INSTITUTE OF MARINE ENGINEERS

INCORPORATED

SESSION 1911-1912

President: The Most Hon. The Marquis of Graham, C.V.O., D.L.

Vol. XXIII.

PAPER OF TRANSACTIONS NO. CLXXV

Notes on Marine Boiler Repairs

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READ

Monday, February 6, 1911.

Chairman: Mr. John McLaren (Vice-President).

In submitting for your consideration this paper of Notes on Boiler Repairs, I would point out that the subject of these repairs is one that few engineers care to take up unless they are compelled to do so. For instance, I have rarely found a young engineer give the subject other than the slightest thought. Sea-going engineers, in most cases, give it little thought until trouble comes, and it is not until they have become either superintendents or surveyors that they reluctantly discover that the boiler is the heart of the driving machine over which they are placed, and is subject to many troubles, more or less caused through dirt. When one considers the many auxiliaries given to the engineer of the present day, compared with those in the past, it is surprisng at times to find boilers in so neglected a state. Such auxiliaries are not placed on board for ornament, neither are they there for the purpose of giving the engineer extra work. They are rather placed there for the purpose of helping him to keep the boilers right, and if judiciously used will do so. Independent float-controlled feed pumps discharge the water into the boilers practically free from air, and at a temperature never thought of years ago. Evaporators give a continuous supply of fresh water to make up for loss. Feed-heaters heat it to the boiling-point, and filters are so fitted that in a natural way they keep out all oil and other foreign matter. All steam from auxiliaries is led back to the condenser, and thus waste is reduced to a minimum.

While all this is the case, as I have already said, it does not in my opinion usually commend itself to the ordinary engineer until he personally finds himself responsible for its upkeep; then, and not until then, does he recognize how much depends upon it, and how essential it is that it should be kept in good condition to enable it to do the work for which it is intended, and the dire consequences that may befall him should anything serious go wrong. All this is new to him; he knows all about the engines, but the boiler, oh! the boiler, what a worry it is, and what a time it does take to learn how to repair it. This is no doubt due to the system of apprenticeship gone through at the present time, which only in a few instances permits the young engineer to have boiler shop experience. Yet it is almost as necessary for a young engineer apprentice as a knowledge of mathematics if he is to be properly equipped and to be fitted for any position of trust other than that of an ordinary workman. At the same time, if an apprentice will disabuse his mind of the demarcation of work as practised in the shops, and use the powers of observation given to him, there is no reason why he should not make himself conversant with the details of the construction of boilers, and, in due course, this training will teach him how they can be repaired.

To begin with, the boiler is not made by rule of thumb. It is designed by established rules, and with the same care as in the case of the engines, consequently each part has the same relative value as the other part, each having a formula giving practically the same factor of safety. This applies in all cases, however much the design may differ, consequently the scantling of the boiler varies only with its working pressure.

It therefore follows that repairs, too, have definite principles which, if followed, make it possible to keep the boiler, at least for a time, up to the level required for it to retain its original working pressure.

It is not my intention to touch upon the question of boiler design ; I will assume that the defects and their repairs are such as would be found and repaired in boilers constructed to the rules of Lloyd's Register or the Board of Trade.

I will therefore treat the boiler in detail, in the order of shell, end plates, furnaces, combustion chamber plates, and tube plates and stays, and in doing so I will endeavour to make my remarks sufficiently clear so that all may be able to follow me.

In cases where I have occasion to mention donkey boilers, I will state so, otherwise my remarks will apply especially to main boilers.

Boiler Shells.—There have been very few cases of late years where it has been necessary to repair the shell plating of boilers, although during the old compound engine days it was common. This has been due to the fact that in almost all cases the shell plates have been made of steel of large size, and have been riveted by hydraulic pressure. Not only have the shell joints (viz., the longitudinal and circumferential seams) been properly designed, but the former have been properly placed well up on the boiler side. In the eighties, it was no uncommon thing to find longitudinal seams at the bottom centre line, and in not a few instances has it been necessary to fit new butt straps or re-rivet the old ones owing to leakage. At the present time, I think I may say that shell seams generally do not give trouble.

Where the end plates are flanged outwards for hydraulic riveting to the shell, it is not uncommon to find considerable local corrosion through leaky rivets. It will in this connexion be remembered that such a seam is only caulked on the outside. At an early stage this defect can be overcome if the rivets are cut out, and the holes countersunk on both sides and re-riveted. Where this is not done, and the seam is neglected, the shell and end plates will require patching, a most difficult and most unsatisfactory job.

While it will be found to be a very rare thing for a boiler to have its pressure reduced owing to shell trouble, it is very usual in the case of donkey boilers, where the shell plating becomes reduced in thickness much quicker than is the case in main boilers, owing to a simple cause. Donkey boiler stop valves are always made non-return, so as to stop the main boiler steam from entering. When the winches are working, the non-return valve is constantly clattering; this, in time, damages the valve and valve seat, consequently when the boiler is out of use there is a continuous slight leak of water into it through the valve. Seeing that the donkey boiler is placed in the stokehold, where it has the heat from the main boilers radiated upon it, or on the main deck close to the funnel and above the main boilers, where it is again subject to the same heat, it is found that the portion next to the source of heat quickly corrodes, owing to the continual wetting and drying of the plates. This applies equally to vertical and horizontal boilers, and the best way to stop this corrosive action is to fit a lift stop valve as well as a non-return valve, and keep the boiler quite dry when not in use. Repairs to donkey boiler shells are expensive, and when it is necessary to deal with them owing to corrosion having gone to an abnormal extent, it is better to renew the boiler than to attempt to repair it, for if the shell is reduced through the cause stated, the chances are that the internal parts will also be reduced to an abnormal extent.

End Plates.—Front plates in the steam space are sometimes found considerably corroded at and above the normal water line, while the top back plate is found quite good. This defect is due to radiation of heat from the uptake caused through the baffle plate being non-effective, either owing to its being closed in all round, or through the air space being choked up with dirt. In short, the end plate being locally heated to a higher temperature than the rest of the plate, and to its being subjected to continual wetting and drying through the pitching of the vessel, the corrosion takes place. The line of demarcation of the corroded part can often be distinctly seen, and takes the line of the smoke-box.

This action can be at once stopped by making a clear air space between the uptake and the front top plate, and keeping this space clean. When, however, the corrosion has gone so far that it is necessary to deal with it, riveted washers should be fitted to each stay outside, or a continuous doubling plate or strip riveted on outside, taking all the stays. Such washers or plates should never be fitted inside, for obvious reasons. Should the stay nuts outside be of the ordinary thickness, the stay may require to be renewed, so as to admit of the above repairs. In any case, the chances are that when the top front plate has been reduced by corrosion so as to require such a repair, the longitudinal stays will also be sufficiently worn to require renewal.

When Tuck's packing was used more generally for manhole door joints, the bottom manholes were often badly corroded inside in way of the riveting of the compensating plate; this was due to the action of the packing and to the liability of the countersunk rivet heads to corrode more rapidly than the plate. In cases where this defect had been allowed to go too far, the whole manhole piece of the front plate was cut out, and a new flanged piece fitted, the same being joggled over the shell outside, and securely riveted to same, as well as to the furnaces and front plate. Fortunately, this method of repair no longer exists, owing to the front plate manholes being flanged and the doors being more carefully fitted. When it is necessary to have manhole compensating rings fitted, it is better to have them connected to the plate by means of countersunk-headed screwed studs instead of rivets; the studs need not be taken through the plate, and are quite as efficient. Bad-fitting manhole doors are still to be found, and should be repaired by fitting a new spigot piece, but as this necessitates new studs, it is as well to fit new doors. In the event of the door being of the present day solid type, or grooved type, a ring of about 3 in. wide and about $\frac{3}{8}$ in. thick should be fitted to the manhole, and be studded on to the door; this makes a capital job, and does not necessitate the renewal of the door studs.

There is another defect which is sometimes to be found in furnace front plates, viz., the grooving and cracking of the furnace front plate flange, to which the furnace is riveted. This is usually found on the upper part of the flange at the crown of the furnace. There are several theories as to its cause, the first being that at the flanging, or at the riveting in of the furnace seam when new, a latent crack which had escaped detection developed from time to time owing to the expansion and contraction of the boiler under steam; the second one being that the crack in the first instance was caused while setting up the furnace at some time by hydraulic jacks, owing to their being out of shape; the third possible cause being over rigidity between the tube plates, thus not permitting what may be called breathing space, due to expansion and contraction of the furnace. In most cases where I have found this defect, the boilers worked under forced draught, and the furnaces have been one of the following type: Brown's, Holmes', Adamson joint, and plain furnaces. There are two methods of repair adopted in such cases, the first being to renew the front plate; to do this means that the furnaces will require to be renewed, as it is practically impossible to fit a new front plate into a shell with, say, three furnaces in position. In cases where this method of repair has been done, the furnaces have been renewed. In cases where the furnaces are in good condition, the second method of repair is to cut out the rivets in way of the crack in the furnace connexion to flange, and if the front plate is fitted on the inside of the front tube plate, to cut out the rivets connecting them together, for a distance equal to the length of the proposed patch. Should the front plate be fitted to the outside of the front tube plate, or should the front plate and tube plate be in one, a new seam of rivets should be fitted. The crack should then be studded at each end, a flanged angle plate about ½ in. thick should be carefully fitted and bedded close on the inside, taking in the seam of tube plate and furnace rivets, also a number of tack rivets through same, here and there. To enable this to be done, a number of the bottom tubes may require to be drawn. After the angle patch has been riveted and caulked, it should be forced with red lead by means of a pump. This makes a capital repair. Such a patch should not be fitted on the outside.

There is also another front plate defect which should be noticed, and that is local corrosion in way of the check valves. It has long been the general practice to put spigots to check valves sufficiently long to go through the plate. On the inside of the boiler, the flange of the internal pipe is secured to the same studs which hold the check valves in position. As a general rule, the pulsations of the pump start the internal joint, consequently the feed water leaks through between the flange and the end plate. When this takes place, and the check valve is placed in the steam space, or about the water level, it is found that the end plate corrodes very badly, in several cases so badly that not only has the plate corroded, but the studs holding the valve in position have corroded to such an extent that I have wondered that the check valve has not been blown off the end plate altogether. In such cases the repair is simple: If the corrosion is only in way of the hole in the end plate, and the studs are not damaged, the check valve spigot should be extended for say about 4 in., and the internal pipe flange screwed on to the spigot; the corrosion in such a case will be at once stopped. In bad cases, such as I have before pointed out, where both plate and studs are damaged, a large washer the same thickness as the end plate should be riveted on to the defective part, the rivet holes should be countersunk on the outside, and the washer properly riveted and caulked. The check valve spigot should be lengthened, say about 4 in., and the valve refitted on to the washer, after which the internal pipe should be connected as in the first repair.

FURNACES.—The furnaces are perhaps the most vital part of the boiler, and if it were only possible to do without them as we know them, the boiler would be as little trouble as the engines generally are. One thing is certain, all of us excepting boiler makers could well do without the ills the furnace is heir to. First of all, some corrode along the line of fire-bars, others corrode along the weld at the bottom, some again crack at the bottom of the corrugations along the line of fire bars; while others crack on what might be called the shoulders, and upon the furnace crown. Then, again, some crack down the corner of the reverse flanges, others crack circumferentially as in the ribbed furnace, others leak at their connexion to the combustion chamber bottom, and finally, they all more or less become distorted, and if not taken care of, become really dangerous.

The causes of these furnace defects are numerous. First of all, take the question of corrosion along the fire-bar line. I have my own opinion as to its principal cause. I may be wrong. It is this. When the boiler is new, it rusts, or to use the ordinary term, it bleeds. Now the boiler scalers never clean a furnace an inch below the line of fire-bars, unless they are properly instructed to do so. In due course, the scale is permitted to cover the rust and to remain there. This goes on from time to time, and is never properly cleaned off, for those in charge, in many cases, never go through the bottom door to examine this part after cleaning. The fire-bar line is subject to considerable variation of temperature, almost more so than any other part of the boiler. This, I think, makes it more liable to chemical action. The red oxide of iron first formed changes into black oxide of iron, and in doing so gives off oxygen, which being in a nascent state, immediately attacks the surrounding steel, and continues the action indefinitely, or until the whole of the oxide is removed. During this time, abnormal corrosion has taken place at the fire-bar line, and the furnace is considerably damaged. There is another cause ascribed, viz., bad circulation. This undoubtedly is the cause of much trouble, yet it is strange that if you take two boilers made by the same makers, of the same steel, from the same drawing, at the same time, and each is placed on board vessels owned by different companies, but worked in the same trade under the same conditions, the one will be found badly corroded along the fire-bar line, while the other will not. From this it would appear that corrosion along the fire-bar line is more a question of treatment than of design or circulation. To avoid corrosion, I am of opinion that if this part is kept well scaled and cleaned, and the water kept as free from acid as possible, it will not exist. In cases where it does exist, soda should be used, and zinc plates should be hung on studs where the corrosion is worst, not intermittently, as is so often done, but continuously, until the corrosion is removed. The Acetylene Welding Company claim that they are able to fill in the sides of furnaces which have corroded. I have not had the privilege of seeing the process or a furnace so treated, but considering that the filling-in agent is deposited in small drops of fluid iron, and that all depends upon the man who does it, it is open to question whether a good job can be made in such a case.

