

SESSION



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The Treatment of Marine Boilers on Long Voyages.

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THE subject of this paper must naturally be of interest to all Marine Engineers, for on the proper treatment of the boilers must depend not only the motive power of the propelling and auxiliary machinery of the vessel, but also of the refrigerating machinery in the case of vessels carrying refrigerated cargoes; and in these latter vessels, even if a stoppage of the boilers be only for a few hours, and does not entail serious consequences to the vessel itself, it may mean the spoiling of a cargo valued at many thousands of pounds.

It is outside the province of this paper to deal with the construction of the boilers, but it may be mentioned that practically every boiler built at the present time is made from Siemens Martin open hearth steel, with the exception of the tubes, which are generally of iron. Occasionally the longitudinal and screw stays and combustion chamber girders are also made of iron. The almost universal use of steel in preference to iron for boilers is due, partly to the much larger plates which can be made of steel than of iron, but mainly to its greater tensile

strength and ductility. Consequently steel boilers can be made of lighter scantlings and weight than iron boilers of the same size for the same working pressure. In fact, the use of steel for the shell plates of large high-pressure boilers is practically a necessity, for with a boiler of say 15 ft. 6 in. diameter, working pressure 215 lb. per square inch, the shell plates would require to be about $2\frac{3}{8}$ in. thick if of iron, whereas $1\frac{1}{2}$ in. is sufficient if made of steel.

Owing to all the material used in the construction of the boilers being tested before use, the excellent appliances now employed in most boiler-shops for bending, flanging, drilling and riveting the plates, and their supervision during construction, the risk of failure of boilers on a voyage due to defective material or workmanship may practically be considered as non-existent.

In this paper the question of treatment of boilers for long voyages is dealt with, but it may be well to say at the outset that whatever treatment is satisfactory for long voyages, will also suit for shorter runs, although the converse does not hold, as with the latter frequent inspection and cleaning are obtainable, whilst for long voyages these are impossible.

Before suggesting the proper treatment of boilers, it may be better to first consider the various causes which may lead to their failure, for in every profession it is well known that when the causes of the disease or failure are discovered, it is comparatively easy to suggest the proper remedies. It is, therefore, proposed to take in order some of the causes to which the failure of boilers may be attributed.

The first cause to be mentioned is shortness of water. It may seem superfluous to many engineers to mention this cause, but a perusal of the Board of Trade reports on boiler explosions will show that cases sometimes occur. More than one such instance has happened through the cocks on the ends of the water-gauge pipes having been inadvertently closed, the water though showing in the gauges, being allowed to get far below its proper level in the boilers, with the result that the combustion chamber tops and furnace crowns came down. In other cases in ordinary working, owing to negligence in not seeing that there was no water showing in the gauges, the combustion chamber tops have come down, the upper part of the combustion chamber back plating has been pulled away from the screw stays, and in some cases the tube plates

also have become distorted. In some of these cases fatal results have occurred, but in all of them total disablement of the boiler has resulted. Shortness of water may also be caused by the vessel having such a heavy list that, though water may be showing in the gauge glass at the centre or one side of the boiler, the combustion chamber top plating near the other side of the boiler may be above the water-level. The German authorities require the working water-level to be fixed so that either when the vessel is upright or listed to either side to the extent of 4° , there is clear depth of 4 in. of water over the highest part of the combustion chamber plates. This has led to the German practice of sloping the tops of the combustion chambers from the centre towards the sides of the boiler.

The failure of boilers through shortness of water can almost always be avoided by careful attention on the part of the engineer in charge, and will not be further dealt with here.

The bursting or perforation of one or more tubes may also disable a boiler temporarily, but as almost all vessels now carry tube stoppers, this defect can be quickly remedied by those on board.

It will be generally accepted that the most frequent causes of a breakdown of boilers at sea are either the collapsing or distortion of the furnaces, or the cracking of the furnace plates. The cause of furnaces becoming distorted is not always easily determined. But in view of the exhaustive tests which have been made from time to time, showing that the hydraulic pressure necessary to collapse the various types of furnaces is many times the working pressure, there is no doubt that the distortion or collapsing of a furnace, provided the boiler is not being worked at more than its proper pressure, must be due to the steel plate of the furnace becoming softened, and this can only happen through its becoming overheated. Further, it is impossible to account for the small cracks which too frequently occur in the furnaces without coming to the conclusion that they also are due to considerable overheating of the plates.

