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# Experiences with Boiler Scale.

BY MR. WM. HENDERSON (MEMBER).

READ

*November* 1, 1909.

CHAIRMAN: MR. F. M. TIMPSON (Member).

CHAIRMAN: We are to have a paper to-night by Mr. Wm. Henderson on "Experiences with Boiler Scale." Unfortunately Mr. Henderson is unable to be present, and I will therefore ask Mr. Adamson if he will kindly read the paper on his behalf. No doubt the paper will be of interest to all who have to do with steamships and boiler scale. Mr. Henderson appears to go thoroughly into the subject.

A YEAR or so ago it was my fortune to serve as Second Engineer on a tramp steamer of some 3,600 tons, which was not then fitted with that useful adjunct to successful steaming —an evaporator. One does not expect to find such a berth a sinecure, and this particular one proved no exception. However, it supplied some interesting and useful if, at times, sad experiences; and a few of these I purpose now to relate.

Much of an engineer's pleasure in his work depends on the owners and his immediate chiefs. Proper fittings and stores he can generally get, but occasionally he feels that that confidence which should be placed in him and his suggestions is wanting. The consequence is that he is sometimes left to battle with circumstances that are a continual heartbreak.

My first proposition is to relate the incidents leading up to a furnace crown accident, regarding the cause of which opinion differs.

The ship, I understand, had been laid up for six months prior to being bought by our owners, and I was asked to join her at Barry, from which port she was to sail in two days' time. On joining her, I found her condenser opened for testing purposes, and I turned my attention to this duty. The condenser was of the usual surface-condensing type, ferruled with wood. The ferrules, however, were in an advanced state of decay ; so far gone were they that they could easily be pulverized between finger and thumb. Search and inquiry disclosed the fact that there were no spare ferrules on board that would fit, those sent being, somehow, sizes too large. Nothing could, therefore, be done, and the condenser was filled, when no obvious leak could be noticed. Of course the water level fell very fast, as one would expect from the combined porosity of 1,600 equally bad ferrules. The attention of the superintendent was drawn to the state of the condenser. He, however, was inclined to be optimistic, and expressed the opinion that the ferrules were good enough. I thought otherwise, but saw no good would result from discussion. The vessel had a triple expansion engine of 1,500 h.p., direct-acting feed pumps and donkey pump, steam being generated from two multitubular boilers. There was no filter, feed-heater or evaporator, so that in normal conditions extra feed should have come from the sea. After sailing, we found that extra feed was not required. We had water in abundance. Then the feed-pumps started making an awful hammering, being unable to cope with the water. We were finally obliged to shut them off, and use the donkey pump to take the water from the hot well. Still the hot well overflowed and latterly we opened all the available cocks and let back the bolts in two joints to allow the excess water to find its way to the bilge. At the same time we overhauled and repacked the feed-pumps ; but, on again trying them alone, found them insufficient. We then reduced the lifts on the main pumps' suction valves, and kept them working in conjunction with the donkey pump. This arrangement at last gave relief, but we had still the uncomfortable knowledge that most of our condensed steam was going to the bilge, and that in its place the boiler was receiving almost pure sea water. Consequently, when we arrived at our destination, eight days' sail, we found that the boiler water, which was fresh at Barry, was $\frac{4}{32}$ or 20 oz. Our boiler conditions were therefore most favourable to the production of troublesome scales, if it should happen that it would be impossible to scale the surfaces for any length of time. As these were practically the conditions prevailing at the time of the accident, you will, perhaps, pardon my dwelling on details.