Corrosion along the weld at the furnace bottom is confined to the Brown's Ribbed Furnace, which is glut-welded. It is rare, however, that such corrosion requires to be dealt with. All the other furnaces are lap-welded, and, unless they have been thinned locally, give no trouble.

Cracking of furnaces, whether it should take place at either the fire-bar line or at any part of the furnace, is perhaps one of the most difficult defects to deal with. I think I am correct when I state that in all cases where the furnaces have cracked the cause is not far to seek. Cracks do not occur in the body of plain furnaces as often as in the case of corrugated ones. One of the advantages claimed for the latter type of furnaces which may be classed as having a female corrugation, is that it sheds the scale better than the plain furnaces, but I am of opinion that this is not the case, for I have found that such a furnace holds the scale at the bottom of the corrugation. This can be proved by any one who will take the trouble to examine a corrugated furnace before being scaled, when he will find that if the scale is, say, $\frac{1}{16}$ in. thick at the top of the corrugation, at the bottom it will be much more. It is obvious, therefore, that the cause of the cracking of furnaces is in every case due to accumulation of scale; this should not be so, for if the furnaces are kept reasonably clean, and the boilers properly managed by those in charge, furnace cracks would not take place.

To effect the repair of a crack in a furnace, it is usual in the case of a corrugated one to what is termed "lock stud" it. This method of repair is, at best, only a temporary one, as it is necessary to renew the studs very often. Lock-studding of cracks in furnaces will not stand, and while it is excusable for a sea-going engineer to do such a job to bring the vessel home, he should not be expected to take the vessel away again with such a repair.

To enable the vessel to continue her voyage until it is convenient for the furnaces to be renewed, the studs should be cut out, the fire side of the crack well countersunk, and an oblong rivet with a thin head carefully riveted in. This, at least, will not be blown out, consequently no one will be hurt, and the owners may be saved the trouble of a Board of Trade Inquiry under the Boiler Explosion Act.

It is difficult to patch a corrugated furnace; I have never seen an instance where such a patch could be called satisfactory. The same can be said respecting any of the different sections of the patent furnaces at present in use, and, as a matter of fact, when once it is necessary to patch them, they are a continual source of trouble and should be renewed. The Acetylene Welding Company claim to be able to weld furnace cracks, and in the single instance where I have seen this done, it was a satisfactory job. Before leaving the question of the cracking of the furnace, there is a point which should not be overlooked. When it is necessary to fit a new furnace and to telescope it into an old saddle plate, leaving a seam of rivets connecting it exposed to the action of the fire, it is found more often than not that the seam cracks from the rivet hole to the edge of the plate. In fitting such a furnace, great care should be taken that the seam is close before a single rivet is put in. The holes should be absolutely fair, and then carefully riveted and caulked. After this has been done, the edge of the furnace plate right round the crown should be chipped with a bevel about $\frac{3}{8}$ in. wide, as if left square the plate edge becomes overheated and cracks to the rivet hole. Should such be found in a furnace fitted this way, it should not be caulked, but the rivets should be removed, the seam closed, and the holes re-bored and countersunk and re-riveted and caulked. The $\frac{3}{8}$ in. bevel should then be cut, as before stated, and the chances are that the defect will be cured.

Cracked and leaky reverse flange corners (viz., that part of the furnace which forms the connexion to the tube and combustion chamber side plates). This defect is due to one of two causes, the first one being due to the corner being of too sharp a radius, and to its often having a rivet fitted in the centre of same; the other cause being that the corner had not been fitted close from the beginning. This defect is a most serious one, as it is practically impossible to make it good. The only thing to be done is to bore out the rivets, re-bore the holes, and recountersink them, close the seam and re-rivet. If the corner is cracked, the only thing that can be done is to fit a patch; great care should be exercised that it will lie close, but even after everything possible has been done, the patch will only last for a short time, and will be an endless source of trouble. It should be remembered that the furnace reverse flanges take the thrust due to the expansion of the furnace under heat. The only way to get such corners to stand is to see that the radius of the corner is not less than 3 in., that the plates are close, and that the rivets have no other function to perform than to keep the plates together.

The most common furnace trouble is, after all, their distortion. While I am unable to state definitely the actual reason of this distortion, I would submit the following as possible causes. First of all, almost every patent furnace sooner or later becomes distorted. One thing is certain, they do not do so through inherent weakness; it must, therefore, be due to something else, viz., accumulation of scale, oil deposit, or some other foreign substance. The defect seems to be accentuated by the high pressure now the rule, because in cases where the pressure is 100 lb. and under this furnace distortion is not so common, although the boiler is working under the same conditions as to cleaning and treatment. It would therefore appear that scale in high pressure boilers is so much more a bad conductor of heat, hence the furnace crown is unable to convey the heat to the water, and becomes abnormally heated, thus losing its power to resist collapse, while the furnace bottom remains, even in a case of total collapse, absolutely fair.

Local distortion of a furnace very often occurs when care is not taken to see that furnace crowns are clean before water is put into the boiler, and is due to one of the following causes, viz., oil spilled locally on the furnace, a tallow candle or a piece of oily waste being left on, or to local accumulation of scale, as, for example, on the saddle plate after the back tube plates have been scaled. From this it will be seen that this defect is one which can to a great extent be avoided if ordinary care is taken.

When local distortion occurs, or a bulge forms on a furnace, it is almost better not to interfere with it other than to keep it clean. Girders are sometimes fitted with a bolt through the bottom of the bulge, and are usually a "Charm," making the bulge worse than before. Unless such a girder has a neutral support it is of no use.

It is also a well known and established fact that many cases of furnace distortion in foreign-going steamers have happened after from forty to seventy days' steaming, while lying under heavy banked fires just before going to discharging berths. The period of danger, therefore, appears to be when lying with steam on boilers and engines at rest. It would seem that making steam without taking it away by the engines is far more dangerous to the furnaces than when making steam to the utmost and engines taking it away. This seems paradoxical, but, in my opinion, it is one of the causes of tramp steamer furnaces being distorted. During the time of banked fires, it would also appear that the deleterious matter held in suspension through the excited state of the water, sinks, and a portion naturally falls on the furnaces, and may possibly have something to do with the creeping down of furnaces, so very common.

The method of repair which should be adopted in cases of furnace distortion depends to a large extent upon the nature of the distortions, and the actual condition of the furnace.

Should distortion take the form of a collapse, the only remedy is to renew it. If the furnace is a withdrawable one, this is a simple matter; should it, however, be a furnace flanged in the ordinary way, it should be cut around the saddle plate, leaving sufficient for a good landing, then down to a position near the fire-bar line but clear of the cross seam connecting the combustion chamber side and bottom plates, then horizontal to the combustion chamber bottom seam, on each side. After the furnace is withdrawn, only the old furnace saddle plate is left in. When the new furnace is fitted and the saddle plate holes drilled and countersunk on each side, the seam should be riveted, beginning at the crown and working down each side equally, so as to make absolutely sure that the crown seam is close; the connexion to combustion chamber bottom should be riveted last. The crown seam should be single riveted, never double riveted, while the connexion to the combustion chamber bottom is better double riveted in all cases. When all the seams are caulked, the one exposed to the fire round the saddle plate should be bevelled, as before stated. This method makes a much better job than to simply cut the furnace circumferentially from the saddle plate, leaving in the old furnace connexion to the combustion chamber bottom, and an extra seam of rivets in a position where the fewer seams the better.

When a furnace has distorted to the extent of over three inches, there is a great risk of it being cracked during the process of setting up with hydraulic jacks; if the furnace is of any age, it is almost better to renew it than to attempt to set it up.

When a furnace becomes distorted or sags, it lengthens, the front plate does not come in, neither does the furnace connexion to the back tube plate; these two points are fixed ones; therefore, to set up a furnace between two such fixed points is to simply spring it up, and may be the reason why it so often sags back again. When it is decided to set up a furnace, the rivets connecting the furnace to the front end plate should be cut out and the caulking edge slackened. The bottom of the furnace should be so prepared that the strain to be placed upon it will be distributed over as large a surface as possible. It should be remembered that each corrugation or rib is a girder. The block used to set back the furnace should be the same section as the furnace, not too large, and so made that it will not indent the furnaces. Push back a little at a time, and if heat is required, apply it only on the water side of the furnace, and only on the part affected. When the furnace has been set fair, it will be found that the rivet holes in the front end plate seam to furnace are unfair. Re-bore the holes, re-countersink, re-rivet with larger rivets and re-caulk.

Vertical donkey boiler furnaces generally give trouble at the bottom vertical seams below the fire-bar line, and crack at the neck of the cross tubes, and at times blister and crack on the body. The first defect is caused through the seam not being properly closed before being riveted. The rivets should be cut out, the seam closed, holes faired, re-countersunk, and re-riveted; simple caulking of such a seam does no good. The cracking of the cross tubes is caused through accumulation of scale, and as there is little chance of them being made tight through patching, they should be cut out, and the holes in the furnace side filled in with a plate of the same thickness as the furnace, having a nutted screw stay fitted to each.

Donkey boiler uptakes crack at the root of flanged connexion to the furnace crown plate through panting owing to expansion, and should be repaired by cutting out the old flange and fitting a flanged collar piece in two parts, thus connecting the uptake to the crown plate. Should the uptake corrode or bulge at water line, it should be renewed. Riveted patches in such a place will not stand, and to fit a girder round it is simply a "Charm."

TUBE PLATES.—Tube plate defects are, fortunately, more rare at the present time than they were some years ago; all the same, they occasionally exist in two forms, viz., cracked tube plates and leaky tube plates. As in almost all other cases of boiler defects, accumulation of scale is the principal cause in each case.

When a tube plate cracks in the nest of tubes, it is essential that the plate should be cut through, and a piece dove-tailed in and clenched over on each side; the tube holes should then be filed out, and two new tubes (stay tubes for preference) fitted. The crack should not be "lock studded," as such a

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repair will not stand, nor should a spectacle plate be fitted on the fire side. Leaky tube plates are easily made good by first scaling them inside, then by driving the tubes through from the outside and re-expanding, care being taken that the expander rollers extend through the tube plate $\frac{1}{8}$ in. on each side. Afterwards, the tube ends in the combustion chamber should be hammered over, as this method is much better than beading over.

It is sometimes found in cases which are met with where withdrawable furnaces are fitted, and where the furnace is connected to the tube plate on the water side, that the tube plate cracks from the rivet hole to the edge of the plate, the defect being caused through the fire impinging on the seam. In such a case, the rivets should be bored out, the holes re-bored and re-countersunk, and the seam re-riveted. After this has been done the tube plate should have the seam edge bevelled with a $\frac{3}{8}$ in. bevel; by so doing, the edge of the seam will not become overheated and not crack further. A very bad case of cracking of the seam in question came before my notice several years ago, where repairs similar to those above recommended were carried out with most satisfactory results. The vessel is engaged in the Atlantic trade, and the superintendent engineer informed me that the seam has given no further trouble, and has not been touched since.

It is often said that leaky tubes are caused through tube plates buckling, and this view is held by many who should know better. It should be recognized that tube plates are abnormally strong to resist buckling, and are in all cases more rigidly stayed than the other parts of the boiler, and while we do not give the plain tube credit as a stay, and rightly so, it is practically one. A tube plate not only has to stand the internal pressure, but it has to stand a crushing strain, due to the pressure on the combustion chamber top, and for these reasons tube plates are at the present time from $\frac{3}{4}$ in. to $\frac{15}{16}$ in. thick. The stay tubes are usually spaced about 9 in. apart, and if the area of the tubes in this space is taken off, it will be seen that very little space is left for the pressure to act upon. Personally, I have never seen a buckled tube plate except in cases where the combustion chamber top has collapsed through shortness of water.

Ten years ago, owing in the first place to a difference of opinion respecting a leaky tube plate $\frac{7}{8}$ in. thick, having every alternative tube a stay tube, I had an experiment made to ascertain the weight required to draw a $3\frac{1}{4}$ in. plain tube out of a $\frac{7}{8}$ in. tube plate similar to the one in question. The experiment was as follows: a plain tube $3\frac{1}{4}$ in. diameter, No. 8 gauge, was fitted into a $\frac{7}{8}$ in. steel plate and expanded in the usual way, the roller of the expander being $\frac{1}{8}$ in. longer than the plate thickness on each side. The tube was then hammered over, as in the combustion chamber. The other end of the tube was screwed into another $\frac{7}{8}$ in. plate, and a blank flange screwed to it by means of bolts and nuts. Inside the tube was placed an iron bolt 3 in. diameter, which rested on the blank flange and extended through the tube for about 3 in. When this was done, it was placed upon a block, the weight resting upon the upper plate into which the tube was expanded. A $7\frac{1}{4}$ in. diameter hydraulic jack was then placed on top of the bolt and secured to the hydraulic flanger. The vertical ram of the flanger was then secured so that it could not move either up or down, and the pressure was put on the jack in the usual way with a hydraulic pump to which was connected a pressure gauge. The pressure was then raised, and it was found that the tube was forced through the plate at 662 lb. per square inch. The area of the jack $7\frac{1}{4}$ in. diameter is 41·28 inches, which when multiplied by 662 lbs. gives 27,327 lbs. To this was added the weight of the jack, 448 lbs., giving a total direct load of 12·4 tons. This completely satisfied my friend that the cause of the leaky tubes in question was not the buckling of the tube plates, but rather accumulation of scale on the water side of them.