This overheating of a furnace, worked under normal conditions of combustion, can only be due to some resistance to the transfer of heat through the plate, owing to some substance such as scale, greasy matter, or other dirt being deposited on the furnace crown and preventing the free access of the water

to the plate. When a thick coating of scale or greasy deposit is found on a furnace, after it has collapsed or has become distorted, the cause of this trouble is at once apparent. An analysis, or even an inspection of the scale, will also show the probable cause of the deposit. If it has been caused by the continued use of small quantities of sea water in the boiler, especially if accompanied by much blowing out, the incrustation will be a hard crystalline scale mostly composed of calcic sulphate. Provided the density of the water does not exceed 1.225 ($\frac{7}{32}$), common salt (sodic chloride), which forms the greatest part of the salts in solution in sea water, will not separate out, but if the density is allowed to reach this latter figure, the sodic chloride will commence to crystallize out, and the scale then formed will mostly consist of this substance.

In one case of collapsed furnaces which occurred a few years ago, the deposit on the two furnace crowns of a boiler, which had been in continuous use for several weeks, was $1\frac{3}{4}$ in. thick, and was composed almost entirely of sodic chloride; there was also a deposit on the lower part of the shell of the same substance 1 in. thick. The density of the water remaining in the boiler in this case was found to be $\frac{7}{32}$. The furnace crowns had come down on both sides of the centre line forming deep pockets which touched the firebars, fortunately without fracturing the furnace plating. Curiously enough in this case the incrustation which had formed on each furnace remained as an arch, in the form of the original shape of the furnace. Had an ordinary salinometer been used in this case the increasing density of the water would have been ascertained, and precautions could have been taken, by means of blowing down, to prevent the density of the water becoming so excessive.

If only fresh water from the shore, containing lime salts, is used for make-up feed, the scale formed will mostly consist of calcic carbonate, but the incrustation will not be crystalline and will be much thinner than in the case of an equal quantity of sea water being used.

Where there is no thick deposit on furnaces which have collapsed or become distorted, and where there is little or practically no trace of oil on the furnace crowns, the cause of the distortion is at first sight not so apparent. But if an oily deposit is found on other parts of the boiler, more

especially if it be on the under sides of the furnaces and tubes, it may be fairly assumed that an oily deposit was really the cause. Such occurrences were discussed in an interesting paper read by Professor Vivian Lewes at the Institution of Naval Architects in 1891. He there stated that oil by itself being lighter than water would remain on the surface of the water, but that when small oil globules come into contact with small particles of calcic sulphate or other solids, the oil particles stick to the solids, which thus gradually become coated with oil, and in time the particles are enabled to cling together, or to stick to the surfaces with which they come in contact. The Professor states that these solid particles of calcic carbonate, calcic sulphate, etc., are heavier than the water, and, as the oil becomes more and more loaded with them, a point is reached at which they have the same specific gravity as the water, and then the particles rise and fall with the convection currents which are going on in the water, and stick to any surface with which they come in contact, in this way depositing themselves, not as in the case of ordinary boiler incrustations, which are chiefly on the upper surfaces, but quite as much on the under sides of the tubes as on the top, their positions being regulated by whether they come in contact with the surface whilst descending or ascending. It may be pointed out that it is not necessary for these small particles to have just the same specific gravity as the water, for even if they were slightly heavier, the intense ebullition would create such currents in the boiler as would prevent their settling, and would keep them circulating till they stick on some surface. He further points out that "the deposit so formed is a wonderful non-conductor of heat, and also from its oily surface tends to prevent intimate contact between itself and the water. On the crown of the furnaces this soon leads to the overheating of the plates, and the deposit begins to decompose by the heat, the lower layer in contact with the hot plates giving off various gases which blow the greasy layer, ordinarily only $\frac{1}{4}$ in. thickness, up to a spongy leathery mass often $\frac{1}{8}$ in. thick, which because of its porosity is an even better non-conductor of heat than before, and the plate becomes heated to redness, and, being unable to withstand the pressure of steam, collapses. During the last stage of this overheating, however, the temperature has risen to such a point that the organic matter, oil, etc., present in the deposit burns away,

or more properly is distilled off, leaving behind, as an apparently harmless deposit, the solid particles round which it had originally formed."

