vent holes also allow deeper penetration of the ceramic bond. Procedure is as follows:

a) The mouldable refractory is cut into sections of approximately 150 sq. in. with a ceramic key disposed centrally as far as possible. Expansion cuts in the burner openings should be radial and divide each opening into four or more equal parts. The trowel is used like a knife, with gentle pressure and a sawing motion, so as to cut the mouldable refractory and not to fracture it or cause incipient cleavage. The depth of these expansion cuts should be not more than 1in. deep.

b) Each of the sections should be further vented by inserting a ¼-in. diameter rod in four positions. The rod should be rotated, as a drill, in order to avoid disturbance of the material as much as possible. These holes should extend right to the insulation.

c) The entire surface of the mouldable refractory wall, including the quarl surfaces, should be stippled with a wire brush or hack saw blade to increase the surface areas.

Formation of Burner Throats for Babcock and Wilcox Oil Burners

Aluminium formers are supplied with each contract for the total number of oil burners fitted on one boiler (Figs. 10 and 11).

Before commencing the building of the front wall all the retaining grids and bladed cones should be in position with the exception of the one register which can be left free for access.

The grids are required to make a satisfactory key to the mouldable refractory as the normal key bricks cannot be built into the small spaces between the burner throats or placed sufficiently close.

The insulation should stop about 2in. from the grids to allow the mouldable refractory to enter the lighting holes in the grids which form part of the key.

After the grids and bladed cones have been correctly bolted into position, the wall can be built as previously described up to the level of the lower registers.

When this level is reached the aluminium formers can be attached to the bladed cones of the lowest registers and this is accomplished by bolting the six cleats provided with each former to the inside of the bladed cone between the blades and then attaching the former to these cleats. It is advisable to coat the working faces of the former with mould oil or grease to prevent damage to the refractory face when the former is removed.

The wall is then built up round these formers until it reaches the level of the next set of registers.

When this next level is reached the aluminium formers are then attached to this set of registers and the process repeated until the wall is complete.

The formers should be left in the lower registers as the wall progresses to prevent any distortion of the throats, and it is essential that the mouldable refractory is well pounded round the formers and grids and that there are no air spaces left.

It may be necessary when the former is erected in the last register for the former to be removed from the first register to permit access into the furnace and it is essential that this throat is well protected with sacking, etc., to prevent any damage whilst the mouldable refractory is still in its unfired state.

Firing and Curing

It should be remembered that the mouldable refractory only develops mechanical strength after it has been fired. Prolonged air drying is undesirable as the shrinkage rate is considerably increased. Erection of mouldable refractory should therefore be delayed until it is assured that the furnace can be lit up within 24 hr. after completion of the mouldable refractory installation and careful planning of work is required in preparing to bake out. The manufacturers recommend a long period of low temperature heating, followed by a gradual increase until the maximum working temperature is reached. This procedure is not always practicable for ships in service, and particularly new construction, and the following methods should be followed whenever possible.

Ships in Service

The boiler should be lit off not earlier than 6 hr. after completion of the installation of the mouldable refractory and not later than 24 hr. If this is not possible, the material should be kept moist with damp cloths until about 6 hr. before lighting off.

One burner at a low firing rate should be lit for 30 min. This burner should then be shut off and a second burner lit for a similar period. Use of each burner in rotation in this manner should be continued for a period of 12 hr. The linings should reach a dull red heat during this period.

After the initial firing described above, the furnace temperature should be gradually increased in a period of 6 hr. to the maximum attainable under the steaming conditions for which the boiler is being used. Final firing at the boiler full power rating is desirable if permitted by the steaming conditions. In port it is good practice to shift the boiler to the auxiliary load.

Firing of the boiler at the maximum practicable temperature should be continued for a period of 6 hr. This is desirable as the maximum temperature obtains for at least 4 hr. When the boiler is shut down the linings should be allowed to cool slowly.

New Construction

The initial firing of a new boiler will be either for boiling out or setting safety valves. It is important that the first paragraph of the section above is observed in either case. A low firing rate should be used initially for the boiling out process, or setting safety valves, so that the temperature of the linings is slowly increased, the linings being allowed to cool slowly on completion. The temperature attained by the linings during the initial firing will be insufficient to achieve a ceramic bond but should be sufficient to dry out the linings. It is very important however that when first working up to any appreciable powers or full load, this should be carried out slowly over a period of at least 8 hr., the lining being allowed to cool slowly when the boiler is shut down.

If time is available after completion of the baking out, and when the brickwork has cooled sufficiently, it is advisable to open the furnace and inspect the lining. Concentricity of burner openings should be checked.

Patching Procedure

If on inspection after service a portion of a wall is found to be spalled, it is not always essential that a repair is necessary and this will depend on the depth of spalling, roughly a depth of 1½in. on a 6-in. thick wall would not require patching, but the general appearance of the face of the remaining refractory must be taken into consideration when the decision is taken; a crumbling surface usually means a repair is necessary.

To carry out such a repair the refractory must be cut back at least to a 3-in. depth or until a good surface is reached, the edges of the patch to be undercut and given a wash of air setting refractory mortar, to form a key for the new material which is to be well rammed home in a manner as near as possible to the building of a new wall.

APPLICATION OF CASTABLE REFRACTORIES

Castable refractories are supplied in various grades and can be used as an alternative to prefired refractory blocks for lining boiler casings other than boiler furnaces or for special items such as burner throat bricks, or possibly furnace floors. It is extremely important that the right grade of material is used for any particular part, depending on the gas temperature in the vicinity of the part to be covered. This is to ensure a correct ceramic bond after firing in service.

Consistency

The material is supplied dry, normally in 1-cwt. 5-ply paper sacks. It is essential that the dry contents of the bag are thoroughly mixed before any water is added, even when a small quantity of material is to be used. After thoroughly mixing, the necessary quantity should be removed from the whole amount. Heap the material into a cone, break the top and gradually mix in clean water until a stiff plastic consistency is obtained, similar to that of ordinary building concrete. The quantity of water required per hundredweight varies with the make of material, but in general water separating from the mixture indicates that it is too fluid and further dry material should be added to obtain a proper balance. Thoroughly mix and allow to stand for a few minutes, then mix again before using. If a large quantity is required the material may be mixed in a cement mixer; if so, all traces of Portland cement must be removed and the inside of the drum thoroughly cleaned.

Keying of Castable

When used as a lining for boiler casings, keys are essential to hold the material in position, and as the thickness of material does not usually exceed 3in., H.R. steel metal twigs are usually used for this purpose.

Application

The boiler casings to be lined are first covered with insulating material in block form, boundary angles being fixed to the perimeter of the casings to protect the edge of the insulating material. After insulation is installed it should be wetted, greased or covered with waterproof paper, whichever is most convenient, to prevent loss of water from the castable. If the casings are to be lined *in situ* the necessary shuttering material, cleaned and oiled with mould oil, in order to prevent the moisture being absorbed by the wood, is to be clamped in place up to a convenient height, the insulating blocks placed on the casing and the castable mass poured up to this level. At this stage the castable is to be thoroughly punned, small section rods being used. Punning should be carried out at approximately 6-in. intervals and great care taken to ensure that the punned surface is thoroughly broken up before the next layer is added, in order to avoid lamination. Shuttering is then continued and the castable poured until the complete casing is covered. The shuttering should be left in position for 1½ hr. and after removal the surface should be kept damp for 24 hr. After this period at least 72 hr. should be allowed for air drying, when the material can be taken into service at the same rate as new furnace brickwork.

Precasting of Special Shapes

It may be found convenient to line individual casing panels independently, bolting up in place on the boiler when completed. In this case the instructions for casting special shapes should be followed.

For the casting of special shapes, such as burner throat bricks, a mould or moulds are made to the finished dimension of the brick required. The mould should be made of reasonably heavy construction and as watertight as possible, and to facilitate removal after casting the mould should be bound and held together by wing nuts. The inside of the mould should be coated with mould oil before pouring. The castable should be well consolidated in the moulds by punning, the interval at which punning takes place being governed by the size of the mould. Materials should be covered with damp sacking for 24 hr. after casting. The mould should not be removed until the casting is completely set, in any case not before 12 hr., and the casting must be left for a minimum period of 72 hr. for air drying before being handled, after which time the casting can be put in place and taken into service with the rest of the brickwork. It should be noted that these pre-cast shapes should be protected from ill usage if stored for spares.

APPLICATION OF PLASTIC CHROME ORE REFRACTORY

The following instructions are intended primarily for chrome ore refractory, known as "Plastic K.N.", used in conjunction with water walls of stud tube construction.

The material has the following characteristics:

a) It is air setting, which ensures that the structure is hard before heat is applied.

b) Its consistency is such that maximum density is easily obtained if properly rammed.
c) When burned in, it forms a very hard, impervious lining that has maximum resistance to abrasion.
d) It has a high temperature fusion point.
e) It has a high specific heat.

