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Causes of Deterioration in Boilers and Measures tending to prevent or remedy them.

BY MR. C. C. NELSON (MEMBER).

READ

Monday, January 16, 1911.

CHAIRMAN: MR. JOHN McLAREN (MEMBER OF COUNCIL).

(Originally read before the Institute of Engineers and Shipbuilders in Hong-Kong and reprinted by permission.)

CHAIRMAN: We have met to-night to hear a paper on a very important subject, "The Causes of Deterioration in Boilers," by Mr. C. C. Nelson, who is in China. The Honorary Secretary will read the paper on his behalf.

BOILERS were once considered of only secondary importance to the majority of Marine Engineers, but lately it has become the practice to study the boiler more, and they now rank in the first place of importance, so that it is essential that they be kept in good order. To do this requires the knowledge of the causes of deterioration, of which causes the principal is corrosion. Water at ordinary temperature (60° F.) and under normal pressure (14·7 lb.) dissolves its own vol. of CO_2, but a change either in temperature of water or pressure of atmosphere will be accompanied by a change in the quantity of gas dissolved ; so that if temperature of water is increased the water gives off gas, but should the pressure be increased the water will absorb more gas. This is the reason that heating the feed water tends to preserve the boilers. And it also shows the advantage of heating the feed water (up to about 200° F. under atmospheric pressure) before putting it under pressure. The carbon dioxide that gets into the boilers can be completely absorbed by the addition of sodic or potassic hydrate. The CO_2 unites with alkaline hydrate forming a carbonate and liberating water.

Sodic hydrate + Carbon dioxide = Sodic carbonate + Water
$2NaHO + CO_2 = Na_2CO_3 + H_2O$.

Corrosion may be caused by the oxidization of the steel by accidulated boiler water, and by electro-galvanic and thermo-galvanic action. The most fruitful of these is rusting, which is directly caused by the carbonic gas (CO_2). This is present both in the air and water and enters into combination with the iron or steel and forms carbonate of iron, which in turn absorbs oxygen, and the final product is oxide of iron (Fe_2O_3). This thin coating would preserve the iron, only unfortunately in this last change the original particles of the CO_2 are liberated and in turn attack the plate and so the cycle continues. Dry pure oxygen alone will not exert any action on iron or steel, neither will CO_2 while dry, but the two together in the presence of moisture set up rapid corrosion.

While rusting may take place anywhere inside a boiler it is often in evidence at the water level on the shell plates, as at this place the washing about of the water alternately wets and dries the plate, which is the exact state iron and steel need to be in to facilitate heavy rusting. The excessive difference of temperature at the line of fire bars tends to set up thermo-galvanic action, to which is assigned the pitting found here, but some authorities state that this pitting is caused by small air bubbles which cling to the sides of vertical heating surfaces ; the period that these small bubbles rest on a plate is long enough for the oxygen they contain to act on the iron or steel and cause small irregularities, on which subsequent bubbles find a still better lodgment, and speedily effect the formation of pitting. The straining of the plates, as at the line of fire bars, loosens the rust and the pitting gradually gets deeper. Mr. Macfarlane Gray's idea of pitting was that it was caused by minute particles of copper, but this was questioned by another authority, who stated that he had found pitting in land boilers, in which there could be no question of copper at all.

ACIDULATED BOILER WATER.—It seems to be generally accepted that boiler water, when using a surface condenser, after a time becomes acidulated, even if the supplementary feed is obtained by means of an evaporator ; there are many theories advanced to account for it, but none seem to be universally accepted, though I think the idea that hot water is in itself a solvent, carries some weight ; but having the acid in the water, the best thing to do is to remedy it by using an alkali, preferably carbonate of soda, or caustic lime, in fact it is advisable to keep the boiler water slightly alkaline. The use of only hydrocarbon oils for internal lubrication of the engines prevents acids from oil forming in the boiler, as it takes a temperature of about 700° F. to decompose these oils, while animal and vegetable oils decompose at about 270° F., and form stearic and oleic acids respectively, besides their own particular acid due to the base they come from.

Sea water contains many salts injurious to iron and steel, but we must take into consideration the different behaviour of salts at the conditions present in boilers with steam up. Sea water put into a boiler will, when heated, deposit Calcic sulphate, at a temperature of about 300° F., which forms an insoluble skin and prevents the injurious action of the other salts. But continual feeding with salt water would increase the thickness of this skin, and in time cause overheating of the plates, etc., owing to its non-conductive properties. Sea water fed into boilers previously containing fresh water will probably, other conditions being favourable, cause corrosion on the same principle that dilute nitric acid will eat right through a leaden vessel, while strong nitric acid will not affect it further than forming a coating of nitrate of lead which prevents the further action of the acid. Chloride of magnesia is always present in sea water, and is exceedingly injurious, it will attack iron or steel with or without the presence of air at about 212° F., while the following chlorides only attack in the presence of air. They are here arranged in the order of their corrosive power:—Ammonium, Sodium, Potassium, Barium and Calcium. Chloride of magnesia will, under certain conditions, decompose and form hydro-chloric acid, which is also highly injurious to iron and steel, but although some authorities quote this as being one of the causes of corrosion in boilers it is a fallacy, as to cause decomposition of magnesium chloride it has to be heated to dryness at not less than about 300° F., and this dryness cannot be obtained when in contact with saturated steam: the only way it could happen would be by the salt water being carried into the super-heater by priming.

Copper salts seem to be a constituent of nearly all feed water; its effects may be seen as green scale on or near the zinc plates. For some unaccountable reason, it does not deposit itself uniformly over the boiler, but only in spots—chiefly non-heating surfaces. The origin of copper salts in boiler water is supposed to be from particles carried in with the feed water, and also that the distilled water acts on copper as a solvent.

Zinc salts act as a preservative in boilers, and the painting of the whole of the interior of a boiler with zinc oxide, and the addition of some zinc salts (the chlorides excepted) to the boiler water, has been proved to be beneficial.

Mercury salts are known to be an efficient protector against rust, and the only reason against their use I can find is excessive cost.

Alkalies.—In some ships slaked lime, caustic potash, soda, or their carbonates, is sometimes added to neutralize any free acid in the water. If added in excess it may do harm, the lime forming as a sediment on the heating surfaces, and the soda eroding the spigots, etc., of the brass valves, and if copper pipes are used in the boiler, galvanic action may be set up. When an alkaline or basic compound is brought into contact with an acid compound the H of the acid and the metal of the base exchange positions and form a salt as:

Sulphuric acid (H_2SO_4) + Caustic soda ($2NaOH$)
= Sulphate of soda ($NaSO_4$) + Water ($2H_2O$)

An alkali also has the power of absorbing and neutralizing Carbon dioxide (CO_2).