I have quoted this extract from Professor Lewes' paper to emphasize the fact that a furnace may collapse through an oily deposit being formed on the crown, and yet little or no oil be found on the crown on subsequent examination. If such an overheating as described by the Professor occurs over a large surface we get a collapse or distortion. If, however, only a local part of the furnace becomes strongly overheated, say between two ribs at the furnace side, we get the local pocketing sometimes found, whilst if the affected part is still smaller, so that its surroundings hold it in shape, when the incrustation sponge yields there is a sudden rush of water on to the overheated plate, and incipient small cracks result from the consequent sudden contraction.

This explanation also seems to account for the cause of several cases which have occurred of furnaces collapsing after the boilers have been kept for some time under banked fires, as under the conditions of comparative quiescence of the water, any oily particles, previously kept floating about by the ebullition, would settle down and be readily deposited on the furnace crowns.

The evil effects of a deposit, no matter what it may consist of, on a furnace crown is intensified when forced draught is used, as a more intense heat is generated on the fire side of the plate than with natural draught, and consequently the crown will become more quickly overheated. Bad stoking of the fire, whereby the fuel is not evenly distributed throughout the length of the grate, causing an intense heat to be generated at a local spot, will also intensify the evil effects.

Whilst on the subject of the collapsing, distortion, or as it is commonly called, the creeping down of furnaces, the advisability of properly gauging the roundness of a furnace at frequent intervals may be suggested. It is well known that many furnaces, doubtless due to frequent slight overheating, do creep down or slowly distort, and it is therefore very essential that a record should be kept of how far a furnace is out of its true circular form after each voyage, so that it may be seen whether there has been any further deviation from its form since it was last examined. Such a record would

enable the superintendent engineer to determine at once whether the means employed to prevent the distortion or creeping down of a furnace were efficacious or not. Through the courtesy of a superintendent engineer of one of the leading London steamship companies, I am able to show you an easy and accurate method of obtaining such records, and also some diagrams showing the alteration from the true circular form of some actual furnaces.

Another very important matter in the treatment of boilers is the prevention of corrosion, for the wasting by corrosion, more especially of the furnaces and combustion chambers and screw stays, has been the cause of many failures of boilers.

As to the actual cause of the corrosion of iron or steel, Mr. J. T. Milton, in the lecture he gave before the Institute last year on *The Corrosion and Decay of Metals*, showed that corrosion of iron or steel was mainly due to the action of a corrosive liquid or medium on the metal, also that, given the presence of air or oxygen in solution in the water, rusting or corrosion immediately sets in. It follows that to prevent corrosion in boilers every precaution must be taken to prevent air in solution being introduced into the boilers with the feed-water. Most of you have doubtless seen the serious corrosion which often takes place in that part of a boiler immediately in way of the feed-pump delivery. Most of these cases occur in boilers where the feed-water is delivered by the ordinary feed-pumps worked off the main engines, which from their construction must draw in a large volume of air at each stroke, and consequently must deliver the whole of this air into the boilers, unless the water is pumped through a feed-heater, or some other means are employed for extracting some of the air.

Independent slow-running feed-pumps, with their speed regulated by a float so that they are always full of water and no air, delivering their feed-water through feed-heaters, are an excellent means of effecting this purpose.

A case of acute corrosion may here be mentioned, due to the introduction into a boiler of an excess of air along with the feed-water, which nearly caused a serious accident. In this case ordinary feed-pumps worked off the main engines were used, the feed-water being delivered into the boiler through an internal feed-pipe secured to the boiler end plate by the same studs which held the feed check-valve in place. The joint of the internal feed-pipe flange to the boiler end

plate having not been properly made, allowed some of the oxygenated water to pass into the boiler at this joint, causing such an acute corrosion on the end plate at this spot, that it was found to be almost entirely corroded away in way of the studs, leaving in fact only one full stud and two partial studs to hold the feed check-valve in position.