During this first run it was the practice to put 4 lb. carbonate of soda into the boilers each day, and I was anxious to see the boiler results. On opening them, the scale on the furnace crowns was found to be $\frac{1}{8}$in. thick and very soft. Indeed as some of it came off in pieces scaling was easy. The deposition of scale, therefore, amounted to $\frac{1}{64}$-in. per day. While in port we filed down and fitted to the condenser some fifty of the large spare ferrules. Still, on leaving after two days the conditions were just as before. After scaling and refilling the boilers from the sea at 7 oz, we steamed twelve days to Antwerp, when the density had risen to 27 oz. (as before an increment of 2 oz. per day). On this voyage we did not scum or blow down the boilers, the intention being to keep water which had given up its scale-forming materials in preference to taking in sea water which contained these. At Antwerp we freshened the boiler water from the river, bringing the density down to 20 oz. ; and later, as the main engines were in use, we took the Sunday of our stay to pump out the boilers and fill them from the dock. I understand that this dock water has much organic matter in suspension, and, according to authorities, our action was not good. Consequently any scale on the heating surfaces would become very much harder and so more dangerous. We had just raised steam again when the owner came on board. He had the trouble explained to him and agreed that time should be given at our next port (Blyth) for condenser repairs. He must have forgotten, because when we arrived there we went at once under the coal-tip and loading began. However, we received on board 1,000 proper ferrules, and in the forty-eight hours in port contrived to fit 500 of them ; still we had 1,000 old ones. The boilers could not be cleaned, as men sober enough could not be got, and thus we put to sea. The additional 500 ferrules fitted at Blyth did good, inasmuch as we were now able to work with the feed-pumps alone. The condenser, however, was leaky enough still, and as before the boiler density was 20 oz. on the twelfth day. We were in sight of our destination (Genoa) when the centre furnace of the starboard main boiler collapsed. Our boiler pressure being 160 lb. we had reduced this to 130 lb. as the custom was, with the rise in density. The furnace was built up, and we arrived in port.

On opening the boilers, we found scale all over the furnaces $\frac{1}{4}$-in. thick, with an even surface except in the case of the injured furnace. Here, in the first four grooves from the back were found fine small crystals which were fused or burnt on the $\frac{1}{4}$-in. surface scale, making a total scale of over 1 inch. A part of this is here, and I hope it will interest you. These crystals or scales appeared to have fallen from the tubes above, for these, unlike the others, were entirely bare. In the port boiler, the corresponding grooves on the centre furnace had, in addition to the $\frac{1}{4}$-in. scale, a coating of the same crystals lying quite loose, so that they could be lifted by hand clear and clean from the surface scale. The surface scale here was comparatively soft and easily removed. The only hard surface scale met with was that over the injured furnace, which seemed dried or burnt and essentially changed in character, thus apparently giving it a heat conductivity of inferior character and bringing about a softening of the iron of the furnace crown. The explanation of the accident seemed, therefore, easy, viz., lack of time and staff to clean boilers, continuous sea-water feed from leaky condenser, consequent heavy deposition of scale extending over a period of thirty days, and probably the introduction of organic matter by filling from the dock at Antwerp.

When the ship again arrived in the Tyne a survey was called and the accident attributed to oil. This verdict seemed amazing, as free oil was never found below the water-line in those boilers. In my experience I have found that this oil is absorbed by carbonate of lime, and settles in a loose form, not as a dangerous scale. A sample of this I lay before you. At the densities at which we worked, the oil should not have had any great tendency to precipitate in the free state. Hence, it should only have precipitated with the carbonate of lime, which is generally supposed to be safe enough. If it had been present at our high densities it ought to have floated to some extent and then we should have had some indications of priming. In this case we should have scummed. However, the oil we were using at the time was of a poor quality as it turned out, and gave trouble later, causing the h.p. piston rings to be ground away. The impure residues were found in comparatively large quantities in the cylinders and valve casings, so that the percentage of oil finding its way to the boilers could not be large. I submit a specimen of the oil found in the piston.

I should like to hear opinions regarding the scale and the ultimate cause of the accident. Being a comparatively young member, I may be pardoned if the indication of my opinions regarding it seem out of line with the verdict of the survey. Still, the accident should never have happened if the manager had taken heed to suggestions from the engine-room staff, regarding the folly of sailing with a useless condenser. The chief engineer seemed to consider it his duty to sail if steam could be raised at all, and I have no doubt the blame fell on him, though the owners were really responsible.