Anti-Incrustators.—Of these Sodic carbonate, in one form or another, generally plays the principal part; its action is to convert the calcic sulphate and magnesic chloride into carbonates.

Calcic Sulphate		Sodic Carbonate		Calcic Carbonate		Sodic Sulphate
$CaSO_4$	+	Na_2CO_3	=	$CaCO_3$	+	Na_2SO_4

The hardening effect of the calcic sulphate being done away with and the calcic carbonate precipitated in a soft condition, when it can be blown out. Ammonic chloride is also sometimes used, and when boiled in presence of calcic carbonate decomposes it, forming soluble calcic chloride whilst the ammonic carbonate volatilizes.

Whenever there is any doubt as to the harmlessness of fluids or salts intended to be put into a boiler, it is better to test them as follows:—Boil them and then put a clean knife blade into the liquid: should rust be formed, should the water be discoloured or should copper deposit itself on the blade, then the substance should not be used. If certain free acids are present, the above test will give no warning, but a few drops of prussiate of potash should be added, when, if steel is being dissolved a light bluish precipitate is at once formed which slowly turns dark blue, or if tannic acid be added, a substance like ink will be formed. Salt in the water can be found by putting a few drops of nitrate of silver in a glass of boiler water, when the contents will become cloudy.

THE BEHAVIOUR OF HYDRO-CARBON OILS IN BOILERS.—Filters should be used for feed water to arrest solids and oils, principally oils, for once the oil gets into the boiler the globules, if in sufficient quantity, coalesce, forming an oily scum on the surface of the water, but if present in smaller quantities remain as separate drops; these drops show no tendency to sink as their specific gravity is about ·889, but they gradually come in contact with the minute particles of calcic sulphate and other solids separating them from the water and in time covering them with oil, which enables them to stick to any surface they come in contact with. The S.G. of the particles will increase as they become more and more loaded with the solids, till a point is reached, at which they have the same specific gravity as the water, and they now rise and fall with the convection currents of the water, attaching themselves to the surfaces they come in contact with, the position on the surfaces depending on whether they come in contact whilst descending or ascending. This deposit is a non-conductor of heat, and also from its oily nature it tends to prevent intimate contact between itself and the water. On heating surfaces this leads to overheating of the plates, and the deposit begins to decompose by the heat, the lower layer in contact with the plate giving off gases which blow the greasy layer, ordinarily about $\frac{1}{64}$ in. thick, up to a spongy leathery mass often $\frac{1}{8}$ in. thick, which, owing to its porosity, is now even a better non-conductor than before; the plate becomes heated to redness and being unable to withstand the pressure of steam collapses.

During the last stages of this overheating, however, the temperature has risen to such a point that the organic matter, oil, etc., present in the deposit, burns away, or more properly speaking is distilled off, leaving behind as an apparently harmless deposit the solid particles round which the oil had originally formed.

IMPURITIES IN THE METAL.—The composition of boiler plates often has a great deal to do with corrosion in boilers. In a ship built in the north of England, her boilers lasted only months, when, notwithstanding that all preventatives and preservatives were tried the boilers were condemned by the B.O.T., and new ones had to be put in. I should think that is a case where there were some injurious impurities in the steel. The steel used for boiler plates is generally that produced by the acid Siemen Martin's regenerative furnace process, as its composition can be regulated better than by any other method for the same cost. The heat in this furnace is produced by a gas, mixed with air, generally coal or water gas, and it is assumed that the metal occludes some of the components of the gas, such as carbonic gas, hydrogen, etc., and that in cooling it gives most of them off again, but should any injurious substance remain it is often the cause of rapid corrosion, and this may have been the cause of the trouble in the above-mentioned boilers. Pickling the plates has been tried with partial success, though it is said to reduce the elongation about 15 per cent., and the ductility about 40 per cent.; this can be rectified by annealing, but it is a question whether the plates will not return to their former state after being in the annealing furnace. It was found on analysing steel that had been galvanized, that it had occluded from ·002 per cent. to ·005 per cent. of hydrogen, and taking into consideration the low atomic weight of hydrogen, these percentages should be multiplied by 32 and 31 respectively to make them comparable with the volumes of sulphur or phosphorus. This goes to prove that under certain conditions the occlusion of gases by metals does take place.

GALVANIC ACTION.—I think that there is room for a great deal more knowledge of this ; even at the present time it is often the practice to blame it for certain peculiarities of corrosion, when nothing else will explain it. The theory of galvanic action is most lucidly explained as follows :—" When two metals of dissimilar nature are immersed in a liquid capable of chemically acting on both of them, and are connected, or are in metallic contact, then that which is the more easily corroded becomes the positive element or anode, while the other metal becomes the negative element or cathode."

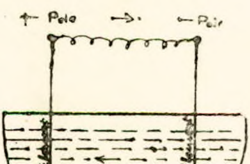

FIG. 1.

The impurities in steel with an electrolyte in contact will cause galvanic action. The electrolite in the case of a boiler is acidulated or alkaline boiler water. Another form of electro-galvanic action is that between different materials, as in the steel shells and iron tubes (steel tubes are used in the British Navy, but iron are still mostly used in the Merchant Service). Zinc is put into boilers to prevent corrosion, and does it, but zinc put into boilers to absorb galvanic action is a fallacy and the polishing of the contacts as is often insisted on, is a waste of time. Supposing that the boiler is just newly closed up, and the zinc plates are in perfect metallic contact with the metal of the boiler, how long is it likely that the surfaces will remain perfectly bright ?—possibly half an hour—when a thin skin forms, and taking into consideration the weakness of the electrolyte (boiler water is never a strong electrolyte in practice), all current stops ;

though I am afraid that after the years it has been accepted, that all discussion on this point will not stop here. Another reason that causes me to think that zinc plates do not continue to act as the positive element in a boiler, is that you never find zinc deposits on the steel of the boiler, which should happen if zinc was the anode and steel the cathode. I expect some of the Members are wondering how I account for the wasting away of the zinc ; well I think this can be explained as follows : Hot water acts as a solvent on zinc and the oxygen in the water chemically combines with the zinc forming zinc-oxide.

Zinc		Oxygen		Zinc-oxide
Zn	+	O	=	ZnO.

It is worth noticing that when two dissimilar metals are immersed in a liquid capable of chemically acting on them both, but not connected, they both corrode ; connect them as shown in diagram, and as soon as current flows, one is eaten away while the other is preserved. I have an idea that galvanic action might be made to preserve the boilers, for we know that if two plates of similar nature be immersed in two separate vessels, and a current made to pass from one plate to the other through the liquid, then the one the current leaves becomes corroded, while the other is preserved.