In addition to the prevention, as far as possible, of the admission of air to the boilers, the use of zinc plates is also an excellent preservative against corrosion, as zinc, being a more corrodible metal than steel, the corrosive fluid will attack the zinc in place of the steel, provided always that the zinc is kept in proper metallic contact with the plates or stays to be protected. In order to ensure this the zinc should be firmly attached to the plates by studs and nuts with a good, clean metallic connexion, and not merely hung in the vicinity of the same as is sometimes done. Experience has also shown that rolled zinc plates give much better results and are more lasting than cast zinc. It is important to so place the zinc plates that in case of their decay and falling away the fragments should not be able to lodge on any of the heating surfaces.

From what has been stated as the cause of some of the failures of the boiler, it is seen that the most essential condition which determines either success or failure is that of the purity of the feed-water, and that there are three distinct substances which are specially objectionable when present in feed-water, viz., air, which is the principal cause of corrosion, and oil and sea water, which either by themselves or in combination are the causes of distortion and cracking of furnaces. The matter of air will not be further dealt with except incidentally in connexion with the question as to the best position for the entrance of the feed-water, but some further remarks as to oil and to the effect of sea water will be necessary.

The only sources from which oil can find its way into the feed-water are from the lubrication of the pistons and slide valves, of the piston and slide-valve rods, and of the air-pump rod and feed-pump glands, so far as the main engines are concerned, and from similar lubrication of the auxiliary engines, including in the latter the refrigerating machinery when this is fitted, as cases have occurred where, although precautions have been taken to ensure that the minimum amount of oil was used in the internal lubrication of the main engines, an

excessive amount of oil was used in the internal lubrication of the refrigerating machinery, and was passed into the boilers through the feed-water from this machinery, being pumped directly into the boilers. The quality of the oil used for the lubrication of the parts of the machinery coming into contact with the steam is of primary importance.

There are two distinct classes of oil used for lubrication, viz. those of mineral origin, which consist solely of hydrocarbons, and organic oils, which consist of various organic acids chemically combined with glycerine, and some of which contain in addition free organic acids. The organic oils as a rule are better lubricants than mineral oils, as they maintain a greater "body" or "viscosity" than mineral oils when at a high temperature, but unfortunately when in contact with steam at a high temperature they all to some extent decompose into a free acid and glycerine; the acid (oleic acid, stearic acid, palmitic acid, margaric acid, etc., according to the class of oil used) becomes at once a corrosive element, and this ought to absolutely prevent their use for all parts of the machinery in contact with steam. When such decomposed oils are brought in contact at high temperatures with metallic oxides or metallic salts, their acids combine with the metallic bases, forming metallic glycerides or soaps. In ordinary language they saponify. If, therefore, such oils are brought into a boiler the water in which contains salts or oxides, say of sodium, potassium, magnesium or calcium, all of which are introduced by sea water, soda, potash, magnesia or lime soaps will be produced. The two former will remain in solution in the water, but the two latter will remain in a flocculent solid form, ready to mix with any mineral oil globules which may be in the water and then to form a sticky mass which will adhere to the heating surfaces with which it may be brought into contact. If, therefore, the organic oils are relatively less in quantity than the salts, etc., brought in by the sea water, we shall get the oily danger referred to in Professor Lewes' paper; whilst if they are in excess, we still get the same danger, but in addition we get the corrosive action of the free acids which have had no metallic salts to combine with. It is thus seen how essential it is that no organic oil should be used in contact with steam. Fortunately this is well recognized and mineral oil is almost exclusively used for these purposes, but still cheap oils, purporting to be pure mineral oils, are sometimes adul-

terated with organic oils in order to give them sufficient "body" or lubricating qualities at high temperatures.