It is supplied in airtight steel containers, the lids of which should be replaced and fastened securely if any material is left in the containers.

Containers should be stored in a cool dry place.

The material has the correct consistency when leaving the makers' works and on no account should water be added.

Preparing for Use

When "Plastic K.N." has been stored for any length of time there is a tendency for the liquid portion to rise to the top; the containers should therefore be inverted for a day or two before opening. When required for use, the lid should be removed, the drum rolled to and fro and then inverted and the contents will slide out.

The material should be dumped on a clean surface, preferably a steel plate or a wooden mixing box which has been well soaked in water and the free liquid poured off; and the mass chopped with a sharp spade to 1-in. or smaller pieces and where installation is delayed cover with a wet bag to prevent air setting.

When "Plastic K.N." begins to air set, it should not be worked or rammed as it will not bond effectively afterwards; adding water will not improve this condition.

Only when it is impossible to obtain a replace supply of "Plastic K.N." should an attempt be made to soften or increase the bonding properties of the material by the use of "Pyrolite" and no other medium. The "Pyrolite" in cement form should be mixed with water to a thick consistency and worked thoroughly into finely chopped P.K.N.

In applying "Plastic K.N." to stud wall tubes it is important that the material should be in the closest possible contact with the studs and tubes and also that it is properly bonded one piece to another.

For this reason construction of the wall must be carried on to completion without interruption. Should there be any unavoidable hold-up, the edges must be covered immediately with damp sacks to prevent air setting. When work is resumed, chop down and roughen the exposed edge before working in fresh material.

Application

a) When applying the material it should be worked up into a ball 3 or 4in. in diameter by hand working, until sufficiently plastic to enable it to be driven in between the studs. It should not be worked too soft as it will then be more difficult to drive into place. In building the wall the "Plastic K.N." should be well pounded to ensure that the material is in close contact with the tubes and studs. An area not exceeding 2 sq. ft. should be completed before proceeding to the next section, and best results can be obtained by building the wall in the direction of the tube rather than across rows.

   The material must not be applied in layers and never brought out to a feather edge, as in air drying this will break away from the tube and eventually spall. For ramming the material use a wooden mallet with a head weighing about one pound; one face should be flat and the other shaped like a very blunt-nosed chisel to assist in forming the curved surface of the wall between the tubes.

   The surface is to be left rough and on no account smoothed off with a trowel; it is to be thoroughly stippled with a stiff flat wire brush before there is any appreciable air drying. After completion of the work, allow the wall to air dry for at least 24 hr. The appearance of the completed wall when dry and cold is that of a rough surface covered with a very large

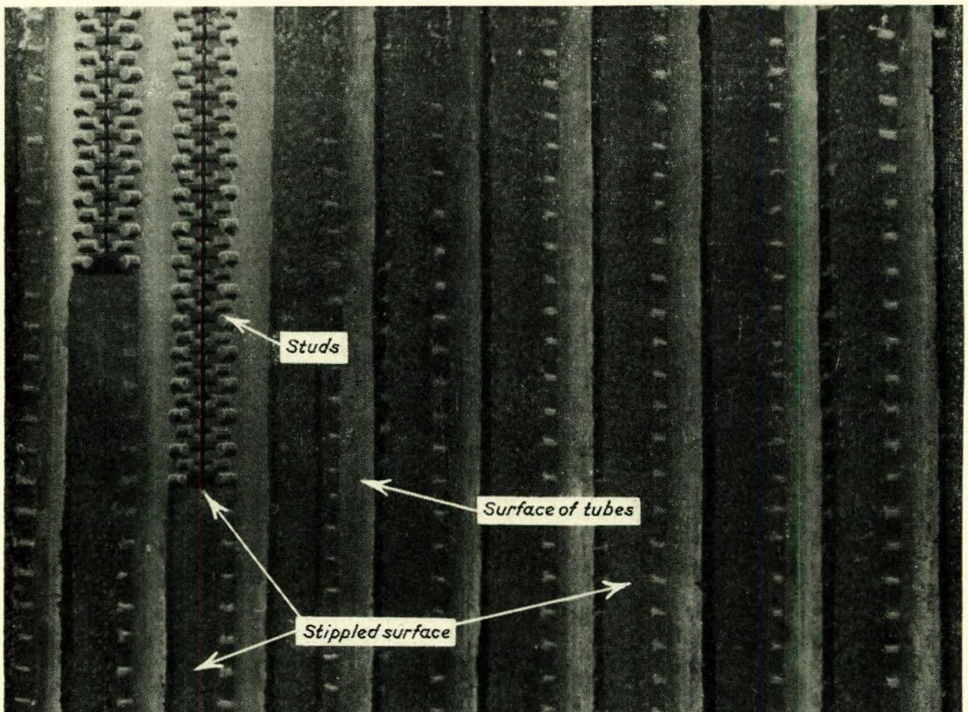

FIG. 12—*Application of chrome ore to studded tubes*

number of hair cracks. This is a normal condition; the cracks disappear when the surface is heated up and reappear when the surface again cools down. On no account should any attempt be made to fill them up or smooth them over (Fig. 12).

b) When applying the material to baffle wall tubes, etc., which have studding similar to that shown in Fig. 13, it should be worked up with the fingers into a wedge shape of a size to be inserted into the open pitched studs. It should not be worked too soft as it will then be more difficult to drive into place.

In building the wall the "Plastic K.N." is applied initially both sides, i.e. where the studs are open pitched. The studding in the centre is such that only ⅛-in. clearance is left between the studs which act as a backing for the "Plastic K.N.". When renewing the wall the P.K.N. need only be rammed from one side, provided that a gas-tight baffle is maintained.

A piece of wood, tapered to allow entry between the studs, should be used for pounding, first cross-wise, then vertically, to ensure that the P.K.N. is forced into close contact with the studs and tubes. The P.K.N. should also be forced through the gaps of the close pitched backing studs and left for keying purposes.

Sufficient P.K.N. should be applied in the first instance so that no further material is required. All surplus material should be removed from the face of the open pitched studs, as, if over applied, the excess material will break off, carrying part of the wall with it.

The wall should be built in the direction of the tubes and not across rows and the material must not be applied in layers. The surface is to be left rough

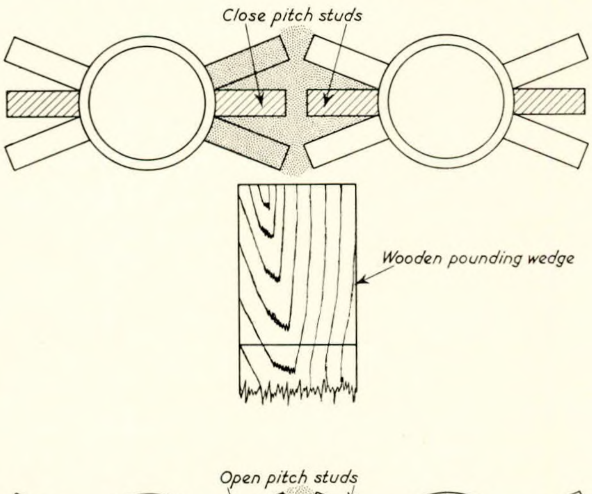

FIG. 13—*Method of pounding chrome ore on baffle walls*

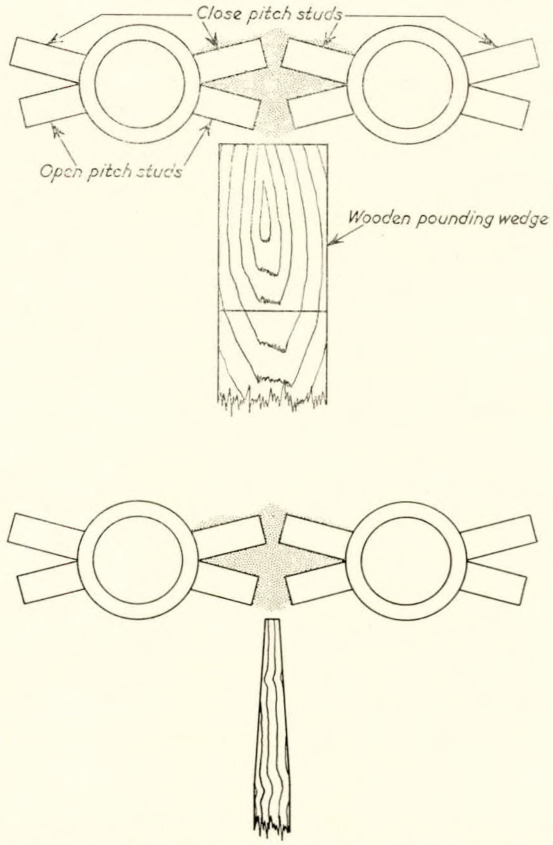

FIG. 14—*Method of pounding chrome ore on baffle walls*

and on no account smoothed off with a trowel; it is to be thoroughly stippled with a stiff, flat, bristle wire brush before there is any appreciable air drying.