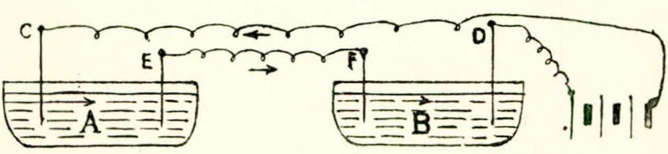

FIG. 2.

In the next diagram—See *Proceedings of the I. Mar. E.* Vol. XX.—let A and B be two vessels each containing the same kind of electrolyte, and let C and D be two plates of steel and E and F two plates of carbon, which is non-corrodible, then the current leaving the battery passes through C into and through the electrolyte into E, then into F, through the electrolyte in B and into D, thence back to the terminal of battery ; here the plate C will become corroded. Surely this is a field which would amply repay investigation by those interested in galvanic action in boilers.

There is another action set up in boilers called thermo-galvanic action : this is caused by unequal heat in the plates, even though it is the same plate, and of the same material ; one of the principal places where this takes place is on the sides of the furnace tubes about the line of fire bars ; but I do not think this action exerts much influence in the corrosion of boilers. The action of stray electric currents is blamed for a great deal more than it deserves, and personally, the only defect I can see this will cause, is the eroding of copper feed pipes.

Another and important factor in deterioration of boilers is faulty construction, and bad workmanship in working plates, etc. When a boiler structure is so combined that certain parts are kept in a state of restlessness, either difference of expansion and contraction, or any movement causing alternate strains, then, all such restlessness tends to wear out the parts thus exposed, not so much by the mere friction as by the process of disintegration, whereby the incipient oxide is prematurely scaled from the surface of the plates, and causes what is known as grooving. This restlessness also causes fatigue and shows as brittleness in the plate. If a boiler is so constructed as to have a tendency to restrict circulation, it may give trouble. This has been known in a boiler that had too little space over the furnaces, to so overheat the crowns as to cause them to collapse ; such was the case in an Atlantic steamer, where the crowns came down nearly every trip. At first the owners tried to remedy this by discharging the engineers, but finally remedied it by drawing the row of tubes above the furnace. Restricted circulation causes the heating surfaces to become hotter than they otherwise would, and it is a recognized fact that acids will attack the hottest part of the plates. Methods of working the plates such as local heating, flanging and working at a blue heat, often cause cracks, etc. It has been found by experience that between 450° and 550° F. (known as blue heat) steel appears to become rotten, though above or below this temperature it may stand bending or other tests. I think the usual methods of annealing plates leave much to be desired.

SCALE.—Always keep scale from accumulating on tubes, especially round the necks, as apart from the loss of economy, it causes leaky tubes, and I suppose nearly all Members here remember the pleasant task that at some time or other has been theirs in the back ends. But it is seldom explained why thick scale round the necks of the tubes causes the tube ends to leak ; it has been told me that they overheat, and the expansion and contraction causes it, but it always seemed to me that it was rather vague, till on furthering considering it I have come to the following conclusion : before tubes are put into a boiler they are annealed, then on expanding a certain action takes place in the metal, resembling, if not, tempering it, which gives it elasticity. Supposing the tube ends are overheated through the heat not passing away to the water rapidly enough, caused by thick scale, then the ends become annealed again, and it may be noted that often the tubes do not leak till a change of temperature takes place, as from a lower to a higher, such as lighting up fires again ; this leaking is caused by the tube ends not now possessing that requisite elasticity to follow up the longitudinal and compressive strains in the tube and the strains in the tube holes. This is remedied by re-expanding, and thus giving the metal elasticity again.

I would like to mention before I finish this paper, a case in which corrosion resisted the efforts of the engineers, until they boiled the boiler out for twenty-four hours with caustic soda. This would generally be thought to be a rather drastic treatment, but it was so effective that they were not troubled with corrosion again, though even after several "washings out" with fresh water before closing up, the boilers were inclined to prime when they first "got away." Another case that happened was this : the boilers when opened were found in excellent condition, they were brushed down and then washed out with sea water. A delay occurred so that the fresh water was not put in until two days later ; then, when the engineer went to have a final look round, he found that the backs of the combustion chambers were bleeding : this was remedied by painting with white zinc and kerosene.

If you are in charge of boilers in good condition, I would recommend the following :—See that steam is raised slowly, and that the water is kept circulating when raising steam, keep boiler water slightly alkaline, scum and blow frequently —by scumming you get rid of grease, etc., and acid, though at the expense of the freshest water in the boiler ; by blowing you get rid of sediment and denser water. When blowing do not let vibration take place any more than is possible, and do not blow at less than 53 lb. gauge pressure or 300° F., since water as it cools will resume the sediment to its full carrying capacity. And always avoid shock action in a boiler.

After trespassing so long on your patience, I will not further enumerate the many other things relative to boilers. I am leaving them for the other Members to bring forward at the discussion to follow, which is the reason of my attempting this paper, as I think this an excellent opportunity to get the opinions of experienced Engineers.

DISCUSSION.

CHAIRMAN : We have listened to an excellent paper, and one worthy of a good discussion. There are several points that were touched upon in Mr. Ruck-Keene's paper enlarged upon with advantage by Mr. Nelson. The subject matter should appeal to all engineers. The subject of the boiler has been before us in one form or another for years, and I hope we shall have a good discussion on it this evening.