Mineral oils, on the other hand, are purely hydrocarbons. As found in nature, crude oil is always a mixture of various hydrocarbons, each of which, if pure, would have a definite boiling point at the atmospheric pressure. By a process of fractional distillation oil refiners separate various grades of oil from the crude oil, the lighter vaporizing at lower temperatures than the heavier oils. In some degree each grade of oil may be supposed to have its own vaporizing point, but in reality each grade is still a mixture of several hydrocarbons, all that can be guaranteed of any grade being the absence of those compounds much lighter or much heavier than the average in the sample. Hydrocarbons being composed of only carbon and hydrogen cannot by any heat treatment be converted into anything but carbon and hydrogen, hence although it is possible by heat treatment to split up a particular compound into two others, one being heavier and the other lighter than the original, or even to separate it into carbon and a lighter oil, no heat treatment can make an acid out of the oil. It is this quality which makes hydrocarbon oils so suitable for cylinder lubrication.

Now all hydrocarbons are similar in some of their properties to other volatile liquids, and although each has a definite boiling point for any definite pressure, above which the temperature cannot be raised without complete evaporation, yet very considerable vaporization can take place at lower temperatures than the boiling point.

The volatile liquid of which the properties are the best known is water. Let us consider the evaporation of water. At ordinary atmospheric pressure water boils at 212° Fahrenheit. At an absolute pressure of $7\frac{1}{2}$ lb. per square inch it boils at 180° F. If the pressure is reduced to 5 lb. it boils at 163° F. At 1 lb. corresponding approximately to 2 in. of mercury it boils at 100° F., and even at freezing point it will still evaporate if placed in a perfect vacuum until a pressure of 4.6 mm. of mercury is obtained (.18 in.).

In the same way the heavy hydrocarbon oils which are used for cylinder lubrication, although they require a much higher temperature than that of the steam to convert them entirely into vapour at atmospheric pressure, will still evaporate and give off vapour at low temperatures. This is taken

advantage of in distilling them in what is called a Vacuum Process.

Further there is the law known as Dalton's law, and which has proved experimentally, that with a mixture of gas and vapour "the quantity of vapour which saturates a given space is the same for the same temperature, whether this space is a vacuum or contains a gas having no chemical action on a vapour."

Let us follow a minute drop of a heavy mineral oil which finds itself carried into a steam cylinder, say on the piston rod. It rapidly attains the same temperature as the steam and commences to evaporate, its vapour mixing with the steam. If the steam were quiescent evaporation would go on until the cylinder space became saturated with oil vapour, and would then cease; but there is no time for this, steam is continually being swept through the engine and continually taking away any oil vapour which has evaporated. The net result is that all the oil, which is swept through the engines into the condenser, enters the latter as "*vapour*" not as liquid oil. The space in the cold condenser will only need a very small quantity of oil vapour to saturate it, and all the remainder of the oil vapour must be condensed into liquid oil. It is, however, so intimately mixed with the aqueous vapour, which is also rapidly being condensed into liquid, that as the exceedingly minute particles of oil become liquid they are mingled with a comparatively immense quantity of water and so prevented from coming together. In this way is produced the well-known opalescence of feed-water, due to innumerable particles of oil of such minuteness that they cannot be seen individually even by very powerful magnification. That these minute particles are oil, can be proved by slowly evaporating the opalescent water, when the oil will be left behind. These particles of oil cling to anything they touch, and some of them are thus caught by passing the feed-water through feed filters. It is those that escape the filter which cling to the surfaces in the boiler and also to the minute solid particles which are separated out from the feed-water in the boiler, to which attention was drawn by quoting from Professor Lewes' paper.

Now consider what happens when a small quantity of sea water enters a boiler mixed with the feed water. Professor Lewes went into this subject very fully in a paper he read

at the Institute of Naval Architects in 1889. He there gives as the composition of sea water the following :—

Calcic carbonate	3·9	grains	per	gallon.
Calcic sulphate	93·1	”	”	”
Magnesian sulphate	124·8	”	”	”
Magnesian chloride	220·5	”	”	”
Sodic chloride	1850·1	”	”	”
Silica	8·4	”	”	”

with traces of other substances.