There is another point respecting tubes and tube plates, namely, tube stoppers. It is occasionally necessary to fit a tube stopper in a burst tube. The common way is to get two cast-iron plugs with a hole drilled through them, also a $\frac{7}{8}$ in. bolt sufficiently long to go through the tube, and to take the cast-iron plugs which are jointed at each end of the tube plate by means of a nut. From this it will be seen that the pressure comes on the nut at each end, and as the heat in the combustion chamber has a tendency to burn off the nut, the plug is always in danger of being blown out, possibly with disastrous results. The plug in the back tube plates should, therefore, be of wrought-iron or steel, the hole through same should be tapped, and the bolt screwed into it and hammered over. The bolt should have an effective diameter of not less than one inch, and should be screwed up at the front tube plate end, where a cast-iron stopper may be used. When this form of stopper is used, it will last for years, and is quite safe.

COMBUSTION CHAMBERS.—The defects generally found in combustion chambers are as follows : Leaky seams in way of the connexion of the furnace to the combustion chamber bottom, and the three-ply joints connecting the combustion chamber bottom to the side and back plates. Local corrosion of the back plate round the screw stay necks, more especially about the fire-bar level, and general corrosion in the same place. Buckling of the back plate between the stays in the line of fire, and cracking of the back plates.

Leaky seams in a combustion chamber I have found from experience are invariably caused through the seams not having been properly closed before being riveted. An engineer should know that practical engineering consists of making the component parts either round or flat. In like manner, boiler-making consists of making rough surfaces sufficiently close to withstand water and steam without the aid of a file or similar machine. The function of the rivet is not to spring two surfaces together in tension, but to hold them together without latent strain. Caulking, again, is not the principal means of tightening a seam, but rather a means to overcome any irregularities on the closed surfaces of the seam.

When a boiler is cleaned out, a boiler-maker is usually sent into the combustion chamber to touch up or re-caulk leaky seams. This he does by first of all chipping the seam so as to remove the old caulking edge. He then proceeds to re-caulk the part, oblivious of the fact that the started seam is only the effect of the cause, and that cause either started rivets or an unclosed seam. It can be safely said that more damage has been done to boilers by chipping and caulking leaky seams than most will admit, and in this connexion it should be remembered that there should be at least a distance from the edge of the seam to the rivet hole equal to the diameter of the rivet. It will thus be observed that there is practically no spare seam to caulk, much less to chip. In cases, therefore, of leaky seams, the rivets should be cut out, the seam closed, rivet holes re-bored, re-countersunk and re-riveted. The chances are that if this is done when the leak is first discovered, the difficulty will be overcome.

Local corrosion on the combustion chamber back plate around the screw stays, more especially below the furnace fire-bar line before mentioned, is caused through inattention during the first years of the boiler's life, by permitting scale to form and remain at the neck of the stay over the red oxide of iron newly formed. Here a similar chemical change takes place as in the case of corrosion along the fire-bar line before mentioned. Not only does this corrosion cause serious grooving on the combustion chamber plate, but when it exists, the stay itself corrodes under the scale, and cases are common where the back plate has corroded from $\frac{10}{16}$ to $\frac{5}{16}$ in. within an inch round the stay, and the stay itself reduced from $1\frac{1}{2}$ in. to 1 in. diameter. This defect is often repaired in a most objectionable manner by cutting out the old stay, and fitting a new stay having a jointed washer with lock-nut inside, the joint either being red lead or asbestos board. Although the usual nut is fitted on the fire side of the combustion chamber, the plate has only three or four threads connecting it to the new stay, and is consequently much weakened. The inside washer is supposed to form a watertight joint; the chances are it does not, with the result that corrosion continues to go on where it cannot be seen, and the so-called repair is a continual source of danger.

The best way in which to repair this defect is to bore out the old stay and fit a 5 in. washer $\frac{7}{16}$ in. thick, with five countersunk headed rivets over the old stay hole, rivet and caulk, then bore through the washer and the old hole and fit a screw stay $\frac{1}{8}$ in. larger diameter than before, having the usual nut at each end. It will be seen that by this method, supposing the thickness of the back plate in way of the hole is reduced to say $\frac{5}{16}$ in., the connexion to the stay will be $\frac{12}{16}$ in., better than it was in the first case; the back plate is thus strengthened and the repair will last the life of the boiler if kept clean. Should a similar defect exist close to the flanged part of the back plate, a similar washer can be fitted, one side, however, taking the holes in the combustion chamber side plate seam.

Corrosion on the fire side of combustion chamber is caused through a slight leak, so slight that no salt is deposited; such a leak is most insidious in its action. It shows itself in the form of a bright red rust, which cakes, and when broken off reveals the fact that the plate is considerably reduced in thickness. Caulking will not heal this defect; the seam should be properly closed and re-riveted, or if in the way of a screw stay, the stay should be renewed, when, if the thread is good, the cause of the defect will be removed.

When corrosion has developed to such an extent that it is general over the lower part of the combustion chamber back plate, the only thing that can be done is to cut out the defective part, taking care that the new seam of rivets does not come in the way of the combustion chamber bottom and side plate seam. To enable this to be done, it is necessary at times to cut the old back plate, say 9 in. above the seam in question, then only the flange of the back plate, taking in the single row of stays in a vertical line on each side of the chamber, then down, and then right across the defective part; by so doing it is easy to fit the new flanged plate, which should be carefully riveted and the new screw stays fitted.

Buckling of the combustion chamber back plates is generally found in the line of the fire, and is caused through accumulation of scale. It should be remembered that a buckled plate is not of necessity weakened. Should the buckling be pronounced, the stay connexion to the plate is damaged, and instead of inserting a fresh screw stay through the centre of the buckled plate, the old screw stays should be bored out, the holes re-tapped a size larger, and the stay nut chamfered to fit the plate surface round the hole. When the stay does not go through the plate at right angles, a suitable washer should be fitted. In no case, however, should screw stays be fitted through buckled plates, as it simply makes it impossible to scale the back plates, and is therefore a source of danger.

When a combustion chamber back plate cracks, the only thing that can be done is to patch it. If, for example, a plate cracks between four stays, and their pitch is say 8 in., the repair is simple. The defective piece, along with the four screw stays, should be cut out, the new piece should be the same thickness as the old plate, and the screw stays renewed a size larger in diameter owing to the old stay hole in the boiler back plate. Never lock stud a crack in the combustion chamber back plate.

The efficient patching of boilers is one of the fine arts in boiler-making, and too much attention cannot be paid to the manner in which it is done. There are, therefore, several definite principles which should be remembered. They are as follows:

A patch should always be the same thickness as the original plate.

No piece should be cut out of a boiler leaving in a square corner, and all patches should have the corners rounded off.

Do not connect new plates to old thin ones ; rather cut out more of the thin till thick is got and make the patch larger.

No patch should be riveted with a joint of any material between the surfaces.

Three-ply joints should never be covered with a fresh patch.

All scarfs should be sufficiently long to take at least two rivets, and four in cases of double riveting.

A patch should lie close without being sprung together with bolts, and should be annealed before being riveted.

It should be remembered that as a general rule a patch can only be caulked on the one side.

All holes should be drilled fair, and countersunk. The countersink should be deep and not more than one and a half times the diameter of the rivet

It is good practice to countersink all rivet holes on each side in patching. This can be done in all cases, even in difficult places, by means of a cutter bar.

No unclosed seam can be made tight by caulking, as in such cases it simply wedges the plate in, and forms a cavity between the plates. When a seam is close and well riveted, little caulking is required.

No bolt patch should be fitted in contact with the fire, excepting in cases of emergency. In such cases it should be renewed with a riveted patch at the earliest possible moment.

It is, in my opinion, absolutely impossible to ascertain the thickness of a boiler plate by means of a hammer test, unless it is reduced to the thickness of paper. When there is any suspicion that a plate is thin, drill a $\frac{5}{8}$ in. tapping hole. Should the plate be right it is easily plugged.

STAYS.—Screw stays, generally speaking, give more trouble than any other part of the boiler except furnaces, through corrosion inside, leakage in the combustion chamber, through the stay nuts being burnt off, and through breakage of stays.

The question of corrosion has been dealt with under the heading of combustion chamber plates, and the only possible repair after they have become too small, is to renew them a size larger, which necessitates re-tapping of the old holes.

Leakage from screw stays in combustion chamber is due to one of two causes, accumulation of scale, or defective screwing. It is common when a screw stay leaks to simply take the nut off, caulk round the stay, fit a fresh washer, and joint and refit the stay nut. This is called by boilermakers "making up the stay." When this is done, the stay necks should be scaled. This method of repair is not satisfactory, and is seldom a cure. It should be recognized that when once a screw stay leaks, the connexion between the stay and the plate is imperfect, and no amount of caulking will do other than make a temporary repair. The proper cure, therefore, is to renew the stay.

The second cause of leakage from stays, defective screwing of the stay and plate, is one which boilermakers will never admit, yet if one will only take notice when a screw stay is being fitted, say into a combustion chamber back plate, he will see that the stay goes very easily through the back plate until it enters the combustion chamber plate, then it usually requires a long wrench to force it home. The reason is that the tap and the screw stay are not the same pitch. For example, a tap is carefully screw cut in a good lathe ten threads per inch, and suppose when ready for tempering is perfect, viz., that in a length of 12 in. there are exactly 120 threads, neither more nor less. It will be subsequently found after tempering that the tap has altered slightly, either lengthened or shortened. Now take a screw stay made ten threads in an ordinary screwing machine ; when finished, upon measurement it will be found to vary, having from $119\frac{1}{2}$ to $120\frac{1}{2}$ threads in the 12 in., consequently when such a stay is fitted into the boiler it goes through the first hole slack, while in the second it is tight, with the result that the screwing of the second hole, which is usually that one in the combustion chamber and the thinnest plate, may be damaged and possibly leak. The remedy is, therefore, to have good true taps, and screw stays made by a machine with a leading screw giving a speed of rest equal to the pitch of the thread required. The dies have then only to perform their true function, viz., to cut the thread, and not to drag along the rest, which in such a case has to be overcome by the die when cutting the thread.

Screw stays are found usually to break at the top or bottom row on the combustion chamber sides next to the shell. There are two theories as to the cause, the first being as follows: A cylindrical boiler shell with internal pressure is in a state of equilibrium, the pressure and resistance being uniformly distributed, but in way of the combustion chamber sides; this equilibrium is disturbed by the sides of the chamber being stayed to the shell. The effect of this is to neutralize the internal pressure at each side. The internal pressure acting outwards at the top and bottom of the shell has the tendency for the stayed parts at this point to be drawn in, so that the shell will assume an elliptical form, the only resistance to this being the rigidity of the combustion chamber sides. It is, of course, more pronounced in the case of a double ended boiler, whereas in a single ended boiler the back end plate gives considerable rigidity to the parts of the shell in question. The effect of this tendency of the shell to assume an elliptical form is to throw a wracking strain on the screw stays between the combustion chamber sides and the shell, consequently they often break.

The second theory on this subject is that boiler shells are more or less round; they should be quite so. For about $\frac{2}{3}$ of the circumference, the combustion chambers are rigidly stayed to them, so when the screw stays break at the positions in question, it would appear to be due to the natural action of the pressure to make the shell round. When the stays are found broken, the new stays should be fitted larger in diameter. When this has been done, I have rarely found them give way again, from which it would appear that the latent strain in the shell had been relieved when the stay first gave way. A broken stay can always be found in a boiler by means of a hammer. If the stay ends are struck in the combustion chamber, they give a certain musical note; likewise, if the plate between the stays is struck, a different note is given. Should the two notes be practically alike, the stay is broken next to the shell, and by going inside, it will be found that a knife may be inserted between the two. I have never found this test to fail, even when stays have been broken during a hydraulic test, and before the water has been run out.

Burnt screw stay nuts in the combustion chambers are due to two causes: the first being welded nuts, and the second the chambers being too narrow. They are usually repaired by rescrewing the stay end with a solid die, and fitting a new nut. This is an unsatisfactory method, for the new nut usually lasts but for a short time. The best method, therefore, is to renew the stays and fit a solid nut, not a welded one.

Longitudinal stays usually corrode next the top front plate, and never in way of the back top plate. It would appear to be due to the air space between the uptake and the front top plate being choked with dirt, causing the heat from the uptake to be carried through the stay ends into the boiler; the stays being subjected to continual wetting and drying, the corrosion takes place.

To overcome this defect, it is a good thing to cover the front end plate with the usual boiler clothing; or, if left clear, to remove the dirt which consists of soot, coal dust, etc., occasionally.

Should the stays become much reduced in diameter, they should be renewed. When this cannot be done by fitting them in one piece, they should be cut in two, and joined inside by means of a nut $2\frac{1}{2}$ times the diameter of the stay. This makes a much better job than by connecting them together by means of a palm, with bolts through them of the same sectional area as the stay.