After completion of work allow the wall to air dry for at least 24 hr.; the appearance of the wall should be as described under (a).

c) When applying P.K.N. to baffle wall tubes, etc., which have studding as shown in Fig. 14, follow the instructions (a), but the material is applied from one side only, i.e. where the studs are open pitched.

Venting

Ramps should be vented but P.K.N. should not be vented where it is reinforced by stud tubes.

Venting and Expansion Cuts in P.K.N. Ramps

The surface of the ramp at the bottom of the walls must be punctured after it has been formed with a series of small holes on 2- to 3-in. pitch to a depth of 50 per cent of the thickness of the ramp. A suitable instrument is a piece of ⅛-in. wire.

Vertical and horizontal trowel cuts 1-in. deep are cut in the ramp, using the trowel like a knife and with a sawing motion. Approximately 9-in. squares should be formed by these cuts but the horizontal cuts must be not less than 6in. from the top and from the toe of the ramp; the horizontal cut must in all cases leave sufficient depth of P.K.N. in order not to weaken the ramp.

These holes and cuts enable the ramp to vent when it is drying out and prevent the P.K.N. from breaking away.

Repairs

If the surface of the wall has spalled or worn thin, proceed as follows:

Remove all damaged P.K.N. down to the bare tubes or studs. Cut down the edges to at least 1in. depth, moisten the edges and old surface with "Pyrolite" and then work in the P.K.N. as directed above.

Thin surface patches or saucer shaped patches must be avoided, as thin edges will only break away.

Note: P.K.N. is difficult to work in very cold weather and is best applied at about 60 deg. F. In cold weather coke fires placed in the furnace will greatly assist application.

SUPERHEATERS

Marine superheaters are of the multitube multipass type secured to the headers in four different ways: by ball joint, by expanding, by expanding and seal welding, and by welding the tubes to stubs already welded in the headers. All types need access holes in the headers if only for inspection, and the remarks made regarding economizer doors apply equally to superheaters.

It will be appreciated that C.A.F. jointing is not suitable for certain types of accessories, such as those illustrated in Fig. 15, but the remarks regarding the care which should be exercised in replacing and fitting these doors apply equally.

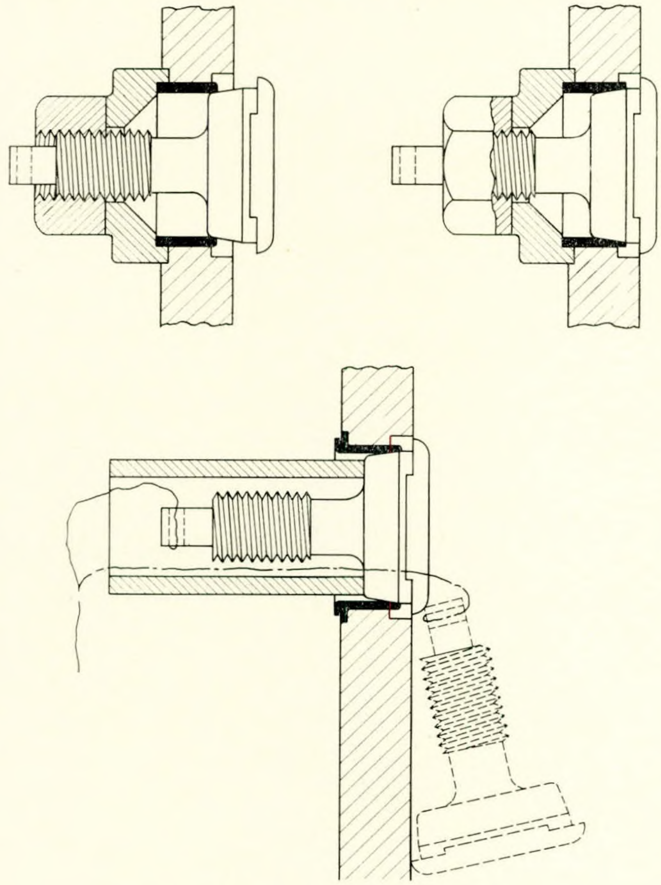

FIG. 15—*Typical taper lip plug*

It is of course essential that under all steaming conditions an adequate quantity of steam should flow through the superheater, and for this reason, except in very special designs, the amount of saturated steam which can be taken from the steam drum must of necessity be limited to a very small quantity, probably only sufficient for the whistle and oil fuel heaters. If the superheater has been under refit for any purpose, inspection should be made to check that the diaphragms forming the various steam passes in the box are intact and in good condition, and that any drain holes in the diaphragms are clear. When raising steam the drain valves should be fully open and should remain full open until the boilers are steaming under steady conditions. For this reason the drains, in addition to a discharge to bilge, should be connected to a steam trap, or led to an adequate drain tank, as otherwise the boiler room will become filled with steam, and undoubtedly the valves will be shut before they should be to keep the boiler room habitable. If they are shut before steady steaming conditions have been reached, there is a considerable possibility that water will enter the tubes at the bottom and that these tubes will distort, usually bending upwards even to the extent of lifting the tube supports off their seats. The air valve should be open and immediately steam is issuing it should be shut and the circulating valve opened and kept open while burners are alight until the boiler is opened to the steam line.

If these few simple rules are followed, the superheater will always be protected and give no trouble as far as steam circulation is concerned. Undoubtedly today the high maintenance in connexion with superheaters is caused by bonded deposits forming between the superheater tubes, and the corrosion or wasting away of the superheater tube supports. The exact reason for the formation of bonded deposits in the superheater zone is complex and is not yet fully understood, and whilst many vessels suffer from this trouble there are many more steaming under similar conditions which do not, but in general it can be taken that the deposits are the function of the vanadium and sulphur in the oil, together with the presence of chloride, which act as a catalyst and cause the deposit

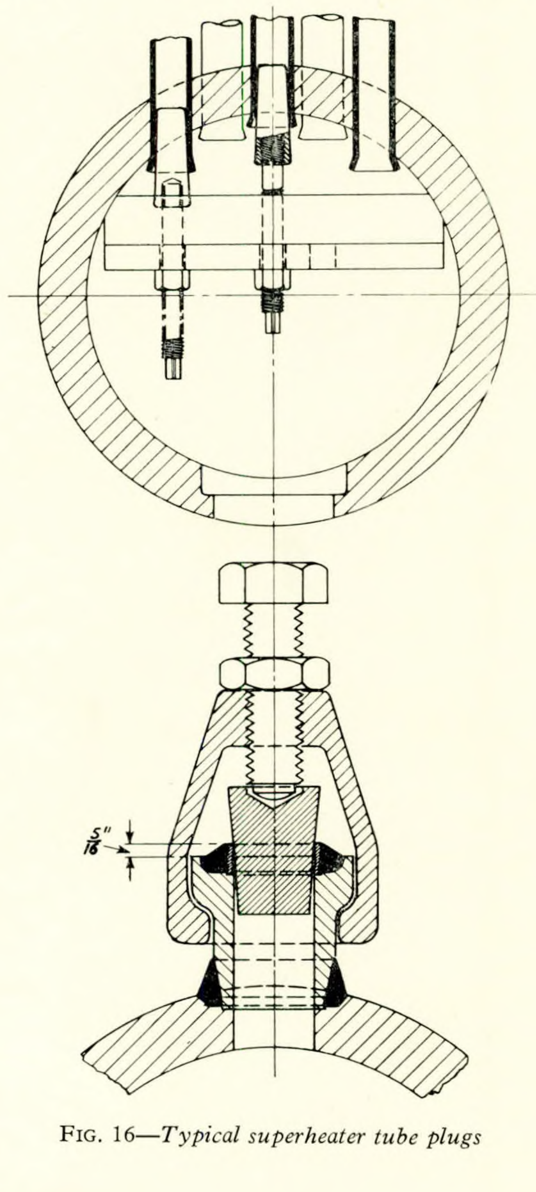

FIG. 16—*Typical superheater tube plugs*

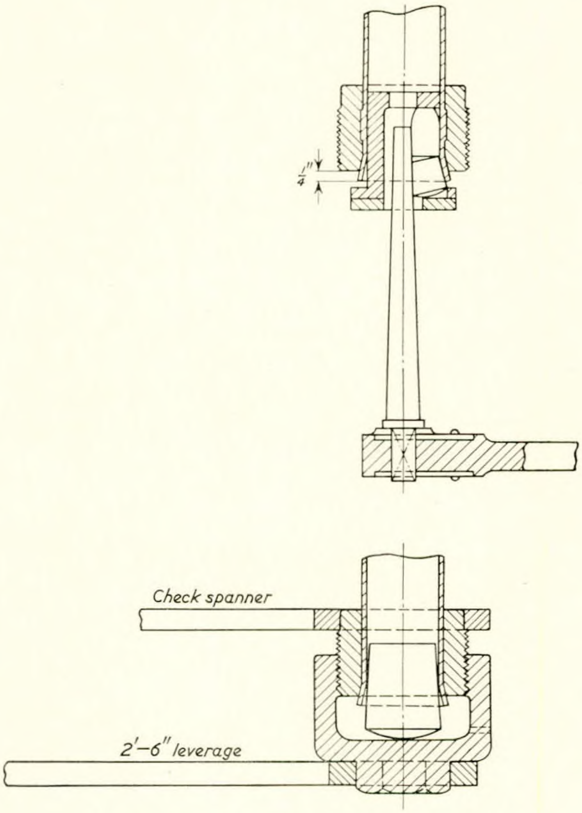

FIG. 17—*Typical superheater plugs*

of vanadium oxides in that particular temperature zone. At the moment it does not appear that there is any known way of completely avoiding such deposits, but the following are ways in which deposits can be reduced:

a) Avoid all salt water contamination of the fuel, and if the bunkers have become contaminated increase the separation by adding to the bunkers or settling tanks "Teepol" or similar chemical.
b) Maintain the combustion in the furnace as near perfect as possible.
c) Operate the superheater sootblowers every 8 hr.