Mr. WM. McLAREN : I might say in starting, that whoever is looking after the papers is to be congratulated on getting permission for this paper to be read here this evening. Even although the paper has already been read at the Institute in Hong-Kong such information and ideas as Mr. Nelson seems to have cannot be too widely spread. I will not commit myself on the chemical side of the question, as I am not in a position to discuss it. Taking the first paragraph, however, where the author says : " Boilers were once considered of only secondary importance to the majority of marine engineers," I would like to know what data he has for starting with that assumption, as I have always thought, during my time at any rate, that the boiler was considered to be of the first importance. If he had a good boiler the engineer was not so much concerned about the engine, as he could patch that up if anything went wrong. But perhaps the author's observations have been made in another sphere than that which I have been used to. In that same paragraph he refers to the question of heating the feed water, and says it preserves the life of the boiler. Does he mean it preserves the surface of the plates, or is it the joints of the boiler he refers to ? because that is important. Is it the boiler as a structure that it preserves ? I do not suppose he means the plate surfaces, but it is just as well to know. Further on he refers to rusting. I cannot say that I have come across rusting in the water and steam spaces, it has been what might be called a corroding action. Again he says : " Sea water contains many salts injurious to iron and steel." In my own experience, in one ship I was in, we found a great difference in the effects of the water in the Eastern and Western oceans. In the east side of the Red Sea and coming across to westward, we had great trouble with corrosion, and a scum came from the boilers which was nearly equal in appearance to red paint. We were about twelve months on that trade, and were then set on the western ocean trade and had no trouble whatever ; the boilers looked totally quite different. What particular cause effected that I could not say, but in any case it was due to the change of water. Mr. Nelson goes on to say : " Sea water fed into boilers previously containing fresh water will probably, other conditions being favourable, cause corrosion." I thought it was the other way about. We always advocated running rather salt, and we could not do that unless we had the sea water to do it with. But then it caused such an amount of labour, and added a scale to the boilers, which meant a heavier consumption of fuel. He goes on to remark about the behaviour of the boilers if oil should get in. I think we are all prepared to accept his opinion that the water should go through some form of purification if there is any doubt of it being free from oil. We have had this question discussed before, and I had the privilege of describing an arrangement whereby the exhaust steam, when it enters the condenser, instead of coming into contact with the condenser tubes, was expanded into a vessel into which the oil was precipitated. In the last part of that paragraph he refers to a spongy layer. I should think the ebullition of the water will tend to prevent this. As far as my experience goes, it forms when the oil does not blow up like a balloon, it gets so " fried " that it resists this action. I think, from experiments conducted by Sir John Durston and others, that it has been shown that the oil remains on the plate in a fluid condition, acting as a non-conductor, and that a layer of paper thickness has often been the cause of a collapse. I think the author has struck a very important note in his remarks on the impurities in the metal. We can judge of that by the pitting of tubes, where one set of tubes are put into a boiler in a new ship, and have had to be renewed within a few months. That is a matter in which the metallurgist can help the engineer. I am convinced, from an observation of the different stages of the pitting we get, that the fault lies in the mixture of the metal, that the metal is not the same throughout. Later on the author refers to pickling, and I would like to ask him: Why would he pickle the plates at all? I do not know what form the pickling would take, but it seems to me to be detrimental to disturb the elongation of the plate after it has been tested. I do not think we hear tests made before pickling and after pickling. It is given out that the boiler plate is of a certain elongation, and there is no question of pickling involved. Certainly all plates should be annealed—that is, after they have been worked, or rolled. With regard to the zinc plates getting a metallic contact, the plates are polished, but a sure contact is made with studs. Further on he observes: "Another and important factor in deterioration of boilers is faulty construction, and bad workmanship in working plates, etc." I do not agree with him in this paragraph at all in reference to the resiliency of construction of the boiler. I think that when the boiler is alive there is certainly no harm in allowing it sufficient "breathing" space. More often harm is done in getting the boiler tightened up. The boiler must have breathing space, and must not be tied up within too narrow a limit. That is a very important thing for engineers to look into. The grooving is due very often to the boiler being tightened up in narrow spaces, or where it is getting the heat, that is the heating surfaces; grooving again will take place owing to accumulation of scale, etc. As to the space between the crowns and the tubes, it will certainly obviate trouble by giving a free space above the heating surfaces, as otherwise there is bound to be local heating. I quite agree with regard to the back ends and leaky tubes; we have all had trouble with them at one time or another. Then with regard to the expansion and contraction of the tube-plate and the tubes. We must consider the amount of heat localised. The water is rapidly driven off by the heat, and therefore a greater quantity of water passes along in course of time, and if there is any sediment at all there is bound to be a greater accumulation of scale at that part, hence the scale that forms round the tube necks. I have seen a donkey boiler where there was $\frac{3}{4}$ in. of scale on the end of the tube-plate ; they found the best thing to do was to let it scale up to a limit, cut the tubes out and retube, as it paid to do so. It was a small multitubular boiler, and it was the best thing that could be done with a boiler constructed like it. The tube ends had to be rolled a few times, and were not becoming any more elastic by rolling, but otherwise. The author says near the end of the paper : " I would like to mention a case in which corrosion resisted the efforts of the engineers, until they boiled the boiler out for twenty-four hours with caustic soda." That might have been brought about by the change of water, in a similar manner to that I described at the beginning of my remarks. I would like to know what class of water they were using, sea, fresh or river water ?

Mr. W. Watson : Inferentially the priming was caused by the remains of the caustic soda.

Mr. W. McLaren : With regard to " blowing down," he gives us precautions to blow down at 53 lb. pressure, and not to get any vibration. I should think it would be impossible to blow down at such a pressure. I will bring my criticism to a close, but before doing so I would like to express my indebtedness to the author for giving such a valuable paper.

Mr. F. M. Timpson : With regard to the last paragraph in the paper, I feel inclined to think that " blowing down " is not marine practice at all. I thought the practice was to scum at 20 lb. pressure, and then, if there was time, to allow the boiler to cool down and pump out . In high-pressure boilers, the practice of blowing down is pretty well done away with. In reference to the use of sea water, I do not think this is common and general. The practice is to use the evaporator all the time and supply with fresh water. As Mr. McLaren has said, the author has brought up a great deal of matter, which leaves plenty of room for discussion. On one point he makes a very brief note, and that is circulation. I think a great deal of boiler troubles are due to bad circulation. One steamship company, with ships sailing from this port, adopted a system of assisted circulation, which shows considerable all-round economy, besides keeping free air out of the boilers. I think the matter of circulation deserves, and now has more attention than it had.

There are many other points in the paper open for discussion, but there are several gentlemen here who are a great deal more experienced than I am on this subject.

Mr. P. S. Doherty: Mr. McLaren raised the question of taking the oil out of the water; I presume he was referring to taking the oil out of the exhaust steam.

Mr. McLaren: Yes.

Mr. Doherty: From land experience I may say that 100 times the volume of the low-pressure cylinder is allowed, and there is ·3 grains per gallon left in the feed water. It may seem a small amount, but it mounts up in the end. With regard to heating the water, I understand that in the Navy at the present time the exhaust steam from the auxiliaries lead into the low-pressure turbine casings, and the drainage only is run into the feed tanks, which is in opposition to what the author has said in the paper. There is just one other point I would like to mention that may be of interest to the members, although really it is not in reference to boilers. It came under my notice lately in connexion with a feed water heater with a steel shell and ordinary bronze tubes and Admiralty bronze tube plates. There was trouble with electrolytic action, the pitting taking place on the tubes, yet when another mixture was put in the pitting took place entirely on the tube-plates. I raise that question entirely in connexion with the subject of galvanic action.

Mr. W. McLaren: If it would help any of the members, I might mention a case in point, in connexion with a water softener. We have the greatest trouble with pitting and the pitting does not attack the same place at different times. These boilers are being examined about once every three months to see if this can be remedied, and our chemist is investigating the matter. That is in regard to a boiler which is working on the south side of the river. We are having trouble also with a boiler on the north side of the river with still water; and with the water still and cold, if the boiler were allowed to settle down for six months with that water in it, there would be holes right through the plates. On the south side of the river the water is 30 to 35 degrees of hardness, that on the north side is about 5 degrees.