Boiler Accidents.—There are three causes of what might be called boiler accidents, viz., "firing up" without water being in the boilers, sinking with full steam up, and total collapse of combustion chamber tops, etc., owing to shortage of water. The first case is rather rare, while the other two cases take place from time to time.

Where fires have been lighted, and blow off-cocks left open, through neglect on the part of those in charge, it will be found that as the pressure was raised, the water was blown out of the boiler, and the furnaces and combustion chambers become overheated, possibly to redness. In such a case, after the boiler has been permitted to cool down slowly, the furnaces and combustion chambers should be cleaned out, and the boiler carefully examined. The safety valves and boiler mountings should be overhauled, and blank flanged. The main steam pipes should be annealed and tested, and the boiler tested by hydraulic pressure to double the working pressure, when any defect will be revealed. The chances are that the caulking in the combustion chambers may be started, the screw stays may leak, and the tubes may leak in the back tube plates. Should such be the case, the rivets should be renewed in way of the started caulking, the leaky screw stays renewed, and the tubes driven in and re-expanded. In the event of any of the stay tubes leaking, they should be renewed. No further damage is likely to be found.

When a vessel sinks with full steam on, it is often stated in the newspapers that the "boilers burst." I need scarcely state that this is not the case, such an idea only exists in the minds of people who know no better.

When a boiler has been subjected to such a sinking, it should be cleaned out both inside and outside, and carefully examined. The chances are that it will have sustained no damage. Should there, however, be any suspicion of anything being wrong, the boiler should be tested by hydraulic pressure to $1\frac{1}{2}$ times the working pressure, when if any defect be revealed, it should at once be made good.

In cases of collapse occasioned through shortness of water, the amount of damage done varies. Sometimes the combustion chamber tops only are buckled. This defect can be made good by simply renewing the combustion chamber screw stays through the girder. When the top flanges of the back tube plate and the combustion chamber back plate are set down, the girders with their stays should be removed, the combustion chamber top plate should be cut out, and the flanges heated and set back. When this is done, a new combustion chamber top should be fitted, the girders refitted and the girder stays renewed. When collapse greater than the above two cases takes place, it is often necessary to renew the internal parts of the boiler altogether. In cases of collapse no hard and fast rule can be laid down, as so much depends on the nature of the damage sustained.

In conclusion, I do not profess to have treated all the defects incidental to boilers. At the same time the examples given are a fair sample of what are to be found generally. Should the principles of repair here given be acted upon, it will be found that whatever may be the nature of the defect, with a little common sense it can be overcome to a very large extent.

DISCUSSION

CHAIRMAN : I think you will all agree that this is a very able paper. It is on a subject with which we are all well acquainted, and one which will no doubt call forth a lively discussion. Mr. Innes will, I am sure, be pleased to answer any questions you may wish to put to him. It occurred to me while Mr. Innes was reading the paper that it was rather strange we should have a paper on boiler repairs when we have so recently had a paper on the preservation of boilers. I will now call upon some of the members to open the discussion.

Mr. H. RUCK-KEENE : It is a very interesting paper we have had from Mr. Innes, and we are very much indebted to him for the information he has given. I do not see very much in it to discuss—it is all so very clear, but there are one or two points which might be emphasized. With regard to the end plates of boilers, he has given an account of some very effective repairs. Little mention, however, has been made of the repairs of these plates by the oxy-acetylene or electric processes of welding. A number of very efficient repairs have been carried out by these processes in the last three years ; in some the plates where flanged for connection to the furnaces were cracked through or badly grooved, and these have been satisfactorily welded in place. In one particular case, where the plates had been cracked in several places for lengths of about 30 inches, I examined the repairs six months after they had been carried out, and it was almost impossible to see where they had been welded. Efficient repairs by these processes depend almost entirely on the skilfulness and experience of the operators : a good operator will effect repairs which will last well and effect a great saving in time and money, but it is useless to try either process with unskilled men. I am quite at one with Mr. Innes as regards his remarks as to caulking the seams in the combustion chambers and in other parts of a boiler. I am glad he has drawn attention to this, as in many cases it is not a repair at all ; it is an aggravation of the evil, and there is no question that the only method to adopt with a leaky seam is to take the rivets out and close up the seam thoroughly. I do not think the boilermakers are careful enough in this respect, for it is very important to see that the patch itself is fitted close, not only on the edges, but in way of the rivet holes also. I always used to make a point of not allowing a patch to be riveted up until it was seen that it fitted, otherwise I found in many cases all the way round the rivet there was a space between the rivet and the patch which could not afterwards be made tight. Mr. Innes draws attention, in regard to furnaces, to the fact that furnaces very often collapse after lying under banked fires. That is certainly a very frequent cause of the distortion of furnaces. In my opinion this is almost entirely due to the fact that when steam is on the boilers and the engines are taking away the steam, the water is circulating upwards or downwards and sweeping away the impurities contained in the water from the heating surfaces of the furnaces ; while, on the other hand, when under banked fires the circulation ceases and any sediment settles down and deposits on the furnace crown. The mischief is caused by the fact of when getting up steam again, this accumulation of sediment has been deposited on the furnaces, leading to overheating of the plating. I notice Mr. Innes comments upon the common method of fitting a tube stopper in a burst tube, and he is quite right in drawing attention to the inefficiency of the ordinary method of putting in a $\frac{7}{8}$ inch bolt with a nut and washer at each end. I have often seen the nuts burnt off ; and only an accumulation of scale or dirt in the end of the tube prevented a serious explosion. With regard to broken stays in boilers, I think Mr. Innes says that trouble is found in this respect more particularly in double-ended boilers. This has not been my experience. The greater number I have seen have been in the backplates, in the single-ended boilers. The places I have found to suffer most have been in the bottom rows in the combustion chamber backs. I might mention a case which came to my notice only to-day in which there were twenty-five screw stays in one bunch broken, and they were in the lower part combustion chamber backs. The chief point about the breaking of stays on the combustion chamber backs is that the combustion chamber plating is hotter than the shell plate, and therefore has more expansion and contraction, imparting to the screw stays alternate bending stresses, which in time often breaks them off close to the thicker back-end plate. As regards double-ended boilers, I found the top stays in the wing combustion chambers were the ones which suffered most. I found more broken there than anywhere else in the double-ended boilers. Mr. Innes draws attention to the necessity for having proper taps for the screw stays. That is a frequent source of trouble.

If the taps are not good there will always be trouble with the screw stays not being a good fit in the boiler. I think we are all much indebted to Mr. Innes for his very valuable paper.

Mr. J. T. Milton: I think, with my colleague Mr. Ruck-Keene, that we owe a great deal of gratitude to Mr. Innes for giving this paper to-night. Mr. Innes is an engineer of very great experience, and he has had exceptional experience with boilers owing to the fact that, having been Lloyd's Register surveyor in the Hull district for many years, he has had to deal with boilers in trawlers, which, as you know, are worked by men who are not skilled engineers. Recently he has been engaged at Hartlepool, and he has come all the way from Hartlepool to read this paper to us to-night. The paper is full of information, and, as one expects from a gentleman with the great experience of Mr. Innes, everything in the paper is based on practical experience and fact, and therefore lends itself very little to criticism. There is one point he has omitted, I think, with regard to the repairing of furnaces. He speaks of where you have not got withdrawable furnaces as though they are almost bound to be made so that they can be telescoped in, But there is another method of making them repairable where this is not necessary. They modify the backs, using the oxy-acetylene system of welding for jointing up the pieces at the back end, and that makes a good job. I think the paper emphasizes a point that Mr. Ruck-Keene impressed upon us in his paper, that the proper way to prevent the necessity of repairs is to keep the boilers clean. Over and over again Mr. Innes, perhaps not always directly, has pointed out that dirt is the cause of this, that and the other defect. Dirt causes the end plates to corrode. Dirt on the inside causes buckling. Dirt is part of the cause, if not all of the cause, of the defects mentioned in connection with the combustion chamber stays in single-ended boilers. I think it is noticed more in single-ended boilers because there are more of them in use. It is most pronounced at the bottom of the centre chamber owing to the greater height of the back plate of this chamber; the plate expands more than the shell plating, simply because it is allowed to get overheated through getting dirty. In regard to the furnace cracks on the front-end plates you will notice Mr. Innes says he has found this defect principally in Brown's, Holmes', Adamson joint and plain furnaces. It occurs where there is a straight length and no great elasticity. The furnace bulges the end plate out when getting up steam and then afterwards contracts. The change of form is due to the temperature, and that is accentuated when the furnace is dirty. I think the plain furnace, if kept clean, will not crack the end plate. The question of taps is mentioned in connection with screw stays. I would not put it down to the taps being incorrect. I have always thought the reason has been that the screwing machine was at fault in making the stays with a wrong pitch. I understand that at least one of the large firms in Scotland, finding the screwing machines slightly in error in pitch, have the threads cut in a lathe with a leading screw that cannot go wrong. I fancy the fault is in the screwing machine more than in the taps. The point remains that the screws ought to be fitted well in both plates. It would be better to screw in from the combustion chamber side, but that does not seem to be quite possible ; but as a matter of fact they go in from the back and in that part the stays are well fitted in. There is a little point here in reference to welded nuts instead of solid nuts. It is well worthy of attention that all nuts exposed to the fire should be solid and not welded ; yet nine out of ten are welded.

I think we owe Mr. Innes a very great deal of gratitude for coming here to-night at such inconvenience. The audience to-night is not numerous, but the gentlemen who are here are skilled engineers who will attach a good deal of importance to his paper and appreciate its value. One other thing it is well to remember is that our papers go all over the world, and although we may at times not get a good attendance at Stratford we get an extended audience wherever the British flag floats. The paper will be printed and sent round everywhere, and a paper like this ought to pass from man to man and from ship to ship. It may interest you to know that already application has been made from one of the engineering firms for a large number of copies to supply to all the engineers in their ships.

Mr. W. Walker : Like the previous speakers I would like to thank Mr. Innes for his excellent paper. It contains a great deal of valuable information, and I would like to touch upon two or three points in it, which he might have made more clear. On the whole the paper is well worthy of the consideration of every engineer. In the beginning of the paper Mr. Innes tell us that "feed heaters heat the water to boiling point, and filters are so fitted that in a natural way they keep out all oil and other foreign matter." My experience with filters is that they do not keep out all the oil. If any one can introduce a filter which will keep out all oil he will make his fortune. In land practice it is found that filters are not adequate, and in addition thereto softening plants are used. The water and oil become emulsified, and when in this condition defy filtration. The oil, shown by the milky appearance of the water, is set free by adding alumina ferric, after which treatment filtration is usually satisfactory. I should like to draw attention to the badly-fitting manhole doors mentioned in the paper. Every one connected with marine engineering knows that many an explosion has occurred through this. If the manhole door or cover is a bad fit and round packing is used, the packing is sometimes blown out, and several deaths have occurred as a result. There is just one point that might have been referred to with regard to cracking in the front-end plate. I do not know whether it has come under Mr. Innes' notice or not. It has cropped up in land boilers both in the Lancashire and water tube types, where the end plate is flanged and hydraulic riveted. Is it not possible that in bringing the flange together to suit the furnace or shell as the case may be the true radius in the root of the flange is spoilt? It is quite possible that the two laps are not parallel; therefore they are forced together and an incipient crack is formed which develops as time goes on. That was pointed out in connection with an explosion which occurred recently. Attention was called to the oxy-acetylene system of welding. I have seen two or three cases recently —not exactly on the line of fire-bars—where oxy-acetylene welding was used very satisfactorily indeed. Tests (tension excepted) have been put upon it and it has been found to be quite as good as the original plate. The only difficulty, as Mr. Ruck-Keene pointed out, is the human element. If you have not a good operator the iron or steel will be oxidized and it will not be a sound weld; but that can be tested before the job is put into use. I thank Mr. Innes for his paper, because the information he has given is certainly of the greatest importance to engineers both ashore and afloat.

Mr. Innes: I thank you, gentlemen, for the very kind manner you have received my paper this evening.

With regard to Mr. Ruck-Keene's remarks on the breaking of screw stays in single-ended boiler back plates, I must say I have had but few cases where a large number have broken, although many cases in which several have given way. I have, however, invariably found them broken in double-ended boilers next the shell on the top and bottom row on the combustion chamber side. When I have found broken stays in the back plates of single-ended boilers, the reason of their breakage always appeared to me obscure.

Mr. Milton has given me little to reply to, excepting the question of taps. Taps are not always as they should be, and I well remember one influential firm spending a considerable time in experimenting, until they got taps which did their work properly, while little or no trouble was experienced with the stays as the screwing machine rest was worked with a leading screw of the same pitch as the thread required.

I quite agree with the remarks of Mr. Walker relative to manhole doors. It will be noticed that I specially mentioned the matter in my paper. At the present time, manhole doors are more carefully made and fitted than ever before, and if ordinary care is exercised, give no trouble. With reference to the cracking of the front-end plate, when flanged outwards, to take the furnace, for the purpose of hydraulic riveting, I have never had an instance of cracking at the roof of the flange, similar to those mentioned in my paper, viz. :—when the front was flanged inwards and hand riveted. I have, however, had cases where the end plate flanged as Mr. Walker states has cracked between the rivet holes on the upper side, and have repaired the front by cutting out the defective part and carefully fitting a patch. This defect seems to have been caused through the protecting bricks in the furnace front being allowed to get into a bad state, thus causing the flanged seam to become overheated, thereby bringing a strain on the rivets which slackened them, then by continual re-riveting the unclose seam, the cracks between the rivets were formed.