The only practical way of removing such deposits when they occur is by water washing; this is discussed later in the paper.

The corrosion or wasting away of the superheater tube supports is again attributable to the impurities in the oil burnt, coupled with the relatively high temperature to which the supports are subjected, and unfortunately at the present time there is no known metal which will withstand this corrosion. It is therefore the designers' aim to make the supports as cheaply as possible and capable of easy replacement, and in conjunction with this to provide access as ample as possible to the superheater, particularly in the middle of the bank, as this will also greatly facilitate water washing.

Should a superheater tube fail in service it can be plugged and Figs. 16 and 17 show the various types of plugs used.

Generating Tube Banks

From the superheater the combustion gases pass the main generating bank of tubes, which on the whole give little trouble in either care or maintenance, provided of course they are kept filled with water and free from scale. From there the gas passes over the economizer and air heater to the uptake and funnel, and this has already been dealt with, with the possible exception of induced draught fans if fitted.

The remarks regarding forced draught fans in general apply to induced draught fans, but in addition it must be remembered that as dampers on the inlet of induced draught fans are not permitted to be fully shut, even greater care has to be taken in the design to be sure that the fan will be suitable under light load conditions, particularly if single speed.

When both forced and induced draught fans are fitted it has been common practice to use the induced draught fan only when raising steam, but it is questionable whether this is a good practice, as it will probably mean carrying a much higher negative pressure in the furnace than is actually required to burn the oil, which will induce air leakage through the casings to the possible detriment of the correct flow of air through the boiler unit, and it is suggested therefore that the better practice would be to use both the forced and induced draught fan, or alternatively the forced draught fan only, as this at least will ensure the correct flow of air and be easier to supply the small quantity required for complete combustion.

Before leaving the boiler as such, mention should be made of the necessity of keeping the boiler mountings in perfect condition and this applies particularly to the feed water regulators and low water alarms. The feed water regulators of whatever make give valiant service, but when needle, piston or diaphragms are incorporated in the design, care must be taken to see that these parts are free from deposits, and inspection should be made as frequently as possible.

Low water alarms unfortunately have not had such a trouble free history, possibly because they only come into action in an emergency and are therefore idle during the greater part of their lives. For this reason inspection should be frequent and care taken to see that deposits do not accumulate in the working parts.

Perhaps one of the most serious aspects of the functioning of the low water alarms is that due to the alarm operating when not required, either by reason of a leak in the system or the movement of the water in the drum in bad weather, the alarm has been shut off. A contributory cause has undoubtedly been a mistaken caution on the part of the designer in allowing too great a margin between the time the alarm comes into action and when the water in the drum reaches a dangerous level. In consequence, any violent motion of the water in the drum brings the alarm into action when the water is still visible in the gauge glass. It is suggested that the alarm should provide its proper function; that is, to act in an emergency, and should be set to operate only when a dangerous level is reached.

A mounting which is so important that it hardly calls for mention is the water gauge, although sometimes when visiting a boiler room one wonders if the aim has been to hide completely the water gauges from the vulgar gaze of the multitude! This occasion is taken to appeal to those responsible for pipe arrangement, ladders and galleries, etc., to give a clear vision of the water gauges from at least one spot in the boiler room; preferably the gauges of all boilers should be visible from this spot.

Distance water gauges are of course a most useful and accurate supplement to the boiler water gauges, as are the bi-coloured type of water gauge viewed through a periscope, but it must never be forgotten that if the operators are to be held responsible for the water level in the boiler, then the water gauge on the drum must be clearly visible from the firing floor.

Boiler blow-down should of course be kept in good condition, and here mention may be made as to the operation of drain valves which are fitted in the bottom box of water walls. These should not be used as blow-downs in the general sense of the word when the boilers are steaming, but it is of the utmost importance that they are used immediately the boilers are shut down at the end of a voyage, so as to clear any deposit which has accumulated in the boxes. Neglect of this duty has on occasion resulted in the deposits accumulating in the centre of the box and restricting the entry of water to one or two tubes, with the consequent failure of the tube.

Sootblowers

Sootblowers are usually one of four types: hand opera-

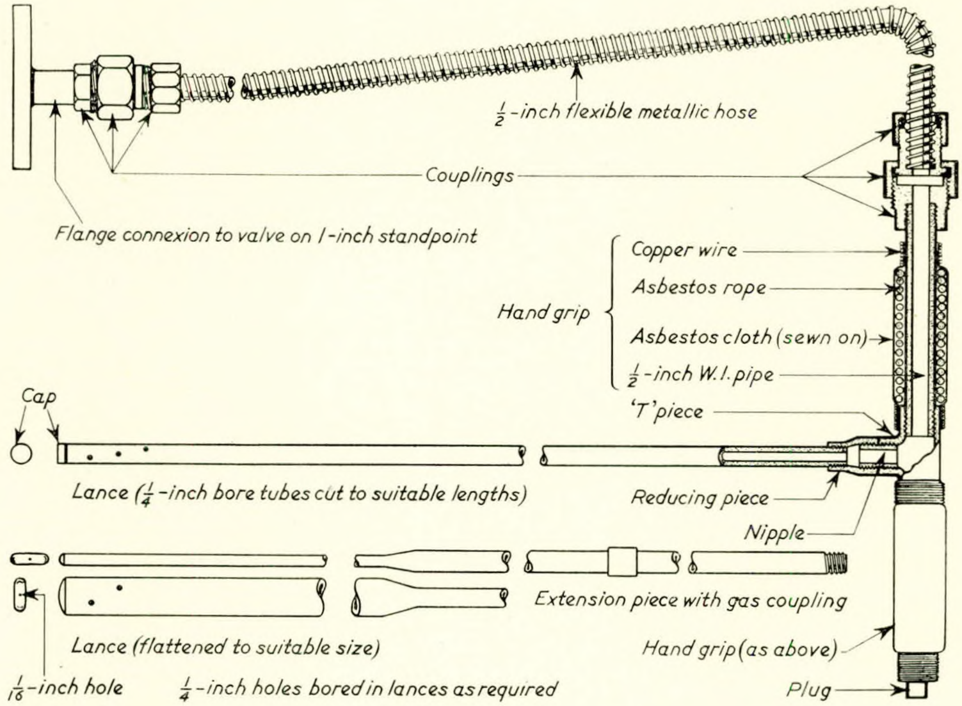

FIG. 18—*Water washing lances*

ted steam, electrically operated steam, air operated steam, and air operated compressed air. With the exception of the first named, all systems are operated automatically and the design preferred is a matter of individual selection, bearing in mind the service requirements, electrical load, etc.