Having ultimately got our condenser tight, it struck me to try a variation on our boiler procedure. Our custom was to scale boilers at a home port or at Rotterdam, where we could fill with fresh water, go out to Genoa, scale and refill from the sea there, and run home. I calculated that on the run from Genoa to Rotterdam (12 days), a scale of $\frac{1}{16}$-in. was formed $= \frac{1}{16 \times 12}$-in. or $\frac{1}{192}$-in. per day.

Scaling and refilling with fresh water, the run out (14 days) involved a rise in density to 13 oz. and a scale a bit under $\frac{1}{16}$-inch, i.e. less than $\frac{1}{16 \times 14} = \frac{1}{224}$ in. per day. If then, we avoided filling with sea water at Genoa, our total scale for the twenty-six days would be $\frac{26}{224} = \frac{13}{112}$, or less than $\frac{1}{8}$-in., whereas if time did not permit scaling but merely refilling at Genoa, our scale was rather over $\frac{1}{8}$-in. It seemed to me to be unnecessary to pump out water, though, at 13 oz. which had parted with its scale-forming matter and to replace it with water at 7 oz. which had not, and which might contain even more calcium sulphate than the usual sea water. In pursuance of this point, on leaving the Tyne as usual with fresh boiler water, I determined to make a trial. We arrived this time at Barcelona, when the density in each boiler was 7 oz. According to custom we should have parted with this water, but to prove my point to my chief we just emptied one boiler. There was really no scale at all, merely a white coating on the heating surfaces which was easily brushed off. It was then filled from the sea at 7 oz. Both boilers had still the same density, one having given up its scale-forming material, the other having it in suspension. For the short journey which would be the best system ?

At Rotterdam the data were :—

No. 1 boiler, steaming 26 days, density 14 oz., scale $\frac{1}{16}$-in.
No. 2 boiler, steaming 12 days, density 14 oz., scale $\frac{1}{16}$ in. full.
So that for that particular kind of voyaging the advantage lay with the new idea as far as labour was concerned, and slightly also regarding the amount of scale actually deposited. In this trip, as previously, 4 lb. of carbonate of soda were added per day. This is generally considered a very safe compound for boilers. True, it does attack the zinc plates, but that is not a critical point.

Another sample of scale which I submit to you is remarkable for the way it has peeled off from the metal. This was the result of an experiment with paraffin oil. The oil was rubbed into the clean metal and allowed to stand for a few hours. I have seen this same point referred to in some of the older papers of the Institute. The result seems most satisfactory. A further trial with the oil enabled us, after ten days' steaming, to go into the boiler and simply lift the scale away in sheets without using a hammer.

Turning to a pleasanter experience with boilers, I spent five years in the China trade in a ship which was fitted with Weir's evaporator and feed heater and an Edmiston filter. The boilers were cleaned every three months at some convenient port and filled with clean fresh water, the only chemical used being ordinary soda to the extent of 2 lb. three times a week. I never saw scale in any part of these boilers, and never saw any marks of deterioration on any plate. Surveyors would not credit our facts when they saw the boilers, but they are facts nevertheless. These boilers in question were fitted with Howden's forced draught, and were worked at 180 lb. pressure. This pleasant state of matters was, in the opinion of the engineering staff, entirely due (1) to careful working of the evaporator, (2) the moderate use of soda, (3) and the occasional change of boiler water, (4) fresh water being exclusively used to refill. This vessel is now eight-and-a-half years old, and the bloom can be seen on the iron to this day.

If then such conditions can prevail on one ship why not on another ? Therefore, I suggest that all such trouble as boiler scale should be eliminated from steamers by the adoption of the following principles.

1. Filtering of all water.
2. Evaporator should be fitted.
3. Heating of the feed water.
4. Adoption of a water circulating device.
5. Moderate use of soda.
6. Use of zinc plates.

I am pleased to say that the owners of the vessel I first spoke of have since fitted it with an evaporator, with good results.