It was agreed on the motion of Mr. F. M. Timpson, seconded by Mr. Milton, that the discussion be adjourned to Monday, February 27.

The meeting closed with a hearty vote of thanks to Mr.

Innes, proposed by Mr. P. S. Doherty and seconded by Mr. R. H. Dalton.

ADJOURNED DISCUSSION.

Monday, February 27, 1911.

CHAIRMAN: MR. A. ROBERTSON (MEMBER).

CHAIRMAN: The discussion this evening is on Mr. Innes' paper entitled "Marine Boiler Repairs." I understand Mr. Innes cannot possibly be with us to-night. We will therefore proceed immediately with the discussion, and I hope members will not lose any time so that the meeting may be concluded at an early hour.

Mr. H. RUCK-KEENE: Now we have had time to go through the paper more carefully, I am sure we have all found it very interesting and instructive; there are one or two points that I should like to refer to. Mr. Innes says in his paper with regard to boiler front-end plates, that the great trouble in the upper part is due to the heat of the fires coming up the uptake and the moisture inside causing continual wetting and drying of the plates. That is quite true. Corrosion is undoubtedly due to external heating and wetting from the steam on the inside, so much so that in Lloyd's Rules allowance is made for this so far as the upper front-end plate of the boiler is concerned, by requiring the front-end plates to be made thicker if a proper baffle plate is not fitted between the uptake and the boiler front so as to prevent the heat of the flame coming into contact with the end plates. The great corrosion in the shell plates of donkey boilers is also almost entirely due to external heating and internal dampness. Mr. Innes' remarks about manhole doors in the front-end plate. Nowadays a good many repairs are carried out very successfully in the way of the bottom manhole doors with the oxy-acetylene and also the electric process by adding on material to the plate corroded. The author does not say much about these processes of welding, and I understand there are gentlemen here to-night who will be able to give us some information on the subject as they are very closely in touch with it. Corrosion in the way of the feed check valve was mentioned. That is due almost entirely to the amount of air passing through the feed check valve; and in all cases I have come across, I have found this to be due to the ordinary feed pumps working off the main engines, by which undoubtedly a large quantity of air is pumped into the boiler along with the feed water; and if the joint of the internal feed pipe be leaking, active corrosion will take place at this part due to the action of the air in the feed water. With regard to furnaces, all marine engineers are agreed that the furnace is the part of the boiler which most frequently requires repairs. All kinds of defects are developed in the furnaces—corrosion, pitting, collapsing, distortion, cracking and other troubles. Cracks in a furnace are due, I think, to a large extent, to a local accumulation of scale. The plate under this scale becomes overheated, and when the scale cracks the water comes in contact with the overheated portion of the plate causing it to crack. A good many repairs have been carried out by the oxy-acetylene and electric systems of welding with successful results, and I would advocate the use of these systems in repairing small cracks. These processes, however, do set up a certain amount of straining in the plate, due to the expansion of the plate when locally heated and subsequent contraction. Near the edge of the plate, where the plate is free to expand and move, it is easy to deal with such repairs, provided the rivets in way of same be first cut out; but in the centre of the plate it is very much more difficult to effect repairs by these processes, and very great care is necessary. Mr. Innes mentions some methods of fitting new furnaces in boilers. It is a wonder that shipowners do not insist upon all furnaces being made withdrawable. The withdrawable furnace is easily fitted and easily renewed; but it is difficult to put a withdrawable furnace in a boiler which was not originally designed for it. This has been done, however, in several cases. The first case I saw was in Antwerp in 1901, when Mr. Fred Edwards schemed out a very good method by which new saddle plates were fitted in an old boiler in such a manner that new withdrawable furnaces with a Gourlay back end were fitted in. To fit such a saddle plate in place in an old boiler involves cutting away a portion of the lower part of the back tube plate, to allow sufficient space on the new saddle plate for the attachment of the back flange of the withdrawable furnace, and as this saddle plate must be in the form of a ring with flanged edges to connect to the combustion chamber side and bottom plating, it is necessary to cut out a portion, say about 12 inches in length, of its lower part in order to get it into place, the part cut out being at the bottom of the furnace. The new piece which has to be fitted has its joints out of contact with the heat of the fire. This piece may be either joggled and riveted, or welded in place by the oxy-acetylene or electric processes of welding.

It must, however, be remembered that with a Gourlay back end the flange of the furnace will in places be considerably farther away from the stay tubes or longitudinal stays, if the latter be fitted, in the tube plates than in the original non-withdrawable furnaces, and the new saddle plates must either be made sufficiently thick to withstand this additional area of unsupported plate or additional stays should be fitted to sufficiently strengthen this unsupported flat surface.

This method of repair has since often been carried out, and I am surprised it has not been done more often.

There is another method not employed in this country, but which has been carried out in France by skilled oxy-acetylene operators, which is as follows :—The old furnace having been cut out, a new saddle plate of the same form as the original one, but in three pieces, is fitted, and then the seams are welded up by the oxy-acetylene process so as to form one new saddle plate welded in three different places. That has been done in at least two cases I know of. When speaking of the oxy-acetylene and electric systems of welding, it should be remembered that although they are very excellent processes if well done, the human element enters very largely in their application. Unless there is a good operator, the metal may be oxidized or burnt, and you may have more trouble with the repair than when you started. It depends almost entirely upon the operator. Under Lloyd's supervision over 300 boilers have been repaired in the last four years, with very successful results, and on investigating those few cases where there have been failures, it has been found that they were due in almost every case to the operator not being sufficiently skilful or careful. With regard to the question of studding, studding is excellent for a temporary repair, but if the Board of Trade reports on boiler explosions are consulted it will be found that, generally, studding is not safe to last a long time. For a very small length of crack it may be quite good, but it should not be left as a permanent repair. There was a recent case reported where a man was very badly scalded through the chain studding being blown out. One other point Mr. Innes drew attention to was the back of the combustion chamber plates. He says that buckling of the combustion chamber back plates is generally found in the line of the fire, and is caused through accumulation of scale. I do not think any of us doubt that for a minute. Screwed stays should never be put in the buckled part. Where there is an accumulation of scale, if screwed stays are put through the buckled part it only adds to the difficulty of cleaning the back of the plate, and if you make that more difficult the accumulation increases, making matters worse. It may be adopted as a temporary repair, but not as a permanent one. The stays may be renewed with stays of a larger size, but additional screw stays should never be put in where there is buckling, or such a course will only aggravate the cause of the buckling.

Mr. Robt. Balfour: In addition to dealing with repairs to marine boilers, the author has given us his views as to the probable causes necessitating such repairs, thus offering a wider field for discussion. With regard to boiler shells, in cases where boilers were constructed of two rings or strakes, the centre circumferential seam or bottom used to give much trouble through leakage or grooving and cracking. This necessitated fitting a covering joggled patch, or cutting out and renewing the defective part—not an easy matter with the limited space for riveting. The cause of this trouble, in my opinion, was due to fatigue aggravated by expansion and contraction, and the seatings, usually only two in number, being fitted too far apart. Had a third seating been fitted under the outer ring close to the landing no trouble would have been experienced. Therefore the importance of boiler seatings cannot be overestimated. In one case which came under my notice, where the lower longitudinal D. B. seams were leaking, the packing pieces between the seating and shell had come out, leaving the boiler resting upon the four points of the seatings, which set up heavy local stresses at the leaky seams. After part re-riveting and fitting iron packing pieces no further trouble was experienced.

End seams at bottom have also given trouble through leakage. This is sometimes caused by the collision chocks being fitted too tight when the boilers are cold and not allowing for expansion, especially in the case of double-ended boilers. The author's remarks regarding mountings are very important and require much attention. With regard to the grooving and cracking of the furnace front plate flange, to which the furnace is riveted at the top part, this, in most cases, I think, will be found where rigid furnaces of ribbed or plain types are fitted. The defect generally starts from the water side and may extend circumferentially at the bend of the flange as much as 36 inches and can be cracked through the plate. The repairs suggested by Mr. Innes are generally adopted, but in two vessels which came under my notice, four and two and a half years respectively, the methods employed were as follows. In the first, the parts of the plates containing the crack were cut out and new pieces fitted, taking in the tube plate and furnace crown rivets, and butted and strapped at the ends. In the second, the cracks were cut out and welded up by the oxy-acetylene process. The boilers in both cases worked at 200 lb. steam working pressure per square inch. It has been my privilege to examine these boilers on more than one occasion since the repairs were made, and I am pleased to say they have proved satisfactory. I may mention that, before satisfying myself regarding the oxy-acetylene repair, one of the pieces which was cut out in the first vessel being available, the crack in this plate was cut out and welded up by the same operator. Afterwards strips were cut off and fatigue tests made with very satisfactory results. When effecting such repairs some of the lower tubes must be removed to give plenty of room, also to enable the operators inside and outside to communicate and to pass rivets, etc. When the bottom part of the furnace front plates are badly corroded, necessitating the renewal of same, the practice is to cut the plate at sides and between the furnaces at places sufficient to admit of the fitting and riveting of the internal butt straps to the new and old plates. In some cases lap joints have been adopted. This necessitates springing the shell and furnace plating apart to admit the thinned edges of the new plates. In either case it is a difficult job, particularly where three furnaces are fitted. As Mr. Ruck-Keene pointed out, the corrosion in the top end plate is due to the impinging of the flame on the uptake end. This is not to be found at the after end, and it is entirely due to the difference of temperature.

As to the cause of corrosion of furnaces along the line of the fire-bar, I consider this is due to the freeing of the air from under the water and the difference in temperature at this level, when rapid ebullition takes place, which may be called the dead and alive water line. This action will be found especially in vessels where the ordinary ram feed pump is fitted, and if the air cock or feed heater is not frequently used the corrosion will be found not only along the line of fire-bar but on the active heating surfaces generally. Therefore, in my opinion, it is a question of treatment and should be arrested in time, otherwise it means renewal of furnaces. The distortion of furnaces, I think, is often due to bad circulation, limited power, forcing fires and inferior coal; in short, trying to make a donkey do a horse's work. As to the jacking up of furnaces, I quite agree with Mr. Innes' suggestions. When new furnaces have to be fitted, the ridges on the old landing caused by previous caulking should be removed and the heel of the back flanges of the furnaces should abut the landing before the outer edge; especially with the bottle-necked type, as it is easier to close the outer edge than the heel of the flange. As Mr. Ruck-Keene remarked, the use of withdrawable furnaces should be adopted more extensively. With regard to cracks in furnaces, I prefer either the oxy-acetylene or electro-thermic systems of welding to lock studding; the latter has served well on many occasions; still, after all, it is a make-shift. Local bulging of furnaces is best dealt with by drilling a hole in the centre to admit of gathering up the plate and afterwards welding up the hole, which will be considerably smaller after the setting up of the bulged part. In the donkey boiler the trouble with the bottom vertical seams below the fire-bar line is not in my opinion due to faulty workmanship, but to the fire-grate being fitted too low, which does not allow any room at the bottom of the water space for deposit. I have had several fire-grates in such boilers raised to meet this difficulty. The position of the fire-door is also often too low, which limits the height of grate.

As Mr. Innes says: "Tube plate defects are, fortunately, more rare at the present time than they were some years ago," consequently I shall merely refer to a repair which came under my notice about a year ago. Two tube plates were badly wasted at the attachment of the furnace crowns. The lower part of each plate was cut across between the bottom row of tubes and landings, also at points below the level of the fire bridges, and new plates were fitted and welded to the old tube plates by the oxy-acetylene system. Test holes were drilled through the welded parts, when it was found that the material appeared to be quite homogeneous. Other two-tube plates were similarly treated in another vessel about the same time and have proved satisfactory. In the combustion chambers, where plates are badly buckled, as is sometimes the case with the back plates, it is best to cut the part out and fit a new plate. Should it be necessary to fit the plate in two pieces, one should be kept larger than the other. This not only keeps the vertical seams to one side of the line of fire, but admits of access to the larger part for riveting, etc., and if a hand hole be at the back end the smaller plate can be got at for holding up the rivets. In fitting new plates care should be taken to see that the heel of the flanges is home to the wrapper plate before the edge. As to patches requiring to be of the same thickness as the original plate, I think that depends a great deal upon the position and size of the patch. I believe in light patches where admissable, close pitched rivets, good counter-sunk holes, and plenty of metal on points of rivets. In fitting stay tubes continuous taps are indispensable, and they should be checked with the pitch of threads of the tubes. All stay nuts should be chamfered on the side next the plate.