Blowers using compressed air for the actual blowing have the advantage of saving a considerable amount of make-up feed water, but suffer from the disadvantage of increasing the electrical load on the ship. It has, however, a further advantage in that the operation is much slower, taking from 3 to 4 hr. to clean a complete boiler unit, and because of this it is possible that the boiler is more effectively cleaned and the soot emission from the funnel is dissipated and not blown out in a single blast. Great care should be taken in positioning the sootblowers and installing the correct type of element for the particular position in the boiler. Perhaps the most difficult to cater for are the blowers for the superheaters, which operate in a very high temperature zone and therefore have a much shorter life. To reduce this high maintenance a "Rack" type blower has been fitted on recent contracts which is of the long element type, the whole of which retracts from the boiler when not in use, and as it can be operated either electrically or by compressed air the action is entirely automatic and calls for no extra labour on the part of the operating staff. As a

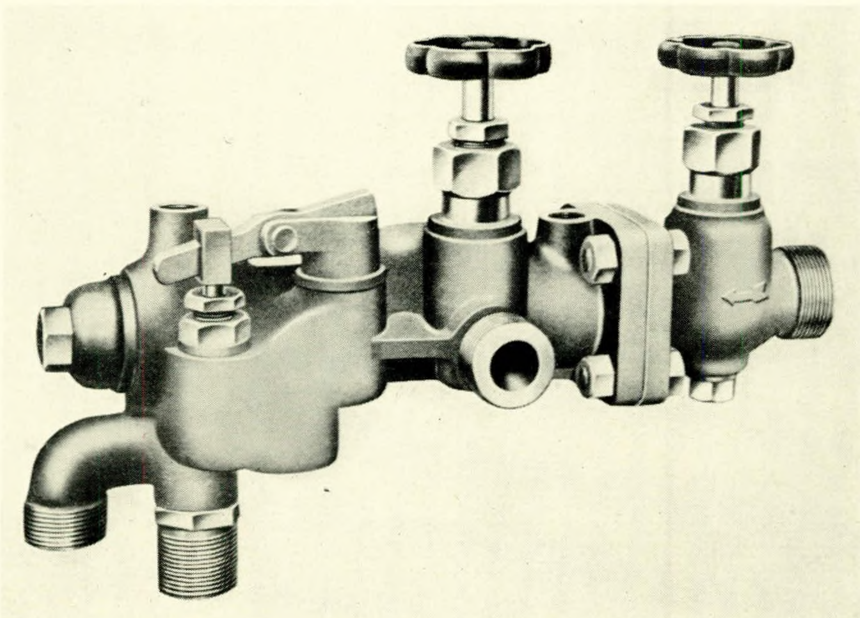

FIG. 19—*Injector system*

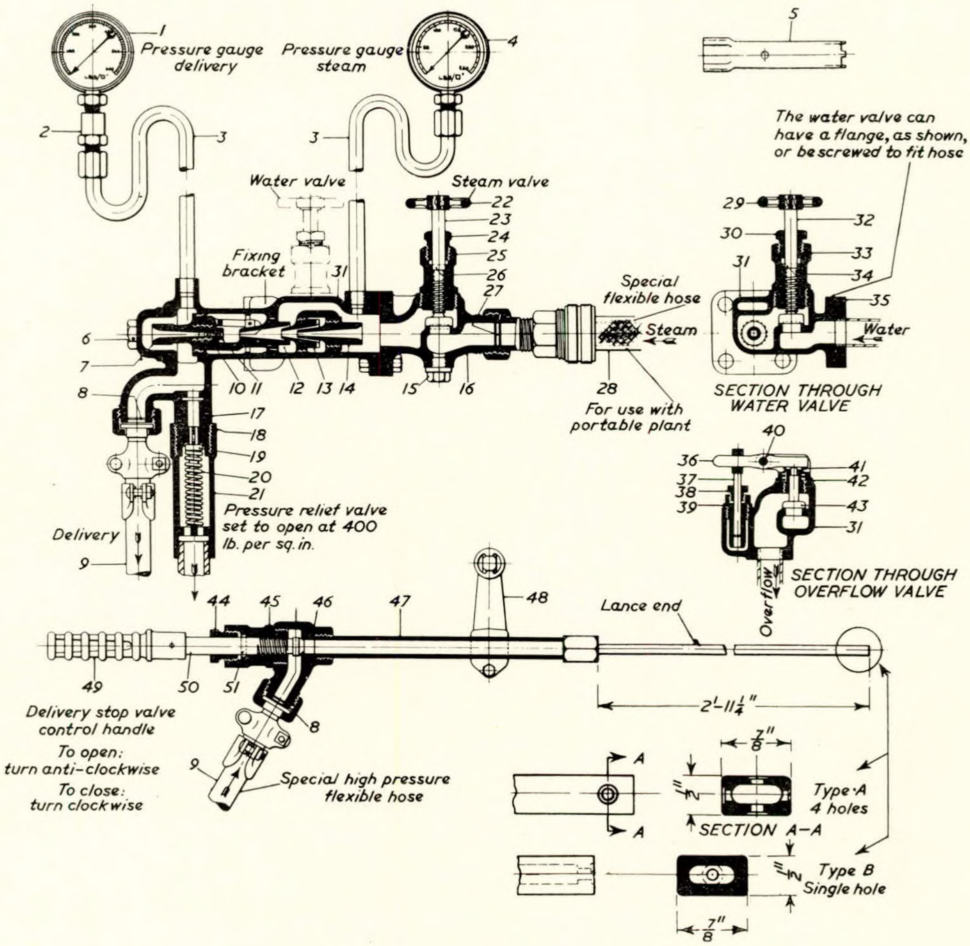

FIG. 20—*High pressure cleaning plant*

1) Pressure gauge—delivery; 2) Snubber; 3) Connecting pipe to gauges; 4) Pressure gauge—steam; 5) Box key; 6) Nozzle cap nut; 7) Discharge nozzle; 8) Joint washer; 9) Flexible hose and connexions—delivery; 10) Setscrew for discharge nozzle; 11) Renewable end for discharge nozzle; 12) Combining nozzle; 13) Draft tube; 14) Steam nozzle; 15) Plug; 16) Body—steam valve; 17) Seating for pressure relief valve; 18) Locking nut; 19) Pressure relief valve; 20) Spring for pressure relief valve; 21) Adjusting nut; 22) Hand wheel; 23) Steam valve; 24) Gland; 25) Box nut; 26) Neck ring; 27) Joint washer; 28) Flexible hose and connexions—steam; 29) Hand wheel; 30) Gland; 31) Injector body; 32) Water valve; 33) Box nut; 34) Neck ring; 35) Flange—water; 36) Lever; 37) Piston; 38) Piston gland; 39) Cylinder; 40) Lever pin; 41) Spring; 42) Fulcrum and guide for overflow valve; 43) Overflow valve; 44) Gland; 45) Box nut; 46) Valve seat for gun; 47) Tube; 48) Gun handle; 49) Handle—valve; 50) Valve spindle; 51) Neck ring

general guide, sootblowers should be operated once every 24 hr., with the possible exception of the superheater blowers, which it is suggested should be operated every 8 hr.

A cause of high maintenance is internal corrosion of the sootblower heads and steam piping. This is due to the fact that modern boiler units carry a plus pressure throughout the boiler; the combustion gases enter the blower element when not in use and with the moisture present from, say, a leaking master valve, forms sulphuric acid. To avoid this trouble adequate air scavenging must be provided on the heads, and it has been found most useful to provide a 1-in. air connexion from the forced draught fan system to the sootblower steam piping, thus scavenging the piping as well as the heads, and should a valve in head become corroded, preventing the gases from leaking into the steam system. To avoid steam leakage it is recommended that double shut-off valves be fitted.

Water Washing

Today it can be stated that water washing is generally accepted as the only effective means of removing bonded deposits which, happily, contain a considerable proportion of soluble matter. Many owners also use water washing as a convenient means of cleaning, and general instructions are given later in the paper.

It might be as well, however, to give a short summary of the history of water washing and to highlight some of the more important features.

During the last war considerable trouble was experienced in the United States and the British Navies due to bonded deposits in the superheaters, which were found almost impossible to remove by the then known methods of chipping and prodding with rods, until in desperation someone thought of turning a hose on the job, when it was found that after a short time large pieces of the deposit began to break off. This led to a considerable investigation and it was found that the most effective way of carrying out this washing was by lances (Fig. 18) with relatively small holes in the ends through which was discharged hot water at 200lb. pressure; the most effective temperature being found to be approximately 160 deg. F., of which the supply is somewhat difficult on board, and has led to the development of an injector system as illustrated in Figs. 19 and 20. Working with 100-lb. per sq. in. saturated