In support of the above proposals let us turn to the nature of scale. This is defined as an incrustation on the heating surfaces of boilers formed by the deposition of matter previously in suspension or solution in the water used. This may be either mineral, or organic matter, or both. The first is not usually essentially changed in type by heat ; the latter may be. Every water supply contains a little impurity, and the very best contain lime, chlorides and many other substances. It is hardly necessary to say that most town water contains a surprising amount of impurity. The direct introduction of this into a boiler is therefore liable to form a scale. The formation of a scale introduces on to the heating surface a substance whose heat conductivity is less than that of iron ; consequently, more heat has to come from the fuel in order that boiler efficiency may be maintained. Thus if we consider the heat given out by the fuel to be constant, the amount passing through to the water is diminished. One authority estimates that $\frac{1}{16}$-in. scale diminishes the boiler efficiency $\frac{1}{8}$ ; so that, accepting the inverse square law, a $\frac{1}{8}$-in. scale reduces the efficiency to $\frac{49}{64}$ or = $\frac{3}{4}$. Again, assuming that more heat can be generated, this is only done at increased cost of fuel and a risk of softening the iron of the furnaces, which not being in contact with the water, is considerably raised in temperature.

A study of the following table should put the argument in a clear form. The substances named may be present in a feed water and the cures suggested bring out the points named.

| Substance. | Trouble. | Remedy. |
| --- | --- | --- |
| Muddy matter . . | Priming and incrustation | Filter, blow down or scum. |
| Sparingly soluble salts | ,, | Where feed is fresh, scum. |
| Bicarbonates of lime, magnesia (iron) | ,, | Heat the feed, and use a little caustic soda or barium chloride. |
| Sulphate of lime . . | ,, | Carbonate of soda. |
| Chloride of magnesia. | Corrosion . . . | Carbonate of soda. |
| Acid gases or vapours | ,, . . . | Feed heating (Weir). |
| Grease from engines or condensed steam | ,, . . . | Filter, carbonate of soda. |
| Organic impurities . | Priming and hardening of scale | Filter. Alum or ferric chloride have been prescribed. |

This table is got together from many sources, and the remedies proposed above for all feed waters are seen to be considered efficient. Filtering and feed heating get rid of mud, sparingly soluble salts, bicarbonates, much sulphate of lime, carbon dioxide and organic matter. A good evaporator gives proper extra feed, and proper agitation of the water in the boiler needs no further recommendation. Organic impurities cannot be entirely eliminated (and the same may be said of many others) except by evaporation, and that is going a bit far. Feed heating alone does not get rid of most acid gases or vapours, as these only separate from strong solutions, and even then leave a mixture which even distils unchanged. Here again, carbonate of soda neutralizes these. Where scale-preventing appliances are not fitted, one has considerable trouble even in deciding what the proper antidotes are, and no hard and fast rule can be set ; although, for example, the above table may be taken as a safe general guide. I quote an experience on a coaster between London and Goole. The boiler water was taken from the Thames, and, of course, contained lime and organic matter which the table would lead us to expect should form a very hard scale. While in London, boiler and feed tank were filled up, and, after one month, on opening the boiler a hard scale of $\frac{1}{8}$-in. was found, which was very difficult to remove. To improve matters, both carbonate of soda and sal ammoniac were used, with good results. Sal ammoniac, at the temperature of boiling water, easily dissolves up carbonate of lime, and the soluble carbonate should decompose the sulphate of lime present. The observed result was that the water surface was kept clear, while the precipitate ultimately formed a very soft scale, which was easily removed. Scumming was not so necessary, a good thing, as we could not afford to do this often.

I may be pardoned a last word which has regard to oil. I have mentioned already the evils of the oil supplied in the ship first named. Most machinery oils are faked up with vegetable oils, which change with heat. Pure mineral oil will not damage iron surfaces, even in boilers, to a fraction of the extent caused by imitations. I am sure you will agree with me when I say that a good o'l pays its way.