Mr. F. M. Timpson: There is one point in the paper I would like to comment upon, and that is the subject of the author's opening remarks. I think Mr. Innes gives a rather unfair reference to most marine engineers as regards the care of boilers, for I believe it is generally acknowledged that there are no boilers looked after with such care as marine boilers. Nowadays the boilers do not suffer from bad workmanship to the same extent as in the old types, when it was constantly the case for the engineers to be working in the back ends, etc. Of course Mr. Innes comes from a district where a great many of the boilers are in the charge of "drivers," or unskilled men, with results that he may have cause to remark on; but as regards the large mail lines and sea-going vessels generally, the boilers are well looked after. With regard to blow down cocks on donkey boilers and accumulation of deposit, I heard of a case recently in a land boiler in which there was a large collection of sludge, and the blow down only made a small hole through the deposit until the accumulation became dangerous. They fitted a perforated internal pipe from the blow down cock to the back of the boiler, and which kept this cleared by regular blowing down. If such a pipe were fitted in a donkey boiler it would have the effect of clearing away deposits. On one occasion I found a donkey boiler filled with mud up to the top mud-hole doors. Marine boilers are almost invariably kept in very good condition, and I did not think we should allow this reflection upon our cloth to pass without a word of protest as far as certificated engineers are concerned.

Mr. A. JOBLING: In the author's opinion the buckling of combustion chamber backs is due to scale, but I do not think it is quite all due to that cause. In some ships I have been in the predominant feature has been the amount of scale, and yet the backs have not buckled; while in others, with practically clean boilers, the backs have buckled. Is it not possible that it is due to bad circulation, as there would be a severe impingement on the surface of the plate due to the excessive temperature at that particular spot.

Mr. S. J. ROSS: In reading through this valuable paper by Mr. Innes, I find he does not say much about circulation. In my opinion a good many of the troubles he mentions arise more or less from bad circulation of the water. Take for instance the stay nuts. If there is good circulation it is my experience that these nuts do not burn away, but where there is a lack of circulation they cause a good deal of trouble. Coming down this evening with a gentleman who is a visitor here, and who has carefully studied the effects of circulation, we were speaking on the subject, and he likened circulation to a man chasing a rat round a room. All the time he chases the rat it does no damage. The corrosion in the boiler is the rat. If you let it rest it will do damage, but if you keep chasing it round by circulation it will do no damage. Reference has been made to the use of zinc plates. I have in my mind at present a 13,000 ton steamer with 36 furnaces. She has been running for about two years now, and has never had a zinc plate in the boilers, but they have taken steps to ensure that there is a good circulation of water in the boilers.

Mr. H. SCHOFIELD: With reference to the corrosion in the line of fire-bars, we all know that it is absolutely impossible, because it is against a law of Nature, for hot water to go down into the cold. It is also impossible for cold water to go into hot without being assisted. Therefore you must have a line of demarcation, as Mr. Balfour stated with reference to the line of fire-bars. If you have perfect circulation that cannot take place. It is just the same in the illustration of the rat, referred to by Mr. Ross. If you leave it alone it will make a hole. If you leave the air just at that line of your fire-bar where there is no commotion taking place, immediately the steam bubble or the water becomes heated it rises of its own free will, and the water flows in to take its place simply because water will take the path of least resistance. It is along that line therefore that you get a deposit of carbonates and sulphates adhering to the plate. That, of course, is proved by Mr. Innes in his remarks with reference to the end plates where he says : " This defect is due to radiation of heat from the uptake caused through the baffle plate being non-effective, either to its being closed in all round, or through the air space being choked up with dirt. In short, the end plate being locally heated to a higher temperature than the rest of the plate." If you take the furnace you will find on the top side of the fire-bars a temperature of something like 2,200° F. ; underneath the furnace it is something like 450° to 500°. There is a great difference of temperature there, and probably there is some kind of force going on—we will term it local electricity—the same as is obtained with the operation of two currents of air bringing about thunder and lightning. So that the line of fire-bars is a point of weakness which can only be overcome by perfect circulation taking place there. With reference to the back ends of boilers, the same thing applies. For instance, it is quite possible, as we all know, to put water in a paper bag and heat it with a blow lamp without burning the paper, because the water takes the heat away rapidly. But with reference to the back water space, if there are globules of steam hanging round, this being a bad conductor of heat, bulging will take place. As we have heard, in some cases it is due to scale, but more often than not it is due to bad circulation.

Mr. T. R. Stuart : I cannot agree with the last speaker that corrosion is due to any large extent to bad circulation. He explained how the temperature rises to 2,000 degrees to the line of the fire-bars, and that is the place where the water most figures. If it is the case that want of circulation is the cause of corrosion, the small amount of air introduced into the boiler with the feed water would very soon leave the water, and, if not steam, water would get to it and prevent the air reaching it. The corrosion takes place in ships not fitted with feed water heaters; and if feed heaters were more often fitted, we should not need another paper on boiler repairs because there would not be so many repairs required. I have sailed in many ships fitted with feed heaters, and in one not so fitted, where the effect of air getting into the boilers was very marked. Internal feed pipes in some cases give trouble through a leak between the pipe flange and the check valve. The check is often in a most awkward place, and if the pipe were put on the front or the shell just where you want the internal feed pipe, it would do away with the awkward joint. In the ship with ram pumps the tubes near the check valves wasted in eighteen months, while the others will last eighteen years. In another thirteen year old steamer, not one tube has been renewed, and there is no corrosion in the boilers, which I put down wholly to the use of the feed heater. The previous vessel I referred to was a cargo ship, where there would be more circulation in the boilers than in a mail ship, and I think therefore that the pitting along the line of the fire-bars is not due to bad circulation. In connection with air getting into the boilers, Weir's heaters are very economical as regards the feed heating, and it is more easy to get rid of the air. Most of the modern ships are run with evaporators, and they work the evaporators as long as they can so as to get into port with as little loss of water as possible. In some cases, at ports of call, water is got from the shore and put into the boilers direct. In my opinion that is a very wrong practice. I think all water ought to be evaporated before being put through the boilers, and ought not to be put in from any port without going through the feed heater. If that is done, and a little more attention is paid to keeping oil out of the boiler, repairs would be almost nil. The only repairs I have seen necessary in marine boilers fitted with feed heaters were in connection with the joint between the furnace and the tube-plate. I have questioned boilermakers on the subject, but they have only shaken their heads. I have asked them what they could do with the cracks, and they have suggested taking out a dozen rivets or so. I have seen these cracks develop in a few days or a few weeks. If boiler constructors took a little trouble to avoid the cause of these cracks they would do us a service. Boilermakers do not usually know how to deal with them. If it is a question of new rivets being required, why is not sufficient provision made at the beginning? I think something might be done to prevent this trouble.

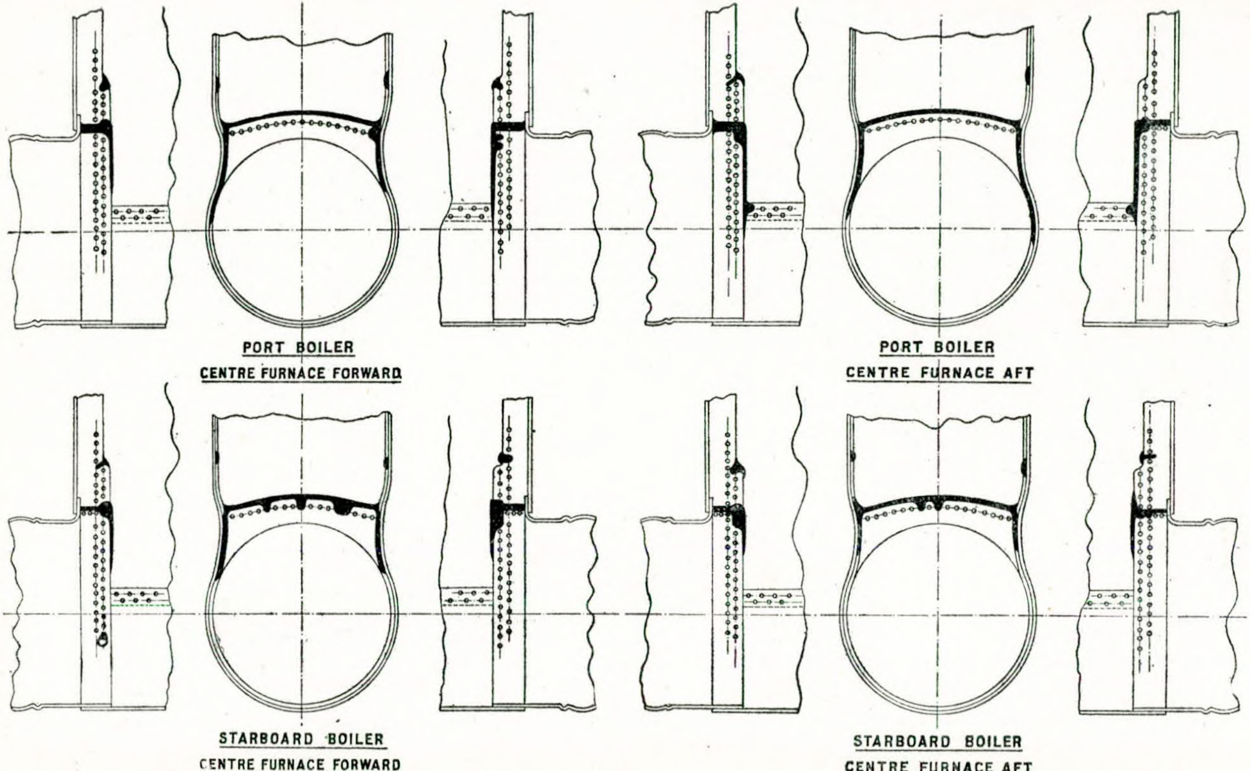
Mr. J. Thom: The writer of the paper has evidently seen a good deal of trouble in connection with boilers, hence his great experience. He has missed nothing as regards the mishaps and troubles engineers have in going to sea, especially when they have not a boilermaker on board. Of course large ships carry a boilermaker, so they have an experienced man who has some idea of how to put things right and keep an eye on weak spots; but even to-day, as the last speaker said, it is the practice occasionally to pump cold water into boilers from the shore, a most dangerous and destructive thing to do.

Boilers as they are treated to-day should only have pure distilled water; if water is taken from the shore, it should be heated up to quite a high temperature before pumping into boilers to get rid of all foreign matter and not ill use boilers. If there is such a thing as circulation in a boiler, pumping in cold water would mean this water going to the bottom of the boiler, consequently the boiler wishes to get smaller and narrower at the bottom; the tear and wear at the joints where there is riveting no doubt causes many of the leaks at the joints and riveted seams. With regard to oil in boilers I think there is no question but that anything in the shape of oil on the surface of a plate has a very bad effect. A very thin layer of the thickness of tissue paper on a furnace crown will increase the temperature so much that undoubtedly the plate will get distorted in some way. That is one reason why buckling takes place. There is no question but what the engineer takes care of his boilers. There used to be a day when it was not so necessary to pay so much attention to them, but that condition of affairs has been changed since pressures have risen. I used to have the boilers I had charge of thoroughly scraped and washed out, after which they gave no trouble unless there was any foreign material got into the boiler or it was a bad class of water. When such was the case I used to boil it out with a strong solution of soda; then do it a second time if the boiler was not quite clean. I do not know if that is done to-day or not. I think there are scarcely any ships that do not use a feed heater to preserve the boilers. The heating of the water is an important point. As for circulation, it is said the water goes up and down. I do not think the water moves in that way. The steam goes up and leaves it behind. With regard to pitting on the line of fire-bars, it is not necessary for me to enlarge on the cause ; but I think it is quite possible that this pitting can be filled up thoroughly and the plate made nearly as good as before by some of the processes now in use, especially the electric arc. Speaking from what has been done and what I have myself seen and assisted in doing, I should say it is quite possible for pitted holes to be filled up quite thoroughly and satisfactorily. If the iron is not sound, cut it away with a chisel until you get it sound, then fill in on the clean plate. You do this work on the furnace in place and patch a few places here, a few places there, and if it is done with a system that does not increase the temperature locally, when you do not see any colour in the plate, you are quite safe. If you use a process where the plate has to be heated to a sufficient temperature to show a colour, it will not be so satisfactory. In some of the processes, the electric arc, for example, the work is quite satisfactory, as it does not go beyond a bluish tinge. Speaking about the check valve, it has been placed in the same position from time immemorial. Whether it is always advisable for the feed water to be put in at this place or not only means longer or shorter internal pipes. Every man has a different idea on the subject. One says deliver at the bottom, another at the top, another in the steam space. Another says the water should be delivered near the surface because it is nearly as hot as the steam, and that it should be delivered at the far end of the boiler from check valve and therefore mixes pretty much at the same temperature as the steam after travelling so far. There are many ideas on that subject that I am sure many of those here to-night could tell us a good deal about, where the water should be delivered and how it should be manipulated before and after entering the boiler. One thing is certain : in raising steam in boilers the water should be forced to go up and down, and I do not know how you can get better results than by pumping large quantities from the top to the bottom to get the temperatures of plates and water similar.