Mr. Timpson: In one case I know of on the south side, the gauge glasses wasted away in about a fortnight, by corrosive action going on right round the glass.

Mr. G. W. Newall: It occurred to me that the greater interest taken in boilers at the present day is due to the difference of pressure employed as much as anything else. Sixty years ago it was considered uncommon to have a boiler with 40 lb. of steam, while since then we have gone up to 250 lb. per sq. inch, and I think this discussion turns principally on the pressures we have to work with rather than on the difference of the construction of the boiler. With the high pressures of course we have their correspondingly high temperatures. I saw a little experiment some time ago regarding the effects of oil in boilers. Take a beaker and boil water in it until the thermometer records boiling point; then if you smear the bottom of the beaker with a little oil, and place the thermometer in contact with that part, the flame being directed upon it, you will get nearly twice the temperature, which is a very interesting and peculiar fact. Although the oil is so thin—the author mentions $\frac{1}{64}$ in. but a smear of oil would not be anything like that thickness—yet I have seen the temperature rise to about 400° F., which is rather remarkable. It is very interesting, because it shows that if you have a small amount of oil on the plates of the boiler you must have that local heating high temperature which often brings down our furnace crowns. Another peculiar feature with regard to boiling water we have had demonstrated in this room. By using a glass boiler standing at a pressure of 5 lb. per sq. inch, as the water boils you will notice in various local places along the furnace top that little tree-like forms of gases are seen coming away, and these seem to stick to local places all the time. It would seem as though the part the gas is coming from is thinner, and that may explain the matter, but it is a very interesting experiment.

Mr. Wm. Walker: I have listened with great pleasure to the paper, but my own feeling is that it might have been a little better arranged. It is very difficult to condense your points and bring them into line, because you find that on the first page the writer speaks about corrosion at the line of the firebars, and then takes it up again later on, where he seems to have repeated himself to some extent. I would like to draw the attention of the members to that question of corrosion at the line of fire-bars. Undoubtedly, as all those of us who have been at sea recognize, it does exist, but the peculiarity is that when we come to land boilers, very seldom do we find it at the fire-bar line. That is a mystery I have tried to solve, but I cannot come to any satisfactory solution. It is only in a very few instances where I have known deep corrosion on the line of fire-bars on the water side of Lancashire or Cornish boilers. It is as well for members to realize this, because it is always the ambition of sea-going men to find a land job, and it is as well to know that corrosion and deterioration in land boilers is different to that in the marine type. The author puts it down to straining of the plates. That may be the cause, but, if so, it would be found in land boilers also, as we have in many instances a much higher furnace temperature generated in land boilers than in marine, so consequently there should be greater straining of the plates. Then in the next paragraph he deals with acidulated boiler water, and advises that the water should be kept alkaline. That is very sound advice. It is always best to have an excess of alkali rather than a minimum ; but, as he points out, if you have an excessive amount you are likely to get wasting of the brass and bronze materials in the boilers due to this cause. In my own experience I know of two boilers, working under the same conditions and with the same water, only one was at 60 lb. pressure and the other at 120 lb. In the latter it was impossible to get the bronze or gun-metal blocks to stand, while in the boiler working at the lower pressure there was no difficulty. It shows there are certain chemical changes take place at the different temperatures which we are not able to account for at present. We analysed the waters and could not arrive at any reason for it, but we changed the blocks, putting in malleable castings, and these stood all right. There must be some chemical change which occurs at the higher temperatures. The author further on says: "Sea water, put into a boiler will, when heated, deposit calcic-sulphate at a temperature of about 300° F., which forms an insoluble skin and prevents the injurious action of the other salts." I would like to caution all concerned to beware of passing a boiler because it has some scale, in the belief that there is no corrosion underneath. My own experience is that even if there is scale in the boiler, on it being chipped away a considerable amount of corrosion has been found existing underneath the scale. The scale, in many instances, does not protect the boiler, it does not eliminate the danger of corrosion entirely. Boilers have been passed as satisfactory because there was a layer of scale, but often on this being knocked away there was comparatively no strength of plate. In fact many Board of Trade inquiries have revealed the fact that explosions have resulted, due to this. The author also treats on the question of zinc salts and zinc plates. I do not think the contact has very much to do with it. I was speaking quite recently to a zinc manufacturer in London, and his theory is that the zinc put into the boiler, on being dissolved forms a kind of milk of zinc, which acts in reducing corrosion because it mixes with the water. He has also a paragraph on boiler fluids. Well, boiler fluids are like books, "of the making of them there is no end," and it is a subject which is certainly worthy of consideration at the present day. The only successful course with some is to have one class of feed water with one class of fluid. Some makers advertise that their fluid, like patent nostrums, will cure anything, but unless the fluid is made to suit the feed water it is only an experiment. In certain cases they do attack the plates, in other cases they will attack nothing—not even the scale. The question of oil has been dealt with, and Mr. McLaren said, I think, that the process would be satisfactory to expand into a chamber of 50 to 1; Mr. Doherty said 100 times the volume of the low-pressure cylinder, and even then he says they get down to ·3 of a grain per gallon. Of course it is the aim to eliminate the oil as far as possible. It is recognized that oil is detrimental as a non-conductor, and that it has a tendency to bring down the furnaces. Land plants are usually dealt with by softening apparatus in conjunction with oil coagulation, and the principal solvent used is alumina ferric. That brings me to another point. Mr. McLaren said that he finds pitting in addition to corrosion. My own experience is this. In certain plants, before putting down softeners, there was no pitting, but after doing so pitting began. It shows that some of the chemical preparations put into the softener plants, lime, soda and alumina ferric or other such materials, have had a bad effect on the boiler. In some instances that has been remedied by putting a certain proportion of oxide of iron in the feed water, but it seems to me that in many instances the water has been purified to such an extent that we get it too pure. If you use rain water, even if filtered, for a boiler you will find there will be a great amount of corrosion or pitting, which shows that soft water is not always beneficial. There must be a certain amount of hardness. With regard to the question of impurities in the metal, the author treats of that very gingerly. He speaks of pickling, and Mr. McLaren asked: Why should the plates be pickled? I remember in one instance the Admiralty stipulated for a plate to be pickled before rolling. The idea was not so much to find out about the strength or about the phosphorus, but to see if the plate would resist the corrosive action. In that particular plate certain corrosive tendencies were shown, and the plate was rejected. That was the sole intention of the pickling. Further on the author deals with the question of disintegration by grooving. I think we find more grooving in land boilers than in marine work, and while it is eliminated in the modern boilers to a very large degree, grooving occurs in the latest construction, that is, the dish-ended boiler. In old Lancashire boilers the breathing space between the gussets and the furnace tops was 3″, it is 10″ in the modern boilers. The grooving is thus greatly eliminated, but not entirely done away with. The front end is where the grooving most frequently takes place, either in the root of the end plate if flanged to shell, or at the root of the angle iron or flanging of furnace to end plate, or over the top of the angle iron on the end plate. But the peculiar thing in some boilers is that instead of the end plate getting this grooving, it is usually on two or three flanged seams back in the boilers, which shows that strains are set up in the boiler itself as the cause, and not corrosion. Some modern land boilers have introduced into them instead of parallel tubes right through, rings alternately about 3″ to 6″ smaller in diameter than the other to overcome this grooving, and give better efficiency by breaking up the line of gases. Say it is 3′ 3″ at the end of the furnace, the next ring would be about 2′ 9″, then it is 3′ 3″ again, and so on to the back end. With the new dish-ended Lancashire boiler there are no gusset stays, the furnace tubes are flanged in the ordinary way, but, unfortunately, they have not been able to eliminate the grooving. This is still found in the root of the flange of the front end plate. In the second last paragraph the author says: "See that steam is raised slowly, and that the water is kept circulating when raising steam; keep boiler water slightly alkaline; scum and blow frequently." I am quite surprised that in the year 1911 that remark should have been made. The more you blow down the more scale you get. If you blow down you are blowing out water which has already deposited scale, to introduce other water which has scale-forming and corrosive properties. The great principle in land practice is not to change the water more frequently than circumstances permit, and I am surprised that an engineer should advise others to blow down repeatedly. Still, the paper all through contains a great deal of good advice, and is well worthy of the consideration of this Institute. I am pleased I have had the privilege of listening to it.