Of these substances when the water is heated the calcic carbonate becomes insoluble, but according to Professor Lewes it reacts upon some of the magnesia chloride, forming soluble calcic chloride and an insoluble magnesian hydrate, and at the same time freeing carbon dioxide. The calcic sulphate is found to be insoluble at temperatures above 302° F., which is the temperature of steam corresponding to a pressure of 54 lb. per square inch ; consequently the whole of the calcic sulphate and the whole of the magnesian hydrate, formed as above described, must become solid and be precipitated even before the feed-water has attained the temperature of evaporation. The magnesian sulphate and the sodic chloride being very soluble salts do not solidify out until the water is very concentrated and has obtained a considerable density.

The insolubility of calcic sulphate in very hot water explains how it is that where the make-up is sea water only, and blowing out has to be resorted to in order to keep the density down to a safe limit, the more blowing out there is the greater will be the quantity of scale deposited. Of course this deposition of the calcic sulphate and magnesian hydrate must take place all the same, whether the sea water is deliberately added or whether it enters from a slight leak in the condenser.

Having stated some of the chief causes which lead to the failure of boilers and described the action of impure feed-water, the following is suggested as the proper treatment of boilers on long voyages, viz :—

The boilers should always be thoroughly cleaned and all scale or deposit on the heating surface removed. A sufficient quantity of zinc plates should be securely attached by studs to the furnace sides, and also to any other part of the boilers where there is any sign of corrosive action. Clean fresh water—and fresh water only—should be used for first filling the boiler and for make-up feed, and the feed-water should be

heated up to about the temperature of the boilers before it is passed into the boilers, as the use of heated feed-water is thought by some to increase the evaporative efficiency of the boilers, and certainly reduces the strains which must be set up when cold feed-water is used. Every precaution should be taken to prevent the entry of air into the boiler along with the feed-water.

Some engineers still advocate the use of a small amount of sea water when first filling the boilers, especially in new boilers, so that a slight scale may be formed on the inside of the boilers, maintaining that by such treatment corrosion is avoided. But as the formation of even a slight scale on the heating surfaces must tend not only to the overheating of these parts, but also to an increased expenditure of coal in proportion to the water evaporated, it is questionable whether this is a good practice.

Especial care must be taken during the voyage to keep all sea water out of the boiler. For this the use of fresh water for the make-up feed is essential. And fresh water must either be carried in the ballast tanks, or, as is now the usual practice in most vessels running long voyages, efficient evaporators must be fitted to provide sufficient fresh water for this purpose, and they must be sufficiently large to work to the required capacity without priming. A certain amount of sea water will, however, be passed into the boilers if the condenser is leaking, whatever means may be provided for the make-up feed, but such a leak should be stopped as soon as possible. To ensure this, the condition of the feed-water as it leaves the hot-well should be regularly and carefully ascertained, in order that the very first discernible leakage of sea water should be known and promptly dealt with. These remarks also apply to the condensers of refrigerating or other auxiliary machinery using steam from the main boilers. In no case should the density of the water be allowed to exceed 1.09 or $\frac{3}{32}$. The best means for ascertaining the density of the feed-water is dealt with at the end of this paper.

The question as to how often the water in the boilers should be changed must depend on circumstances, chiefly on how the density of the water has been kept. On long ocean voyages it may be impossible to make any examinations, but it may sometimes be possible to change the water in part of the boilers at coaling ports, even although the stay in port is short.

To avoid unnecessary risks it is advisable to change the water frequently and examine the interior of the boilers, more especially in the case of new boilers.

In some vessels running out to China and Japan, whose boilers I at one time surveyed annually and often at intervals of six or seven months, the water was regularly changed only at the end of voyage out or home, say after about fifty days' steaming. And though these boilers were from six to eight years old, they had never required the use of a boiler maker for repairs, nor had a scaling hammer ever been used in them, brushing and washing down being all they required when opened out. These boilers were worked under natural draught and were amply large for their work and consequently were never forced. Fresh water was always used in filling them, and great care taken to prevent any air in solution being pumped into the boilers. All feed-water was heated by means of feed-heaters, and also passed through filters, and ample evaporators were fitted for feed make-up, zinc plates being also used to prevent corrosion, of which I may add there was no sign.