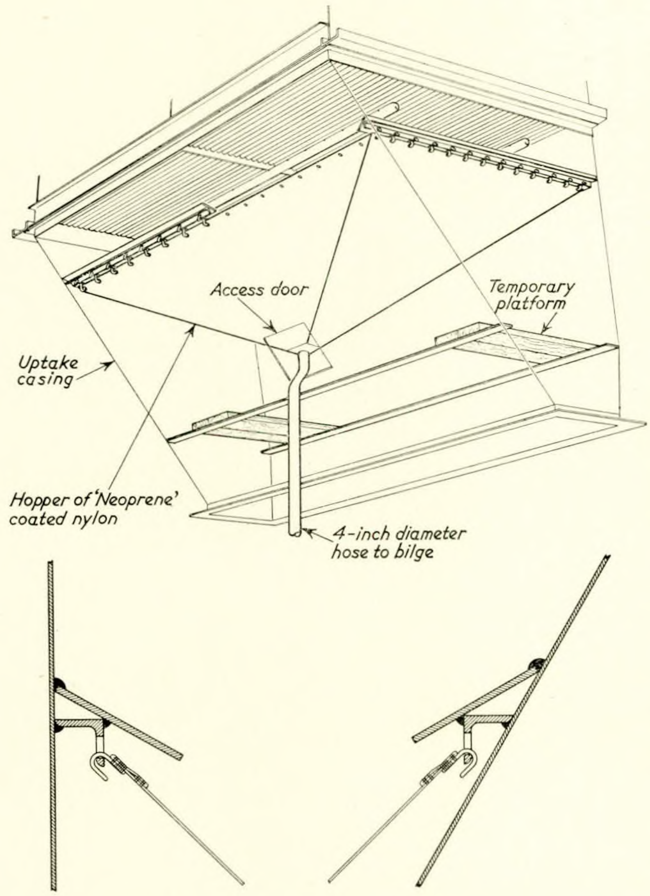

FIG. 21—*Typical arrangement of hopper for water washing*

steam it will give the pressure and temperature of the water required. If a superheater is badly fouled water washing must be carried out for a considerable period before it can be cleared, and under these conditions it is advantageous to first wash with water to which has been added a detergent, but if carried out at regular intervals—if possible every 3 or 4 months—it has been found that in 12 hr. the whole of the surface of a boiler unit can be cleared down to bare metal. It was thought at one time that trouble would result from this method of cleaning in the furnace brickwork, and corrosion of boiler casings, etc., but it has been found that if one golden rule is followed no special precautions need be taken. The golden rule is to light a boiler off and dry it out thoroughly immediately after water washing has been carried out. For this reason it is recommended that very careful consideration be given to the possibility of carrying out water washing while the vessel is at sea. In this way the work is supervised by the operating staff, who have everything to gain by carrying it out properly, and the boiler will of necessity be lit-off immediately the water washing has been completed. This also has the advantage that when the vessel is due for survey, if the boilers are water washed just prior to reaching port, it arrives in clean condition ready for inspection and any refit required. If the work is left to be carried out after the vessel is alongside, invariably the boilers are first water washed and then left in a wet condition until the refit has been completed, perhaps even ten days after the washing. Furthermore, as water washing must always be carried out before any repairs are made to brickwork, it is not possible to wait until the refit has been completed before water washing.

Access holes should be provided in the boiler casings to facilitate the water washing at sea, and means of securing a hopper below certain parts; a typical arrangement is shown in Fig. 21. A ring main should also be provided for the convenience of attaching hose connexions, etc.

On occasion the sootblowers have been used for water washing. In this case a distance piece is placed in the steam line to the blowers beyond the shut-off valves. To water wash, this is removed and replaced by a bend having a hose connexion at the inlet. A hose is coupled up and the sootblowers are used in rotation to water wash the boiler. It must be remembered that if this method is adopted there must be a means available to supply large quantities of hot water. On certain vessels sea water has been used for this purpose, finishing off the cleaning with fresh water, and as far as the author knows no troubles have occurred with boiler casings or brickwork as a result of the use of salt water.

INSTRUCTIONS FOR WATER WASHING

When burning certain fuels it may be found that the lanes between the tubes of the boiler, air heater, economizer, and particularly the superheater, become slagged up and choked with bonded deposits which cannot be removed by normal sootblowing.

Since nearly all of the slag formed consists essentially of a non-soluble base bonded by a relatively water soluble binder, the use of water under pressure will accomplish the dual purpose of (a) loosening the binder and (b) flushing away the loosened insoluble residue. With the old or stubborn deposits a sustained period of water washing may be found necessary.

Water washing must be continuous and without breaks until all deposits are removed, otherwise half soluble deposits will harden. It should be realized that once deposits start to form, especially on superheater tube surfaces, the subsequent build-up is rapid, therefore water washing should be carried out at the first opportunity.

A wetting agent such as "Lissapol N" can also be used to great advantage before the actual washing commences. Generally speaking, the required solution is made up as follows:

Lissapol N	5 gal.
Soda ash	16-17lb.
Common salt	16-17lb.
Water to make up to	100 gal.

Water washing consists essentially of the following steps:

a) Soaking tubes or use of a wetting agent.
b) Supplying fresh water at a temperature of approximately 150—160 deg. F.
c) Delivering the hot water to a lance at a pressure between 200 and 250lb. per sq. in.
d) Directing a lance into the slagged section so as to remove the accumulations most expeditiously. Every effort should be made to insert the lances from the loop end in between the banks of the superheater tubes.
e) Drying out the unit.

The equipment for these operations can be seen in Fig. 18.

A relatively high pressure, 200/250lb. per sq. in., and temperature of 150—160 deg. F., must be maintained in order to obtain the best results. If the water supply is not available a Davis and Metcalfe injector is recommended.

A 1-in. to 2-in. diameter steam hose, preferably wire-bound, is ideal for carrying the water to the nozzle.

The lance or nozzle itself is usually made up from odd lengths of $\frac{1}{4}$-in. pipe. From one to four $\frac{1}{8}$-in. diameter holes should be drilled along the pipe near the end. At times it may be more convenient in reaching certain areas to drill only one $\frac{1}{4}$-in. diameter hole in the end of the pipe at a desired angle so that the spray is directed out from the end of the pipe to reach those points; a thin flat lance for penetrating into the banks of tubes can also be extremely useful. In addition, several types of nozzles may be required for any one boiler. However, since the equipment is extremely simple, each operator may best determine for himself the set-up that is most suited to his individual needs.

The injector (Fig. 19) is fitted with valves that control the supply of steam and water, and gauges giving the pressure of steam supplied and pressure of delivered water. Complete equipment for water washing, with two lances, is supplied with the injector.

Washing Sequence and Drying out

When cleaning the whole boiler unit, water washing should normally start at the top of the primary economizer or air heater and work down systematically through the secondary economizer and boiler bank tubes to the furnace rows. Water dripping down from the top banks tends to soften the slag accumulations in the areas below those being washed—thus making the cleaning job faster and easier when these lower areas are reached.

Should it be found necessary to water wash only a particular section, such as the air heater or economizer, a "Neoprene" coated nylon hopper can be placed below the part and the water drained through a convenient access door. This will prevent the deposits removed from the upper banks being carried down to foul the banks below.

During water washing the accumulation of water is removed *via* the permanent drains fitted, which must be kept clear.

The drain in the furnace floor should be uncovered by removing the raised brick in the floor, the position of which is indicated on the brickwork drawings. Water washing can commence as soon as the unit is cool enough for a man to enter.

Once water washing has started it must be continued until washing of all surfaces has been completed and all deposits removed, otherwise some types of deposit when wetted and allowed to dry will harden and become more difficult to remove. Deposits will collect at the bottom of the tubes, especially under the superheater; these should be removed by prodding and drawn out with suitably shaped rakes. After water washing, all deposits which have been removed from the tubes must be thoroughly washed away.

The unit must be dried out immediately upon completion of the washing procedure; using a very light fire it will usually be found to take between 8—12 hr. to thoroughly dry out the boiler. One burner with a lighting-up size sprayer plate is most convenient for this purpose.

Provided the unit is dried out immediately upon completion of the water washing, no damage will occur to the brickwork or insulation. The necessity of lighting up and drying out after water washing cannot be too strongly stressed, and it may be found more convenient to carry out water washing when a ship is in service, rather than leave it until the boilers are out of commission, when it is not possible to light up the boiler immediately.

Method of Using a Wetting Agent

a) When a wetting agent is used it is sprayed on the deposit with a suitable type of sprayer designed to prevent wastage of the solution by dripping off. The spraying should be continued until the deposit is thoroughly wetted or until the deposit drips, no longer absorbing solution.
b) In some cases, particularly with the harder type of deposits, it may be an advantage to allow the wetting agent to soak in for several hours, but careful observation should be made to ensure that no drying out occurs.
c) The normal form of water washing should then be followed, as indicated previously.

Internal Condition of a Boiler

Regarding the internal parts of a boiler, all that is necessary is to keep the boiler filled with water free from scale forming solids, and surely nothing sounds easier; but unfortunately life is not so simple, and to maintain the boiler water in good condition it is essential to make frequent tests and pay strict attention to water treatment, details of which are the prerogative of the specialists, and it is only intended here to make some general remarks.

First and foremost a plea should be made to ensure that the whole of the feed system is thoroughly clean and free from deposits when originally erected or when any refit has taken place. It may be considered worth while for all feed pipes to be pickled and cleaned internally of scale formation. In service one of the most frequent causes of scale deposit is the carrying of magnetic oxide from the feed system into the boilers, and in certain vessels this is a major problem. It is not easy to pinpoint either the cause or the actual part from which the oxide emanates, but in general it is due to the feed water not being sufficiently alkaline, and one possible reason, perhaps the major reason, is the introduction into the feed system of make-up feed evaporated from hard or salt water containing CO_2. Thus, the water is in an acid condition and reduces the Ph value of the feed as a whole to below that which can be considered safe. To counteract this, volatile amines are introduced into the boiler water treatment and give off an ammonia gas which is carried over with the steam and enters the feed water in the condenser, counteracting the CO_2 that may be present.