Mr. A. Robertson: It seems to me there are one or two points which have not been brought into this paper and which it might be of value to bring forward. From my comparatively short experience with boilers, I think it is very often a case of allowing the minor details of the engine room and boiler room to be neglected, and that a great deal of the trouble on board ship at the present time, and in the past, has been due to not taking notice of little details which are apt to escape one's attention. These minor defects gradually develop and create serious trouble, whereas if they had been taken notice of at the beginning they would not have been allowed to develop. One thing that not infrequently happens on board ship, especially when the junior engineer is a little careless, is neglect in looking after the evaporator supplying feed water. The evaporator is allowed to prime, and you get salt water as feed. There is no mention in the paper of the external care of boilers, and I think this a very essential point to which to draw attention. For instance, corrosion is occasionally found taking place on the front end plate, underneath the furnace fronts, owing to the want of something to protect the front of the boiler, the action of the gases from the ashes gradually causes deterioration and must be guarded against. The position of the feed water inlet also is, I think, very often responsible for deterioration. In one ship I was on we had to alter the position of the feed inlet, and we stopped to a very considerable extent the corrosion that had been taking place. The back stays were continually going at the necks and the position of the check valve was altered from being towards the centre of one of the combustion chambers to a position in between the two combustion chambers, so as to allow the feed water a clear run into the boiler, and that reduced the corrosive effect. We used to put in about fifty or sixty new stays after a trip of six months, so that you can tell there was very serious corrosion going on continually.

Mr. ALFRED COOKE : The paper to which we have listened this evening contains a great deal of sound common sense, and the author has pointed to most of the principal causes of deterioration inside the boiler. I think there is little doubt that a great deal of trouble is caused by oil or other impurities going in with the feed water. I have seen some cases of pitting and corrosion in the vicinity of the feed inlet, and, as mentioned by the last speaker, the position of the feed inlet has been altered with beneficial results. In my opinion impurities in the metal, alluded to by the author, have much to do with the trouble in some cases. I have seen new boilers where it was found almost impossible to stop the corrosion, and the remedy was used that the author refers to, of boiling the boilers out with a strong solution of soda, and this had the effect, eventually, of stopping the rusting. There was a slight tendency to prime at first, but that was soon got over. Then again the author speaks of faulty construction. No doubt in many cases that has been a bad point about the boilers, but I do not think it has been so much in evidence recently. I have been with boilers where it was absolutely impossible to get to the scale in certain portions of them. The stays of the combustion chamber and the shell were so close that you could not get a tool of any kind to work between them. I might mention one instance of faulty construction that came under my notice. It was a set of boilers, two double-ended and two single-ended. In a very short time, with the two double-ended boilers there was considerable trouble with the tubes leaking. There was no scale around the necks to account for it, and eventually the tubes were so worn away that some of them had to be renewed. When the new tubes were put in they were found to be an inch too long, and in cutting this off, on hammering upon it we broke it into fragments ; there was no elasticity in the metal at all. Eventually these double-ended boilers had to be re-tubed entirely. In the single-ended boilers there was little or no trouble. Further on the author says : " If a boiler is so constructed as to have a tendency to restrict circulation, it may give trouble. This has been known in a boiler that had too little space over the furnaces, to so overheat the crowns as to cause them to collapse." I have also seen that same thing remedied by taking the bottom row of tubes out.

Mr. TIMPSON : Mr. McLaren made reference to the difficulty of scaling boiler tubes. I was on board a boat some time ago where a patent tube scaler was used for running through the tubes, and I understood from the chief engineer that it cleaned them effectually. They opened up the boilers after the first short run, and found large deposits of scale on the top of the furnaces which had been loosened during the scaling. This tool was on the pneumatic principle, and lifted the scale off with a hammering action. It cleans from the fire side.

Mr. W. WALKER : They use it with the Babcock boilers also. It has a hammering action, but they get the same trouble as with the old style of cracking scale off by heat. It causes the tube to lengthen, and they have leaky ends after using it.

CHAIRMAN : A good deal has been said about filtering the water to prevent oil getting into the boilers. In my opinion the filters are always on the wrong side ; they are on the pressure side instead of on the suction side.

Mr. W. McLAREN : Mr. Walker referred to the fact that when the boiler was covered with scale this should not be taken as meaning that the boiler was safe. It takes years of experience for one to be able to detect the various peculiarities in connexion with the scale in boilers, and once he has gone through that experience he is rather on the safe side. The same thing applies to bleeding. I have never seen bleeding start in the manner described by the author, at the end of the paper. Bleeding is a very dangerous thing when not attended to, and the first cause of pitting. If you scrape off the scale and it gives the semblance of bleeding, you will find there is something wrong going on there.