Other boilers which I have examined and found to be in good condition are continuously under steam for about forty-two days at a time before the water is changed. Others I believe run for twice that time without changing the water, with satisfactory results, but, generally speaking, for vessels running for such long distance voyages as to Japan, Australia or New Zealand, even when the density has not exceeded $\frac{3}{3\frac{1}{2}}$, it appears advisable to change the water at each end of the voyage.

Great care should be taken at all times, more especially when raising steam, to prevent quick variations of temperature and consequent strains being set up in boilers, as these are often the cause of leaky seams, and of the cracking of the furnace saddle plates and combustion chamber plating. To avoid such strains, at least twelve hours, and better still twenty-four hours, should be allowed for raising steam in the boilers.

Some engineers prefer to light all the fires at once when commencing to raise steam, others light the wing fires only, and others again light only the centre fire. The first plan appears to me to be the best method, as by so doing the heat, being gradually generated in all the furnaces alike, enables

the boiler to expand more equally. During this process of raising steam the water in the boiler must be kept in circulation so as to obtain, as far as possible, an equal temperature of water throughout the boiler. There are many methods of effecting this, one of the simplest and most effective being by pumping the water from the bottom of the boiler and delivering it back into the boiler through the feed-pipes, having first heated it in the feed-heater by steam from an auxiliary boiler.

There does not appear to be a concurrence of opinion as to the best position in the boiler for the feed water to be delivered, but in every case care should be taken that the incoming feed-water does not impinge directly on the plating or tubes, for should there be any air in the feed-water, acute corrosion will probably be set up on that part of the boiler against which it impinges. Probably the best position is as near the surface of the water as possible, so that any air which may be in the feed finds its way directly into the steam space.

The best hydrocarbon oils only, of a high specific gravity and high vaporizing point, should be used for the internal lubrication of the cylinders and slide valves, and the amount used should be reduced to the minimum possible. It is now generally found that the swabbing of the piston and slide rods is sufficient for internal lubrication, except in new engines or in some cases where the working surface of the valves is limited, or where a cylinder has been bored out, or a slide valve planed up and not yet worked up to good surfaces.

When electric light engines or fan engines are fitted and their crank-shafts are run in oil baths, extra precautions must be taken to prevent an excess of oil being splashed on to the piston and slide rods, as trouble has often occurred through oil getting into the boilers through this cause.

Even when internal lubrication is reduced to a minimum every possible means should be taken to prevent oil entering the boilers, and feed filters are now generally fitted for this purpose.

When forced draught is employed care should be taken to prevent an excessive air pressure in the ash-pits and furnaces. This is often due to the speed of the fan not being reduced when the air valves are closed on one or more of the furnaces,

when cleaning fires. Keeping the firebars well and uniformly covered and the bridges intact are also important points, not only in preventing extra strains being set up in the boilers, but also in ensuring that the air supply is evenly distributed to the whole of the fire on the grate, thus ensuring a more perfect and economical combustion of the fuel.

At the end of a voyage the fires should be allowed to die out in place, and the boilers allowed to cool down gradually, say for about twelve hours, with dampers shut, to prevent any undue strains being set up due to rapid cooling of certain parts of the boilers.

The blow down cocks should only be opened for a few seconds to see that they are in working order. After the boilers have been cooled down they should be pumped out and thoroughly cleaned.

Before concluding this paper it may be of interest to give a short description of the hydrometers now used by the Admiralty for testing the density of the water in the boilers, and of the feed-water. And in view of the great importance of frequently ascertaining these densities, it is considered that every vessel proceeding on a long voyage should be supplied with a set of similar hydrometers as well as the appliances for carrying out the nitrate of silver test, and the engineer in charge should be instructed to carry out these tests regularly and frequently, and to log the results.

No. 1 is a hydrometer made of brass, so as to withstand moderately rough usage, and graduated from zero to 40° on both sides of the stem, one side being graduated for a temperature of 200° F., and the other for 100° F. Normal sea water would be 10° in this hydrometer, and 40° means four times the saltness of the sea.

No. 2 is a hydrometer made of glass and similarly graduated on stem to No. 1 as regards density, but only one scale is provided, suitable for use at 200° F.

No. 3 is the same as No. 2, but is graduated for use at 100° F.