Alternatively, hydrazine is introduced in the boiler water treatment, which acts in a similar way regarding the feed and has the additional advantage of absorbing small traces of oxygen which may have entered with the boiler water.

A further alternative is to consider the use of passing the make-up feed through a double bed demineralizing plant, which will remove entirely the CO_2, and ensure that the make-up feed is entirely free from all injurious salts. At one time such a plant was considered, due to its size, unsuitable for a marine installation, but recent research has shown that this is not the case if used for only the make-up feed.

It is of no use employing any of the above methods without at the same time introducing either a recording apparatus or making frequent tests of the feed water to ascertain its Ph value to make sure that it is alkaline, and at least daily tests should be made. In a modern installation the oxygen content of the feed water is sufficiently low to avoid any appreciable trouble, particularly where deaerator feed heaters have been installed either in continual use or for harbour and manœuvring conditions only, but it is nevertheless important that daily tests should be made for oxygen to ensure that everything is working properly, and the carrying of low vacuum conditions in the main machinery should be avoided.

CONCLUSION

It is recognized that this paper has omitted or dealt inadequately with many aspects of care and maintenance, such as methods used in expanding tubes, cutting out tubes, etc., but it is safe to state that precise details of these are contained in makers' instructions as supplied with their products. If the present paper has given some indication of the reasons for, and the cure of, troubles which arise, and has emphasized that a high pressure high temperature boiler unit is a piece of machinery and not just something to contain water, with the result that more attention is paid to the care and maintenance, it has done all the author could wish and will be the means of reducing what is today one of the highest individual costs in a ship's maintenance.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues, Mr. W. A. Erskine and Mr. L. A. Woodhouse, for the assistance they have rendered in compiling this paper. Thanks are also due to Babcock and Wilcox Ltd., Foster Wheeler Ltd., John Thompson Water Tube Boilers Ltd., The Superheater Co. Ltd., and Yarrow and Co. Ltd., for their ready help in supplying useful information regarding their products. Acknowledgement is made to Babcock and Wilcox Ltd. for permission to use their manufacturing instructions.

INSTITUTE ACTIVITIES

Meeting for Informal Discussion

An Informal Discussion was held at the Memorial Building, 76 Mark Lane, London, E.C.3, on Thursday, 29th October 1959, when the subject of "Steam *versus* Diesel Propulsion for Large Ships" was introduced by L. Greenacre (Associate) and C. B. Robinson (Associate Member).

The opening talk was followed by a period of free discussion. Mr. W. R. Harvey (Vice-Chairman of Council) was in the Chair and 101 members and visitors were present.

A vote of thanks to Messrs. Greenacre and Robinson, proposed by the Chairman, was carried by acclamation. The meeting ended at 7.30 p.m.

Section Meetings

Bombay

Chairman of Committee

Consequent upon the appointment of Rear Admiral T. B. Bose, B.Sc., I.N., as Local Vice-President for Bombay, Mr. B. S. Sood has been elected Chairman of the Committee and Mr. J. E. Radcliffe has been co-opted to Membership of the Committee for the period until the next Annual General Meeting in February 1960.

Meeting for Junior Members

At a meeting held on Thursday, 19th November 1959 at 5.45 p.m. at the B.E.S.T. Conference Hall, Bombay-1, a very interesting paper on "Shipbuilding and Shipyard Practice with Particular Reference to India" was read by Mr. D. B. Irani, Ship Surveyor, Ministry of Transport and Communications of the Government of India.

The meeting was specially arranged for the benefit of junior members and 115 members and visitors attended, including apprentices from the Directorate of Marine Engineering Training. Rear Admiral T. B. Bose, B.Sc., I.N. (Local Vice-President) was in the Chair, and he led the discussion on Mr. Irani's paper; Messrs. K. Parthasarathy, B. Ananda, C. S. Sundaram and R. G. Sathaye also took part. Mr. Ananda showed various lantern slides which illustrated the Japanese method of ship construction and these were much appreciated by the audience.

A vote of thanks to the author and the Chairman was proposed by Mr. C. S. Sundaram (Honorary Secretary) and was accorded by acclamation. The meeting ended at 7.40 p.m.

Scottish Section

Junior Meeting

A Junior Meeting was held at the Institution of Engineers and Shipbuilders in Scotland, Glasgow, on Wednesday, 28th October 1959 at 7.30 p.m.

Mr. G. J. Thomas (Chairman of the Section) presided and introduced Mr. A. T. Willens (Member), who then gave a most interesting and instructive paper entitled "The Engineer Surveyor".

A lively discussion followed which was ably dealt with by Mr. Willens.

A vote of thanks to the author was proposed by Mr. A. Campbell, who also complimented Mr. Willens on the excellent subject matter of his paper.

The meeting terminated at 9.0 p.m., after which light refreshments were served.

Joint Meeting

A joint meeting with the Aberdeen Mechanical Society was held at Robert Gordon's Technical College, Aberdeen, on Friday, 6th November 1959 at 7.45 p.m.

After welcoming the Scottish Section representatives to Aberdeen, Mr. A. N. Carnegie, President of the Aberdeen Mechanical Society, asked Mr. G. J. Thomas (Chairman of the Scottish Section), to preside. Mr. Thomas then called on Mr. A. Hunter and Mr. G. C. Eddie, B.Sc., M.I.Mar.E., to present their paper, "Fishing Vessel Development".

This paper was very well received by the eighty-five members and visitors present, and a lively discussion followed, which was ably dealt with by both authors.

Mr. C. R. Skinner aptly proposed a vote of thanks to Messrs. Hunter and Eddie for their interesting and instructive paper and this was carried enthusiastically.

The meeting terminated at 9.25 p.m.

General Meeting

A general meeting was held at the Institution of Engineers and Shipbuilders in Scotland, Glasgow, on Wednesday, 11th November 1959 at 7.30 p.m.

Mr. G. J. Thomas (Chairman of the Section) presided, and after welcoming the 115 members and visitors present, introduced Mr. R. Beattie (Member) who gave a paper on "Notes on Development, Design and Operation of Harbour and Coastal Tugs". This was followed by the showing of a film depicting tugs at work in various ports, launching of ships, and general harbour activities, all filmed by the author himself.

Both the paper and the film were highly appreciated by all present, and this was specially mentioned by Mr. D. W. Low, O.B.E. (Member of Committee), when he proposed a vote of thanks to Mr. Beattie.

The meeting ended at 9.40 p.m., after which light refreshments were served.

South Wales

Honorary Treasurer

Consequent upon the death of Mr. George Thomas, Mr. G. K. Beard, B.Sc.(Eng.) (Associate Member) has been appointed Honorary Treasurer of the South Wales Section.

Senior Meetings

Two senior meetings of the Section have been held at the South Wales Institute of Engineering, Park Place, Cardiff.

On 19th October 1959, Mr. E. E. Williams, B.Sc., Liaison Officer of the Department of Scientific and Industrial Research, gave a lecture entitled "Cavitation" before forty-one members.

The lecture was aimed primarily at giving a general appreciation of the fundamental nature of cavitation and identifying its various forms and consequences with the practical environs in which it occurs.

The introductory section dealt with the historical aspects of the phenomenon and its close connexion with marine and hydraulic machinery fields; in particular the solid foundation for experimental technique in investigations on ships' propellers as laid down by Sir Charles Parsons was stressed.

The next section, dealing with the various forms in which cavitation occurs, defined these and sought to indicate the practical conditions under which they occur and in particular the various parameters controlling the forms. The occurrence of cavitation in such widely separated fields as chemical engineering, medicine and nuclear power indicated how fundamental were the factors controlling the phenomenon. The effects of cavitation, primarily those on performance, and that of erosion damage and noise, were again related to its fundamental nature and the most widely held theories of damage were described in detail.

Finally, a short description was given of some of the more advanced research facilities and experimental techniques, with particular reference to the new water tunnel at the Ship Hydrodynamics Laboratory, Feltham. The need for continued study of the fundamental problem of cavitation was stressed in the concluding remarks.

A lively and extended discussion ensued, in which most of the questions were designed to elicit the practical marine application of the theoretical and experimental results of cavitation research.

A vote of thanks was extended to the lecturer by Mr. J. E. Church (Chairman) and seconded by Mr. F. F. Richardson. The proceedings ended at 9.40 p.m.

On Wednesday, 18th November 1959, a paper entitled "Heavy Oil Burning" by J. S. Clarke, O.B.E., Ph.D. (Member), and G. J. Hudson, M.A., was presented.

Dr. Clarke was unable to attend, but his deputy, Mr. C. K. J. Price, gave the lecture. The lecture led to a lively discussion; some searching questions were dealt with admirably by Mr. Hudson.