Mr. JAS. ADAMSON (Hon. Secretary) : I should have prefaced the reading of this paper by saying that it was read originally at Hong-Kong, in connexion with the Institution there. I read one or two extracts when Mr. Ruck-Keene read his paper on boilers. The desire was expressed that the paper might be reprinted in full ; with the permission of the kindred Society and the author this proposal has now been carried into effect. Many of our old members will remember the days when the engine-room rather than the stoke-hold received the first care, but while Mr. Nelson's remarks might have been justified some twenty-five to thirty years ago, I believe it is not so to-day, as the boilers receive the best attention from engineers as a rule. It is so certainly in my experience, and my practice has been almost invariably for the last twenty-eight years to examine the inside of every boiler under my supervision every voyage, when emptied. I should say that troubles with boilers nowadays, for want of attention and management on the part of the engineers, are rare. The recommendation of an independent feed pump might be added to those given by the author, to lessen the amount of air, an excess of which is detrimental to the boiler. I have examined a set of boilers into which the feed water was pumped by the ordinary plunger pumps; the corrosion was visible over a considerable area inside and apparently attributable to excess of air. An independent feed pump was subsequently fitted with beneficial results. I do not think that corrosion along the line of fire-bars is now found to any extent, due to the improved methods of treatment in raising steam, in better circulation and in cooling off on arrival in port. The corrosion and pitting have generally been found at the line of the furnace where the great heat of the crown merges into the cooler bottom of the plate—the area covered by the conflict which takes place between the upper and lower temperatures. Some boilers have been found pitted at the back ends of the furnaces and fire-boxes, and others quite free from such, although apparently working under the same conditions; these differing experiences probably indicate differences in the material of construction or in the feed waters used, or to leaky valves keeping the bottoms wet when the boiler was empty. When steel for boilers was comparatively new defects were not uncommon, due partly to the material not being up to the high standard of the present day, and partly to the same treatment being meted out to the higher pressed steel boilers as to those they were gradually superseding. As experience and knowledge increased, by means of the Board of Trade publications, rules and memoranda, by discussions and interchange of thought among engineers, and by experimental tests and research on the part of manufacturers to understand and improve the material for the various purposes, the defects and troubles were gradually lessened and have become comparatively rare. One case was brought to my notice about two years ago, which reminded me of some of the earlier experiences with steel plates and furnaces splitting without apparent adequate cause. Two single-ended boilers in a group of five gave trouble in three of the six fire-boxes. The heads of the rivets binding the wrapper to the bottom plate began to drop off: closer investigation showed very fine cracks between the rivets on the pitch line; these were only visible when the rivets were out, as they started from the joint side of the plate and had not extended through the thickness. An attempt to weld the plate failed, as the cracks extended before the flame jet and opened out; the plates had to be cut out and patches fitted; the plates seemed to be hard. This might arise from one of several causes: Original material not being up to the mark, undue hammering or punching in building the boiler, or bad usage at sea or in port. These causes were carefully considered, and on investigation it was proved that the treatment of the boilers had been alike to one and all of the group, and on the best lines of modern practice. The material was approved tested steel, the rivet holes had all been bored, an analysis of the material showed nothing abnormal, and the mechanical tests were satisfactory. The portions cut out were tested without revealing adequate causes of the defects which had developed; and the plates, it was stated in reply to inquiry, had not been rolled to the bare breadth at the mills. Another peculiar case attended with serious results was that of the boiler of the *Pahud*, the shell plate cracked and burst under steam, and the boiler of the sister ship was said to have developed similar cracks, such having been found on examination. Referring to the process of pickling plates commented upon, I have in a former discussion stated the case of new boilers I examined after a voyage, where the shell plates in the steam space were found to be severely pitted under the mill scale, which was abnormally heavy. The scale was thoroughly removed and the bared plates coated with bitumastic solution. This course entirely stopped the action and the solution formed a fine protective skin, which after about eighteen months' service was found to be quite fresh and clean. The object of the pickling is to remove the mill scale before the plates are built into the structure, as it is admittedly detrimental and a cause of deterioration.

When a ship is laid up, the boilers especially ought to receive special attention. I have on occasions examined boilers which had been left to look after themselves for a season, awaiting a customer, and the results were far from pleasing; rust, scale, and pitting being severe on the surfaces of the plating, due to the water or moisture allowed to remain inside. A thorough course of scaling, cleaning and drying has usually stopped the bleeding action, then a coating of solution applied to the plates, and, before refilling, a quantity of zinc plates fitted, have proved efficacious in preventing further wasting. Many years ago, by friendly invitation of the owner, I examined a set of boilers which had been running without zinc for about nine months. They were among the first of the high-pressure class about twenty-eight years ago ; the furnaces were badly pitted, and the insides coated heavily with rust sediment, showing severe oxidation. From these observations it was manifest that zinc should have been used, and it would probably have prevented the deterioration. My experience is that zinc plates carefully attached are productive of good and preserve the boiler from corrosive actions. When electrogens were introduced about 1882, great care was taken to see that the contacts to the boiler and furnace plates were clean and good. However I found that in the boilers then fitted they were not efficient ; indeed in two cases they were quite the reverse and on sawing the zinc balls through to expose the copper bar, as I expected, there was a layer of oxide between the bar and the zinc, which destroyed the contact when casting the zinc ball round the bar. They fell out of use for many years, but were again placed on the market with improved methods of manufacture, to ensure clean contact between the copper bar and the zinc. The results have been certainly better in several boilers I have examined fitted during the last four years, due to the improved methods. The donkey boiler has had a much better life during the present than past generations ; and while formerly it did not serve half the time of the main boilers, it now remains co-existent with them, twenty years of work still leaving many of them almost unimpaired in health. Every part of a boiler should be accessible as far as possible, and the fittings, and internal pipes and connexions certainly, should be easy of access for jointing up and overhauling. While feed water filters are valuable auxiliaries, the use of oil for internal lubrication is avoided as a general rule, save what enters by swabbing the rods and when changing speeds on entering ports. The addition of soda when filling the boilers is good. With further reference to the quality of steel, several peculiar cases have come under observation and investigation. German steels give high results in tests, but it has been considered inadvisable to allow these tests to be a basis to work up to in practice. An instance of this may be cited in connexion with gas cylinders, the CO_2 makers demur as to recharging those of German make; a question arises whether the steel in certain processes of manufacture is perfectly homogeneous, and whether the scraps placed in the furnace to produce the billet may not have contained certain pieces with a greater affinity than the others for some of the ingredients which combine with the steel, thus rendering the rolled plate of varying hardness over its surface. The percentage of phosphorus and nitrogen are relatively very small in approved plates, but these percentages might vary in different parts of the same billet, or again the combined percentages of phosphorus and nitrogen may be in excess of the recognized limit which experimental tests have established. It was recently stated that some plates cracked without apparent adequate cause, and on investigation it was found that a number of plates had been placed one above another on leaving the rolls, and the outer edges of the plates were thus exposed to the cold weather, while the insides were kept hot by the pile; hence the inequality in the plates, and when work was put upon them there were failures. I have endeavoured to add these remarks as the reader of the paper on behalf of Mr. Nelson, with whom I agree on many points, but differ from on others, including those bearing on the blowing down, as referred to by other members.