No. 4 is a sensitive hydrometer, and is made of glass with a large bulb and small stem. The graduations are for use at 100° F., and the stem contains only two degrees altogether, each tenth of a degree showing about the same length as a whole degree on Nos. 1, 2 or 3. It is, therefore, ten times more sensitive, each tenth representing one-hundredth of the saltness of the sea. The accurate result is only obtained at 100° F.

and as the density of water changes pretty rapidly with the temperature, the change being almost exactly the same for 1° F. as for one-hundredth of the saltness of the sea, it is necessary to be sure that the temperature of the water is correct, and the instrument must be used in conjunction with a sensitive thermometer.

The sensitive thermometer used has a scale so graduated that fractions of a degree of temperature are easily discernible.

A special "hydrometer pot" is used, which consists of a tall narrow brass jug with a handle. When filled with water from the boiler the hydrometer can easily float in it without touching the bottom.

In practice it is found, in order to get a really accurate reading from the sensitive hydrometer of the true density of the water in a boiler or feed-tank, that the following procedure should be followed, viz. :—

1st. The hydrometer pot must be absolutely clean, as an inaccurate density of the water may be given if this precaution is not taken.

2nd. A bucket of cold water should be ready into which the hydrometer pot can be stood to reduce the temperature quickly.

3rd. A stirrer, made say of a piece of perforated brass on the end of a wire, is necessary so that the temperature of the water in the hydrometer pot may be kept uniform.

4th. The hydrometer itself must be quite clean. This is important.

The water in the hydrometer pot should be cooled down to about 105° F., and the pot should then be taken out of the bucket, keeping the thermometer in it and stirring continuously. At 101° F. the hydrometer should be put into the pot and the reading taken.

NITRATE OF SILVER TEST.

An ordinary solution of nitrate of silver is employed. For convenience in using it, a special drop bottle should be used, which will allow one drop only at a time to drop.

Test-tubes should be used, and if any salt is present in the water one drop of nitrate of silver (AgNO_3) in a test-tube sample will speedily reveal it.

If one or more drops of AgNO_3 in a test-tube show *no* trace of salt in the water, it is quite certain that there is none in

the water tested. Care must be taken that the test-tube is quite clean, and that no sweaty fingers have contaminated the water or test-tube.

As the drop of silver solution falls through the water a very little experience is sufficient to judge whether the water is free from salt. Oil in the water is found not to have any effect, but lime has. The colour of the precipitate with lime is, however, very different from that due to sea-salts. As a test of the tightness of condensers the nitrate of silver test is the most sensitive, simple and satisfactory. It is considered, however, that the hydrometer is good enough for testing the density of the boiler-water.

A hearty vote of thanks was accorded to the author; and it was subsequently announced that the adjourned discussion would take place on January 10, 1910, an opportunity being thus afforded for members both at home and resident abroad to send in communications.

The meeting concluded with a vote of thanks to the Chairman.



The following were elected at the meeting of Council held August 12, 1909 :—

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George Bodley, Auckland, N.Z.	Charles Martell, Grimsby.
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B. B. Conry, Bombay.	Wm. J. Sage, London.
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R. N. Duncan, London.	J. C. G. Williamson, Buenos Aires.
A. F. Ford, Aden.	P. J. Adie, Buenos Aires.

AS GRADUATE.

C. V. Lewis, London.

TRANSFERRED FROM ASSOC. MEMBER TO MEMBER.

W. Gale, Addlestone.



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SESSION



1909-1910

VOL. XXI.

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PRESENTATION OF "STEPHEN"
& "RITCHIE" AWARDS

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"THE TURBINE," BY "URANUS"

(MR. J. S. GANDER, ASSOC. MEMBER.)

"FEED HEATING," BY "ENIGNE"

(MR. W. W. ADAMSON, ASSOCIATE).

RITCHIE AWARD PRIZE ESSAY.

"THE FUNCTIONS OF THE AIR AND
CIRCULATING PUMPS," BY "VACUUM"

(MR. WALTER SMITH, GRADUATE).

REPORT OF AWARDS COMMITTEE ADOPTED JULY 8, 1909.

REPORTS OF SUMMER VISITS TO
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