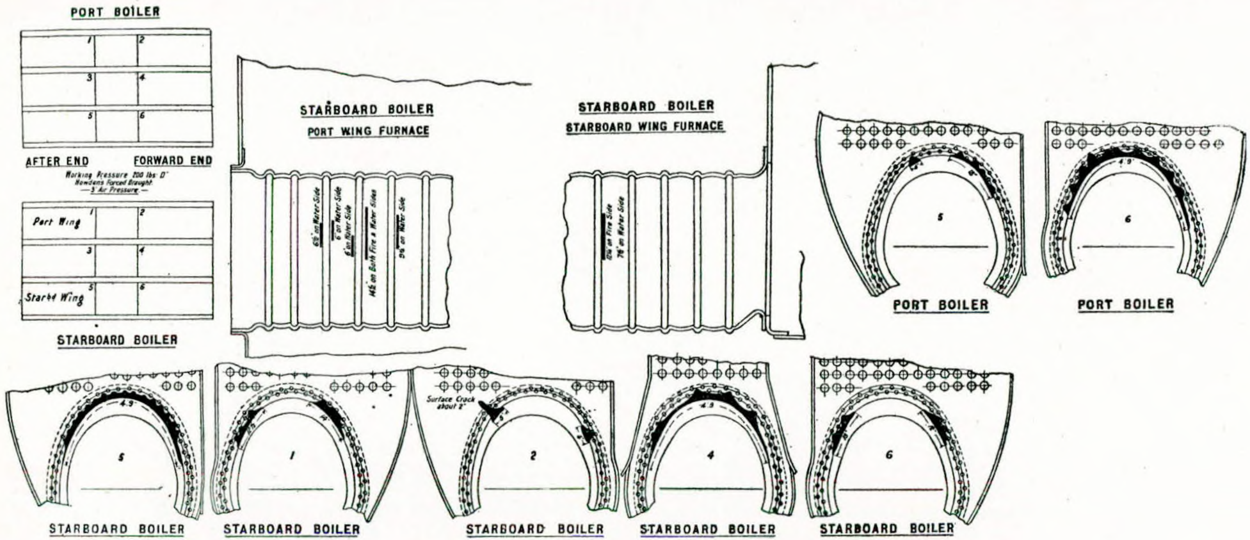
Mr. R. S. Kennedy : Several previous speakers have referred to new methods of repairing boilers by means of the oxy-acetylene and the electric systems of welding. I, personally, am interested in the carrying out of such repairs by a system of electric arc welding, and although I had not intended to speak at this meeting, it was suggested by one of the members that drawings of actual work done by this process might be of interest. I have therefore pleasure in handing round a few blue prints. It will be seen that these repairs are of a very extensive character, and besides building up of landing edges, etc., show the welding up of fractures, all being done without interference with the surrounding structure. Mr. Ruck-Keene made some most pertinent remarks as to the success of these building up processes depending largely upon the skill of the operator. Of course the great point is to get the drop from the welding pencil, at welding heat, added to the exact part of the plate, which is also at welding heat.

With the electric arc process it is only necessary to bring a portion of the plate about the size of a sixpence to welding heat, and this is done almost instantaneously so that the job is not heated to a great extent elsewhere. It would be a difficult matter to get the drop from the pencil on this exact spot if it were not assisted in its passage by the flow from the negative to the positive pole, similar to the action in the ordinary arc lamp. The great point to observe is not to expand the metal beyond the area you are trying to join together, otherwise it will suffer from subsequent contraction. I refer particularly to cracks, and of course all these processes are a building up, and even in the welding up of a crack the metal containing the flaw is cut away and the hole filled up again. These cracks are most generally found in the fire spaces and in flanging where subject to expansion and contraction.

Mr. E. W. Ross : This paper of Mr. Innes' is a most practical one ; there are many details dealt with, but even all those mentioned do not complete the whole list. As the author says, there are very few difficulties with the shell plates, although now and again one finds a broken rivet here and there. Some months ago, in speaking on a former paper, I mentioned that the time had come when the shell plates should be rolled circumferentially all in one piece, and I see by the recent engineering papers that there is a firm getting machinery ready for that class of work. I believe eventually that form of shell plate will be adopted, that we will have no longitudinal seams at all, only the circumferential. I quite agree with Mr. Ruck-Keene in his remarks about lock studding. Whether he means by



ILLUSTRATING REPAIRS BY THE ELECTRIC ARC SYSTEM OF WELDING.



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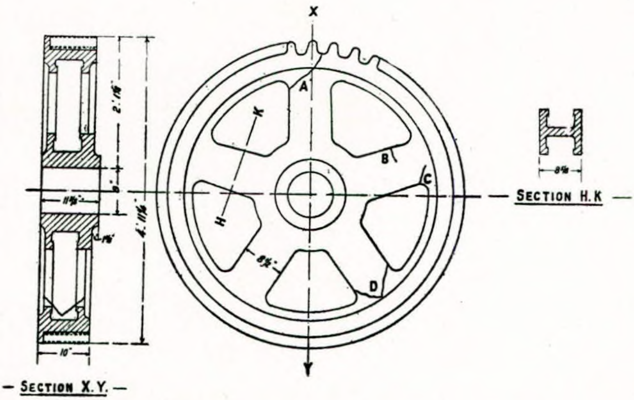
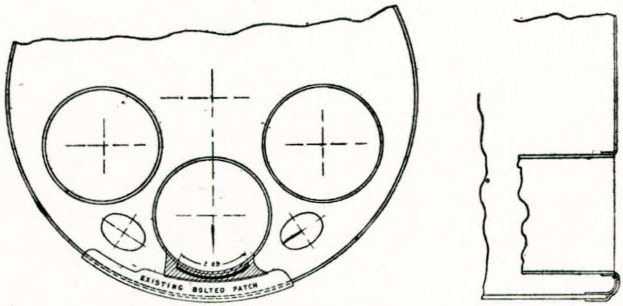


a Both flanges fractured to centre line and partly in rim.

b One flange partly fractured.

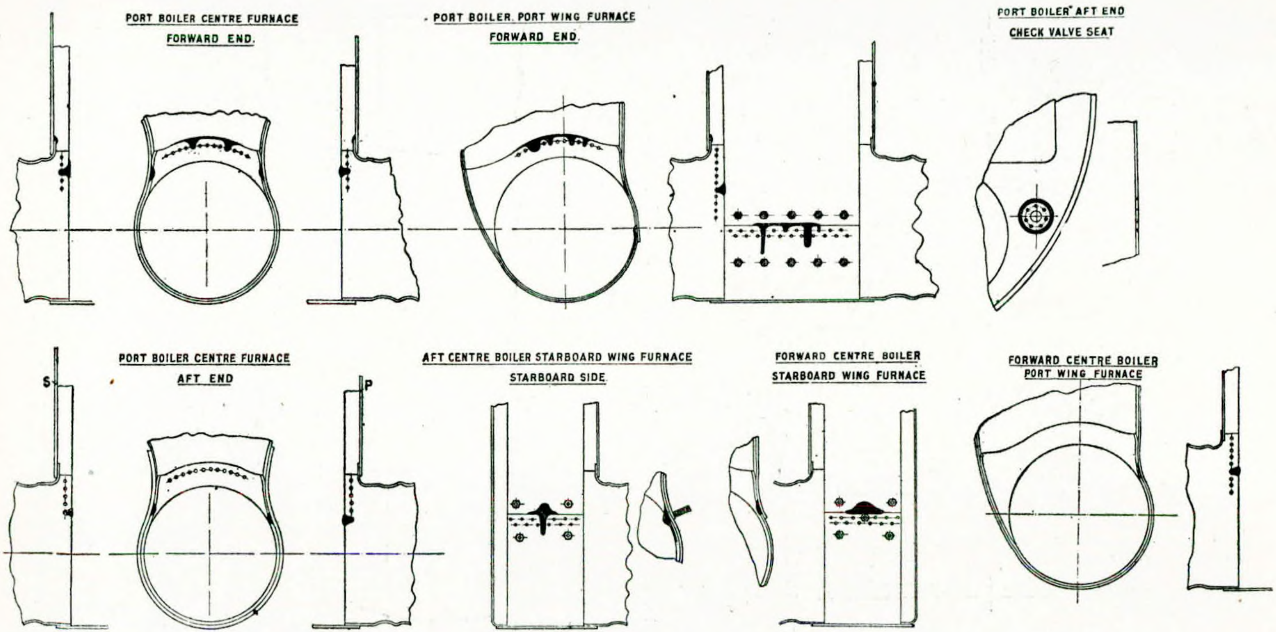
c Do. do.

d Both flanges and the web fractured. Arm completely separated.



Part cut out and welded-up shown in full. The portion thickened-up is shaded.

ILLUSTRATING REPAIRS BY THE ELECTRIC ARC SYSTEM OF WELDING.


PORT BOILER CENTRE FURNACE
FORWARD END.
PORT BOILER. PORT WING FURNACE
FORWARD END.
PORT BOILER AFT END
CHECK VALVE SEAT
PORT BOILER CENTRE FURNACE
AFT END
S
P
AFT CENTRE BOILER STARBOARD WING FURNACE
STARBOARD SIDE.
FORWARD CENTRE BOILER
STARBOARD WING FURNACE
FORWARD CENTRE BOILER
PORT WING FURNACE

lock studding one stud running into the other, or a small space in between the two holes, I do not know. Lock studding is preferable with a small space between each hole ; but lock studding at the best is only a temporary repair. As regards extra stays in cases of buckling ; of course there should be no necessity for these. The proper number of stays are there for the pressure, and it would only be as a very temporary repair that extra stays would be fitted. A good deal would depend upon the time at disposal for repairs. If there were time there is no question that the best plan would be to cut out the plates and renew with the original number of stays. Mr. Innes gives very little credit to engineers and to those who look after the boiler cleaning when he talks about boilers never being cleaned more than 1 inch below the fire-bars. I think that must be some extraordinary experience. With regard to the renewal of the boiler tubes, the fact that air is a considerable cause of corrosion in the boilers goes without saying. I have in mind one particular ship over twenty years old, in which the renewals have been very few, and even those have been of recent date. I heard the other day about a set of twenty year old boilers being so clean inside that the Board of Trade surveyor would not insult the boiler by putting on a dirty boiler suit he had had on in another ship. We have heard to-night a remarkable suggestion that there is no such thing as circulation. To me that is a revolutionary idea. The ordinary laws of convection produce circulation in the boilers. One of the speakers seemed to infer that the water dropped by gravitation and beyond that there was no movement at all. With regard to lighting the fires, I have often heard it stated that the centre fire should be lit first. To my mind that is a most detrimental thing for the boiler ; it sets up unequal strains right away. Why not light up all the fires at once and set them away equally, without giving unequal strains in the boiler in the vicinity of the centre fire. We have with us to-night a gentleman who has had a good deal to do with electric welding. I have seen some electric welding done, though not on boilers, and I am sure we would all like to hear a few words on the subject from him.

Mr. W. Forrester : I have had a good deal of experience with electric welding, and have not had any failures with it. I have built up, in one instance, the back of a combustion chamber of a single-ended boiler, where the metal was wasted to $\frac{1}{8}$ inch, just past the first row of stays, for 5 feet in length. We built it up to $\frac{1}{2}$ inch thick right across, and put new stays in. That was a task most difficult of accomplishment by any other means, and we had only a few days in which to do it. It would have taken a week in the ordinary course, whereas we did it in three days and made a much better and more lasting job, being absolutely free from leakage. With regard to welding a fixed plate, take the case of a furnace fixed at each end—a plain furnace. I admit you can weld cracks in other kinds of furnaces, either longitudinal or circumferential, because the corrugations will lend themselves to it. This has been done by the oxy-acetylene system, but no operator has been able to weld a crack in a plain furnace by the oxy-acetylene process, or on any fixed plate, without loosening one end by taking out rivets. It cannot be done unless you loosen one of the ends of the furnace and you get an equal expansion right through. That is the only way in which it can be done by the oxy-acetylene process, but I will guarantee to do it by the electric process without a crack, and without taking out any rivets, and the metal deposited will be as ductile as the surrounding metal, especially after the vessel has run three or four voyages. In reference to the stay nuts burning off in the combustion chamber, that is a great trouble. It is not due to the want of circulation, because at this particular part of the boiler there is the best circulation. It is because there is no conduction through the nuts. The nuts are screwed ten threads to an inch probably, or little more than $\frac{1}{8}$ inch in depth, and when red hot, which they must be, as they have got hot enough to burn away, they are therefore of no use as nuts. I had an idea of using the welding process to weld a pan head on to the stay, forming a homogeneous mass with the stay and also with the plate to which it is screwed. That could be done, and it would add to the effeciency of the boiler, by having something that would conduct the heat through the plate to the water. And much better than a nut, as a nut in this case is simply a lamination. Of course there is the objection that the Board of Trade will not allow us to weld steel—the plate is steel and often the stays—because the stay is in tension between the two plates in the water space. Well, I admit that, but if you look deeply into it, after the stay goes through into the firebox and into the nut I think you will find that the stay is in shear. It is the shear of the thread of the nut. The tension is between the two plates, but after that I think it is in shear, and I think they might be welded. If they would allow it, I think it could be done without any danger; that is to say, form a pan head on the stay, weld it to the stay and to the plate. And a few dozen of these would increase the valuable heating surface in a boiler. With regard to chain studding, my idea is much the same as Mr. Ross's, to leave a space between the studs. The holes should be countersunk before tapping and drilled, so as to get a thread right round the stud. Copper is a far superior metal to use to stud a crack, because studding usually is only useful for getting a vessel into port to repair it, but copper will give no trouble. The difference of expansion in the two metals allows a good effect to be obtained, and I have used copper with very good results, both in marine and locomotive boilers. There is an item here with regard to badly-fitting manhole doors. The author advocates putting a strip 3 inches wide and $\frac{3}{8}$ inch thick on to the door if you have a grooved plate. I take it that would be put on around the circumference of the manhole door to fill that space. Pinning on would be awkward unless it were welded to keep the water from coming through. The only other thing to do would be to caulk it all round and make it tight, which would be very difficult and would not make a practical job. But of course there is no need for it to be done; all that would be necessary would be to weld these places up. Regularly I have cases of grooving in the bottom of the boilers, pieces cut out, by constant leakage, and I have never yet had a failure in welding them up perfectly. I think that in the future, from my own point of view, electric welding will take a much greater place in boiler repairing than at the present day. It is comparatively a new thing in Great Britain, and although I do not say we are altogether slow in the matter, the North German Lloyd have been using it on their fast Atlantic boats for the last four or five years. I have seen work done by the arc system that would be impossible by any other method. It has been well tested, and I have every hope for it in the future. The stay tubes of the boiler are a most important part in the boiler, and unless they are a good job at first, they are the most difficult to deal with when once they give way. Under present pressures, to make a trip of six to ten weeks with stay tubes leaking at back ends means often that the thread of the stay tube is worn clean off the tube and the plate. It is easy to put an expander in, but that is not a good thing to do. A stay tube ought to be put in tight enough without being obliged to use expanders on it; then it should be caulked inside with a round tool as you put it in. It is a most important point to caulk each stay tube as it is put into the boiler, when building before putting in the plain tubes. They can be caulked at the outer ends at any time, but not inside as a repair. Imagine two surfaces with a thread of nine or ten to the inch. If you put an expander in you destroy the thread, on the tube and plate, and practically ruin the stay.