Mr. Doherty: I might mention a matter which occurred to me while Mr. Adamson was speaking about plates. I was privileged a short time ago to see plates produced by an electric process taken up by a German firm. Ingots can be produced with any degree of phosphorus or nitrogen desired, as owing to their use of the electric arc any degree of chemical purity may be obtained.

Mr. W. McLaren: I have great pleasure in proposing a vote of thanks to the author for bringing this paper forward. It is very interesting both on the mechanical and on the chemical side, and he deserves our heartiest thanks.—Mr. F. M. Timpson seconded the motion, which was carried with applause.

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

MR. NELSON'S COMMENTS ON THE DISCUSSION.

RECEIVED FROM HONG KONG.

The heating of the feed water, I think, tends to preserve the boiler as a structure, especially the internal surfaces, as hot water cannot carry as much air as cold; this point was emphasized in the paper, on page 5. My experience with regard to oil is that when found in boilers it has lost all its fluidity and has changed to a gummy consistency. Of course, I admit this has special reference to what is seen at the water line, but I think it would be in a similar state on the crowns at first, till the heat again changed it to a spongy mass, after which the heat would be so great on the plate that the furnace would come down towards the bars and the spongy mass change to a kind of sediment.

Mr. McLaren asks: Why pickle plates? I have seen plates that seemed to have a good surface before putting into the pickle, but when they were taken out, the surface showed up quite differently; if the surface was not too bad it was faced up with a hammer. I understand all plates for the Admiralty must be pickled; this is remarked upon also by Mr. Watson, and is more fully referred to by the Hon. Secretary. I quite agree with Mr. McLaren in regard to a live boiler, and I meant to convey my idea as such—when I commented upon restlessness in a boiler I meant that restlessness of certain parts of a boiler relatively to other parts was bad, such as too rigid staying in certain parts, etc. The evil of such was dealt with in the discussion on a previous paper some time ago. Regarding the boiler that was boiled out with caustic soda, it was one of a set of boilers in a ship of about 3,000 H.P. The water was town reservoir water; very pure and soft.

Every engineer considers it bad practice to blow down a boiler, but you do not always have the time to wait till it has cooled and then pump it out. I was trying to express the best way of dealing with a bad practice; but I contend that if you wish to freshen your boiler slightly when you have a chance, say with the evaporator, it is far better to blow a little out at 53° F., for the reason I mentioned in my paper. Mr. Timpson says that "in reference to the use of sea water, the home-going vessels never use it." I am rather surprised some of the members did not question this statement, as it is a common thing for steamers to use only the salt " make-up " ; for instance, I might mention two Atlantic liners I know of—the *Majestic* and the *Teutonic* ; and I would point out also that one of our members read a paper some time ago, stating they filled up with sea-water and used salt extra feed on the ship he was on—a triple expansion job. Engineers have related hair-raising experiences with densities, of steamers using sea make-up and often after filling up with sea-water, on trips such as from British ports to South America. Again Mr. Timpson says : " Use the evaporator all the time and supply with fresh water, and there will be no corrosion or scale, as long as there is no leaky condenser." Well, I would not like to risk it, without testing with litmus ; or if I had none of that I would certainly put in some alkali on the off-chance, as otherwise you have everything favourable for pitting and corrosion.

I think Mr. Walker's statement : " Even if there is scale in the boiler, on it being chipped away a considerable amount of corrosion has been found existing underneath the scale," is far-reaching. I have seen the plates perfect under the scale ; also I have seen them bad, but I do not think any inspector or superintendent would pass a boiler without seeing under the scale, but where you find a whitish floury scale that will brush off easily, you invariably find a perfect condition of the plates. I take it that it is the " scum and blow frequently " that has surprised Mr. Walker, but I thought the previous part of my paper would have explained what I meant. I will try and make myself clearer : Boiler water gets a certain amount of sediment in it, also a certain quantity of oil, so that when rapid circulation stops, as occurs when engines are stopped, with banked fires or fires dying out, it is an excellent plan to scum a little and blow off say $\frac{1}{2}''$ measured in the glass. The former clears the matter floating on top and the latter the sediment at the bottom of boiler. My experience has proved it very beneficial to the boilers, and I still recommend it to engineers. Further, Mr. Walker says : " The more you blow down the more scale you get." I would like him to explain how he would get more scale if the make-up was from the evaporator, which is the most usual in good practice. Also I do not agree with the statement : " The great principle in land practice is not to change the water," as I certainly believe in emptying the boiler, say every three months, examining and cleaning, both in land and marine boilers, where possible.

Mr. Robertson states that I have left out the external parts of the boiler—well, the reason was I wanted to shorten the paper, and you can generally see what is going on on the outside. Besides the parts Mr. Robertson mentions, that portion of the shell round the valves on tops of boilers, should come in for some attention, owing to leaky glands. A good method, I think, would be to have an angle round them, and the lagging to stop at angles, so that the condition of the plates can readily be seen in their immediate vicinity. He touches on a very important point where he mentions the inlet of the feed pipes on the boiler. I have seen boilers with two and three different patches on the boiler end, where check valves had been and the plate had corroded away. It is most important to have the brass spigot of valve chest right through the shell, and the internal pipe jointed on to it. There are several other things I would like to mention, but owing to shortness of time to get these answers back I must leave them. In conclusion, I wish to thank the Chairman and Members for their discussion of my paper, and hope when I can get the time to prepare another paper.

The following were elected at the meeting of Council of the Institute held on Thursday, May 26, 1911 :—

As Members.

Emil Aitken-Quack, Birkenhead.
George Frederick Amor, Antwerp.
Reginald Bruce Baseley, Falkland Islands.
A. B. Clements, Shanghai.
Joseph Conner, West Hartlepool.
D. K. Dadachanji, Bombay.
William D. Farmer, Thornton, Fifeshire.
Charles M. Ferguson, London.
William Barton Kay, Gillingham. Art. Engr. R.N.
Alexander Macrae, London.
Engr. Lieut. William Edmund Marshall, R.N.
Robert Morton, Liverpool.
John Murray, Fremantle, West Australia.
David Myles, Wallsend-on-Tyne.
Thomas Neave, Hong-Kong.
Arthur Edward Philp, Liscard, Cheshire.
F. H. Roberts, Southport.
William Sampson, Liverpool.
Charles Norman Skipper, London.
D. Turnbull, Shanghai.
Thomas William Wilson, London.

As Associate Member.

A. John Lebeda, Leeds.

As Graduates.

Benjamin Charles Carter, London.
Ian Garvie, Gourock.
Joseph Martin Heesem, Plymouth.
Harold Burt Locke, London.

Transferred from Associate to Member.

William Britton, Aden.
Dhunijishaw Jemsetji Master, Karachi.