The questions covered a wide field and can be summarized as follows:

1) Effects of radiant heat on furnace walls.
2) Causes of panting in boilers.
3) Effects of viscosity of oils on atomization.
4) Effects of additives in fuels on atomization.
5) Stack and tube design in boilers to prevent the effects of "blow back" and excessive pressures on watertube boiler casings.

Annual Dinner

An enjoyable evening was spent by over 200 members and guests on the occasion of the Annual Dinner of the South Wales Section which was held on the 6th November 1959, at the Royal Hotel, Cardiff.

The toasts of the evening were as follows:

"The Queen", proposed by the Chairman of the Section, Mr. J. E. Church.

"The Shipping Industry", proposed by Mr. David Skae (Vice-President), Chairman of the Bristol Channel Shiprepairers Association.
Response by Mr. R. G. M. Street, Past Chairman, Cardiff and Bristol Incorporated Ship Owners Association.

"The South Wales Section", proposed by Mr. W. R. Harvey (Vice-Chairman of Council).
Response by Mr. J. E. Church.

Mr. Skae and Mr. Street referred in their speeches to the economic factors controlling the shipping industry, showing an insight and knowledge of these problems that the audience fully appreciated.

Mr. Harvey interested the members greatly by his account of the steps taken in Canada to further the activities of the Institute. Mr. Church in his response thanked the principal guests of the evening for their support and sustained interest in the activities of the Institute. He welcomed especially the contingent of Swansea members and guests, who had some fifty miles each way to travel; support and interest of this nature were most heartening.

Sydney

Film Show

A meeting of the Sydney Section was held on Wednesday, 30th September 1959 when the Local Vice-President, Captain G. I. D. Hutcheson, R.A.N., was in the Chair and forty-five members and guests attended. A series of films of technical and general interest was shown, by courtesy of the Vacuum Oil Company Pty. Ltd. A vote of thanks to the representative of the Company was proposed by Mr. N. A. Grieves (Honorary Secretary) and carried by acclamation.

Annual Dinner

The Annual Dinner was held on Thursday, 22nd October 1959, at the Wentworth Hotel, Sydney. Captain G. I. D. Hutcheson, R.A.N. (Local Vice-President) was in the Chair and there was an attendance of 107, comprising fifty-five members and fifty-two guests. The official guests included: Mr. R. G. C. Parry-Okeden, Chairman and Managing Director, John Lysaght (Australia) Pty. Ltd.; Professor D. M. Myers, University of New South Wales; Mr. A. Twamley, Assistant Director, Technical Education; Captain A. M. Clift, R.A.N., General Manager, Garden Island; Mr. D. S. Carment, President, Maritime Services Board of New South Wales; Mr. J. W. Donovan, Chairman, Australian Steamship Owners' Federation; Mr. A. B. Thornton, Managing Director, J. and E. Hall (Australasia) Pty. Ltd.; and Mr. W. J. Knight, Managing Director, Marine and Industrial Power (N.S.W.) Pty. Ltd.

After the Loyal Toast, "The Institute of Marine Engineers" was proposed by Mr. R. G. C. Parry-Okeden; Captain R. G. Parker, O.B.E., R.A.N. (Member) responded on behalf of the Section. The Toast of "The Guests" was proposed by Mr. J. Renfrew (Member) and replied to by Professor D. M. Myers.

The Dinner was once again a most successful and happy function.

West Midlands

At a meeting held at 7.0 p.m. on Thursday, 22nd October 1959, at the Engineering Centre, Birmingham, Mr. S. A. G. Emms presented an illustrated lecture entitled "Electrical Marine Equipment". There were thirty-four members and guests present, the Chair being taken by Mr. J. R. Cotterill, J.P. (Vice-Chairman).

Mr. Emms commenced his lecture by giving a brief account of the increasing application of marine electrical equipment since electricity was first utilized for lighting over seventy years ago. Consideration was given to the problem of design, for, in addition to performing a function, marine equipment had to withstand such conditions as dampness and vibration. Mr. Emms compared the advantages and disadvantages of the various types of a.c. and d.c. circuits used on shipboard, and gave his opinion on future trends.

To the delight of everyone present Mr. Emms gave an account of a number of typically humorous incidents which he had experienced during the sea trials of electrically propelled vessels.

As the lecture lasted longer than usual, there was only time for three members to put questions to the author.

In proposing a vote of thanks, Mr. L. D. Trenchard (Member of Committee) thanked Mr. Emms on behalf of all the members and guests, not only for an excellent lecture but also for bringing "an atmosphere of the sea" into that Midlands lecture room.

The meeting ended at 9.10 p.m.

Student Section

A meeting of the Student Section was held at the Memorial Building, 76 Mark Lane, London, E.C.3, on Monday, 2nd November 1959 at 6.30 p.m., when a panel consisting of a Marine Manager, a Marine Superintendent, a Superintendent Engineer, a Lloyd's Register of Shipping Surveyor, and a Representative of the Ministry of Transport discussed "The Day to Day Management of a Ship and Its Machinery".

Mr. F. A. Everard (Chairman of the Student Section) was in the Chair and thirty members and visitors were present.

A vote of thanks to members of the panel proposed by the Chairman was carried by acclamation.

The meeting ended at 8.10 p.m.

OBITUARY

ALBERT BURROWS

Appreciation by Captain J. F. Allan

Mr. Albert Burrows died on 1st July 1959 after a long illness, at the age of sixty-seven.

He served an apprenticeship with Gray's Holborn Engine Works, South Shields, and after obtaining his Second Class Steam Certificate he joined Houlder Brothers and Co. Ltd. in April 1915. After serving in various capacities Mr. Burrows was appointed chief engineer in the well known *Imperial Transport* and subsequently in a number of other vessels of the company. In January 1935 he was appointed Engineer Superintendent in charge of the Liverpool office.

He was transferred to the London office in 1944, where

he remained until he retired, owing to ill health, in April 1957.

Mr. Burrows always had a great interest in refrigeration and besides being a Member of the Institute of Refrigeration he served as a member of the Technical Committee of the Refrigerated Research Council from 1945 until March 1957.

He was elected a Member of the Institute of Marine Engineers in 1938 and was elected a Member of Council in 1947. He served a four-year term and was re-elected in 1952 for a further period; he retired from the Council in 1954.

Mr. Burrows will be specially remembered by his colleagues in Houlder Brothers for his valued advice on difficult engineering problems, which was always given with the best grace and with unfailing good humour.

JOHN EDWARD VICTOR HOOD (Member 7673) was a native of Newcastle upon Tyne. He served an apprenticeship with Henry Watson and Son of Walkergate from 1918/24 and at the age of twenty-one embarked on a seagoing career as fourth engineer with Charlton McCallum of Newcastle upon Tyne. He was with the Hain Steamship Company from 1927/30, during which time he obtained a First Class Board of Trade Steam Certificate. For the next eight years he was employed by the United Steam Navigation Company of Newcastle upon Tyne, most of the time as chief engineer of the s.s. *Dalmore*.

Mr. Hood came ashore in 1938 and worked for a short time at Vickers Armstrong Ltd. as an inspector, returning to sea in the early years of the war in ships owned by James Nourse Ltd. After obtaining a Motor Endorsement he became chief engineer of the m.v. *Hughli* and sailed in several of the company's vessels, becoming their commodore chief engineer.

He died suddenly in Trinidad after a heart attack on 9th October 1959, aged fifty-six years. He was buried at sea from m.v. *Hughli* as she left the island.

Mr. Hood had been a Member of the Institute since 1934.

ROBERT KELLIE (Member 17332) died suddenly at his home in Ottawa on 4th September 1959.

He started his career as an apprentice with the Fairfield Shipbuilding and Engineering Co. Ltd., Govan, and then joined the Khedivial Mail Line as a junior engineer, serving them for three years. From 1928/31 he was a third or second engineer with Andrew Weir and Co. Ltd, and then second engineer for the next four years with H. Hogarth and Sons Ltd. He returned to Fairfields for a few months in 1935 as a fitter and then sailed as second engineer with John I. Jacobs and Co. Ltd. until 1939. He obtained a First Class Board of Trade Combined Certificate in 1937. After serving throughout the Second World War as a second and later chief engineer with the Anglo-Saxon Petroleum Co. Ltd., he went to Victoria, British Columbia, in 1950 as a chargehand in the Department National Defence at Esquimalt Naval Dockyard. In 1956 he was transferred to Ottawa and attached to the Engineer-in-Chief's Department there, an appointment he still held at the time of his death.

Mr. Kellie joined the Institute in 1956.

COLIN FREDERICK WATERHOUSE (Probationer Student 18519) died in Hamburg on 22nd July 1959 as a result of an accident on board m.v. *British Vision*.

He was born in 1939 and attended Chatham Technical School where he obtained a General Certificate of Education in Metalwork and Geometrical and Mechanical Drawing. He was then apprenticed to the BP Tanker Co. Ltd. and had just started his first voyage at sea when he met his death.

Mr. Waterhouse was elected to membership of the Institute in 1957.