Speaking from a boilermaker's point of view, I will not touch upon the question of circulation at all. With regard to the feed check valves, they have always been put in the same position since I have had anything to do with boilers—since the early sixties, but the water is moved into different places by internal pipes. I know of a superintendent in Liverpool who carried internal feed pipes into the steam space and delivered the water below the line of bars. He got the water heated in that way, but I could not say whether it was better or not on the whole.

Mr. J. Clark: There are two things I would like to mention in connection with this paper. One was referred to by Mr. Milton and is prominently stated in the paper itself; that is, the question of cleanliness. Dirt is the prophet of the breakdown to the engineer. The other point emphasizes principles with regard to the repairing of boilers, which are vitally important. Should a mishap take place that causes an opening, it is very important, and Mr. Innes brings this out in all cases, that no stresses must be set up in trying to bring the parts into position again; in other words, the patch must be made to suit the new conditions. At the beginning of the paper dealing with boiler shells the author mentions about leaky rivets. He says: "This defect can be overcome if the rivets are cut out, and the holes countersunk on both sides and re-riveted." But I think that is rather going against principles. If you countersink a hole you are reducing the resistance to shear in the rivet. It seems to me that, instead of countersinking, it would be much better to gas weld it or electric weld it. The author has gone into the subject very fully and has elicited a most interesting discussion.

Chairman: There is one point which members might take into consideration ; that is the effect of too much air pressure with forced draught. It is a difficulty that is not quite so common at the present time as it used to be when forced draught first came into general vogue ; I had experience in one case where serious difficulty was caused by excessive blast, and it led to a considerable amount of trouble the following trip.

Mr. FORRESTER : With regard to the question of forced draught, Howden & Co. recommend $1\frac{1}{2}$ inches or so, but I have known 5 inches to be used. The boilers suffered very badly from bird-nesting at the back, and the outlet for the gases through each tube was probably not more than $\frac{1}{2}$ inch instead of $2\frac{1}{2}$ inches. You may imagine that the flues or the combustion chamber would have a tremendous heat in it by reason of the gases being retained. That could never have happened with natural draught. The consequence was the furnaces were put out of shape, the tubes were leaking, the stay ends were burnt off, and other troubles ensued. We put a valve in the uptake that lifted a tap and could not be tampered with, and by this means they never had more than 2 inches on. They had not so much trouble, but they could not get the steam. That was the fault of having too small a boiler, and, as Mr. Balfour said, "expecting a donkey to do a horse's work."

CHAIRMAN : That exactly bears out the case I referred to. On one trip they had the pressure up to 5 inches, and frequently over $3\frac{1}{2}$ inches. This led to overheating and consequent leakage, which caused grooving of the saddle plate. The following trip the grooving was excessive in one furnace ; the furnace practically did no work the whole voyage, and the saddle plate had to be renewed when the vessel got home. To prevent excessive draft after this a valve was put on the casing, but that did not prove very effective, as when it raised on one or two occasions it blew all the dust into the engine-room. Eventually a reducing valve was fitted on the fan engine steam pipe and set so as not to allow the pressure to exceed $2\frac{1}{2}$ inches.

Mr. STUART : What happens if there is bird-nesting in the tubes with the fan at 5 inches, and only $\frac{1}{2}$ inch outlet in the tubes ? The gases cannot get away, but cling all round the furnace in the ordinary course; but there should be no bird-nesting with the high pressure, and I do not think the excessive draught can do any damage whatever. There are occasions when excessive draught with dirty boilers may cause some trouble; but if there is bird-nesting one should hesitate to put a fan off, at any rate I should.

CHAIRMAN: We have to thank Mr. Innes for the paper he has given us on this subject. It is a subject which will appeal to all marine engineers at the present day, and it is becoming more important as we advance in engineering science. I think you will all agree with me that we have had a discussion which will add to the interest of the paper and will also interest the larger number of our members who cannot possibly be with us here this evening. This paper will particularly interest our members on the seas, and prove no doubt of lasting benefit both to the younger and the older members. I was pleased to hear one of our members say he did not believe boilers were neglected at the present day by the engineers. I think it is the rule in every engine-room now to look after the boilers first; one can very soon tell when there is anything wrong with the engine, but with the boiler deterioration is a silent process, and, therefore, one has to keep constantly on the lookout to prevent trouble arising.

A hearty vote of thanks was accorded to Mr. Innes on the proposal of Mr. F. M. Timpson, seconded by Mr. J. Clark.

The meeting closed with a vote of thanks to the Chairman on the proposal of Mr. J. Thom.

MR. INNES: At the outset, I stated that it was not my intention to touch the question of the design of marine boilers in any way whatever, and it will be as well at this stage to keep to the subject of my paper, viz., Boiler Repairs. The question, therefore, of fitting withdrawable furnaces as against ordinary ones, or the fitting of solid headed screw stays, that is, I presume, in the form of a tap bolt, as against the ordinary screw stay with nut, scarcely comes within scope of my subject. Had it been boiler-making, I might have touched upon these points as well as many others.

Mr. Ruck-Keene mentions the fitting of a new saddle plate in an old boiler to take a withdrawable furnace, the previous one being of the ordinary type. I, too, have had similar jobs done. The saddle plate, however, in at least two cases I had, were in two pieces and lap jointed, top and bottom. Only the centre furnace in each case was done, the boilers being about 12 feet 6 inches in diameter, and 180 lb. pressure. The job was a most expensive one. I felt that the area above the bridge was much contracted, so did not recommend that it be done again, more especially as equally good results were obtained with the method of repair already mentioned in my paper.

Mr. Balfour recommends the cutting out of bulged combustion chamber back plates, and the fitting of new plates having a vertical and cross seam exposed to the fire. If the combustion back plate is sufficiently thick to withstand the pressure, why should it be cut out simply because the plate is bulged? It does not of necessity follow that it is any weaker than when flat; all that is materially damaged is the screw stay connection. Vertical and cross seams in a combustion chamber are difficult to clean, and give trouble, and for this reason I never recommend a patch in a combustion chamber above the line of fire-bars unless compelled to do so. I have had many cases of buckling in combustion chambers of a most pronounced type, and the repairs recommended in my paper have in all cases been a complete success without any cutting out.

Mr. Timpson thinks I am rather unfair to marine engineers as regards their care of boilers. I would be very sorry if it were thought so, as such was not intended. At the same time it is a most patent fact, that nearly all the defects the boiler is heir to are due to dirt, or want of care on the part of either the superintendent or the engineer. One cannot compare liners with tramps, or passenger steamers with cargo coasters. The former have a regular gang of scalers under a responsible foreman, while the latter have to put up with "contract scaling." It may surprise many when I state as regards the vessels named by Mr. Timpson, which are in charge of drivers, that their standard of cleaning boilers is equal, if not superior to, many of the liners, and I have in my mind many cases where at twelve to sixteen years of age the boilers are free from corrosion, have not had a single tube or stay renewed, and have practically cost nothing other than for having furnaces set up during that time. The secret of this is, after the boilers are cleaned, the superintendent engineer personally goes through the bottom door, and looks up, or in other words, does the reverse thing to the scaler, who looks and works down. Top door examination alone for cleanliness is of little use, and generally a waste of time.

The defect mentioned by Mr. Stuart, viz., cracking from rivet holes to the edge of the seam on the furnace connection to tube plate, can be got over if the rivets are cut out, the seam properly closed, holes recountersunk and re-riveted, after which the $\frac{3}{8}$ inch chamfer should be cut along the seam edge; cracking of the seams to the rivet holes is due to the landing edge becoming overheated.

Mr. Clark seems adverse to countersinking rivet holes on each side. Personally, I consider that in repair work, countersinking makes for better and closer work, and should always be done when the seam is to be closed and riveted by hand.

Mr. E. W. Ross is scarcely correct when he says that I give little credit to Engineers and those who look after boilers, when I state that "boilers are never cleaned one inch below the fire bars". What I did say in speaking of corrosion at the fire-bar line of furnaces was, "Now the boiler scalers never clean a *furnace* an inch below the fire bars unless they are properly instructed to do so." This, I am sure, is a truth which Mr. Ross will admit.

Mr. Forrester does not seem to be quite clear as to the repair of solid manhole doors, or grooved ones, grooved sufficiently deep to take the packing and the flange of front or bottom plate manhole as the case may be. When it is necessary to repair such a door, owing to the spigot becoming slack, all that is required is to fit an oval plate 3 inches wide by $\frac{3}{8}$ inch thick into the manhole, say $\frac{1}{16}$ inch slack all round. Pin this to the spigot of the door, when it will be found that the packing cannot be blown out, and that neither jointing, caulking, nor welding are necessary. Besides this, nothing requires to be done to the door studs, providing they are in good order.

Several gentlemen have mentioned the burning of screw stay nuts in the combustion chambers, and have suggested theories as to the cause. Screw stay nuts, if solid, should not burn off, if the combustion chambers are sufficiently wide. In cases when I have found them, the nuts have either been welded ones, or the chamber has been too narrow. If a screw stay is fitted at right angles to the combustion chamber back plate, a proper fit in the hole, the nut solid, a good ordinary fit, and faced, it will lie close to the plate, when it will be found that neither caulking nor welding the nut and stay end is required. With reference to the remarks on lock studding, so dear to boilermakers, whether the studs are interlocked or a small distance apart, whether they be of copper or not, the job is but a temporary one, and as a method of repair is most objectionable and unsafe.

I am much indebted to the gentlemen who have given us so much information as to the electric and oxy-acetylene process of welding.

As I have already said, I have had little experience of them; we have not the oxy-acetylene plant in the district where I am stationed, and when it has been used, an operator with the required apparatus has been brought from Newcastle, and in both cases where the process was used the work was most successfully done. I was then impressed by the fact that all depended on the skill and faithfulness of the operator, and I felt, and still feel, that while many repairs, such as those in the furnaces and combustion chamber, can be done with safety, the process has its limitations. In other words, it is not, in my opinion, applicable to those parts in tension, for example, repairs to shells or end plates, where the plates are so much thicker and under tension. Then again, while it must be admitted that certain repairs can be done successfully, why is it that neither the electric nor the oxy-acetylene process of welding has been applied to new boiler work? We glut-weld shell plates from 1 inch to $1\frac{17}{32}$ inches thick, and afterwards flange them every week in my district. I have seen hundreds of furnaces lap welded, and scores of them welded to the back tube plate, all of them being done by the ordinary coke fire. All have, however, afterwards been properly annealed. To my mind, therefore, the weak spot in both the electric and oxy-acetylene for repairs is, the work cannot afterwards be annealed. Let us hope that in time this difficulty will be overcome, as these methods of welding place a great power in the hands of the engineer.

I will not reply to the gentlemen who have spoken on matters pertaining to the working or management of boilers at sea, as it does not come within the province of this paper.

Gentlemen, I can assure you that it has been a pleasure to me to find the interest my paper has created. I am glad there has been a good discussion, and thank you all for your appreciation of my effort to bring before your notice a subject which has always been to me one of peculiar charm.

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VOL. XXIII.

PAPER OF TRANSACTIONS, NO. CLXXVI.

MODERN DEVELOPMENTS IN BRITISH AND CONTINENTAL OIL ENGINE PRACTICE

By MR. E. SHACKLETON (ASSOCIATE MEMBER).

Read Monday, March 20, 1911.

CHAIRMAN: MR. JOHN LANG, R.N.R. (MEMBER OF COUNCIL).

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