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CHAIRMAN : I think we can all quite appreciate Mr. Henderson's troubles with a leaky condenser. Oil has been a fruitful source of trouble with furnace crowns, and I have also heard of instances where oil has been blamed and on examination no trace of oil was found. In his closing remark Mr Henderson says that it pays to use good oil. There can be no doubt of this, and I do not think any company of standing would give anything but a good cylinder oil at the present day. Mr. Henderson remarks on the use of paraffin oil. The boiler insurance companies will not allow it to be used at all now, owing to the danger of explosions when the boiler is opened up. I understand there have been several cases where men have been injured through this cause. A few years ago a Clyde river steamer used paraffin largely to prevent priming. It is searching as regards scale, and that sample Mr. Henderson shows justifies his contention that rubbing the surface with paraffin oil tends to prevent the scale from adhering to the surface.

MR. JAS. MARTIN : I have seen Rangoon oil used for taking the rust off the deck of a ship. It was simply applied with a brush and left for a day or two and the rust was then shovelled up. Rangoon oil is merely prepared from crude paraffin.

CHAIRMAN : In the case he refers to Mr. Henderson points out that " the verdict seemed amazing as free oil was never found below the water line in those boilers," yet the accident was attributed to oil. He goes on to say, " I should like to hear opinions regarding the scale and the ultimate cause of the accident." Of course we know that scale impregnated with oil would be a worse conductor than scale alone. Mr. Henderson has evidently taken a great deal of trouble in specializing each particular sample he has put before us. There are points in his remedies for the various troubles which perhaps some of our members might pass a criticism upon, and the meeting is open for any remarks they may have to make upon the paper.

Mr. E. Shackleton : As far as these deposits of cylinder oil are concerned I should be pleased to have a proper technical report made upon them if such would be agreeable to you ; I think it would perhaps be better to have an analysis of them before making a definite statement. With regard to the adulteration of cylinder oils, I should think the author of the paper is somewhat adrift because I think even if the manufacturer desired to adulterate cylinder oil he would not use vegetable matter—in fact, he would be out of pocket if he did so. As to the use of paraffin, I should say that if it were used for the purpose of keeping down scale, even under emergency conditions, the manufacturers of packing, especially for the main steam pipe glands, would soon be protesting. Paraffin has a very bad effect upon packing in conjunction with water if used for any length of time. The author also advocated sal-ammoniac with the idea of decomposing the sulphate of lime. Perhaps in cases of emergency that may be used with good results, but I think if the ship were going to lie up for a month or two after that treatment there might be various opinions about the state of the boiler mountings and other fittings. It is well known that sal-ammoniac, if left for a while, will rust almost anything, so that I think it would require to be added in very small quantities.

Mr. E. W. Ross : Those who are continually at sea get experience on points we on shore do not see much of, although we certainly see the effects very often, but Mr. Henderson appears to have been particularly unfortunate in the voyage he describes ; it is very unusual nowadays to be without means of using sea-water by use of evaporators, especially with a boiler pressure of 160 lb. Cure is one thing, prevention another, and the paper seems to point the moral that we should devote our attention more particularly to prevention as the best means to keep the boiler free from scale. This is an important subject, and if we defer it for another evening possibly we might get more sea-going men here to give their experience for the benefit of all.

CHAIRMAN : It certainly seems, as Mr. Ross remarked, that Mr. Henderson was very unfortunate in the first experience he relates. It was rather hard that he should be sent away with such poor means of coping with the difficulty ; it is far from being a usual thing, as any shipowner with any regard for his property would not allow it. I had an experience about eighteen years ago on a coasting boat under somewhat similar conditions, but only making a twenty-four hours' run either way. The condenser plate was cracked, and we had a lot of trouble with the boiler tube ends leaking as a result of the scale forming round the necks. It was a somewhat similar experience as to the loss of fresh water, but Mr. Henderson had the trouble with the condenser ferrules.

Mr. RAINEY : I cannot help thinking very often that this question of scale is a matter for chemists. The writer of the paper seems rather in doubt as to what scale consists of, and I think if that were determined it would soon be found whether the trouble was due to oil or salt water or to organic matter in the water. As far as I can see the only remedy to prevent impurities is to provide sufficient evaporators, not capable merely of doing the bare amount required of them. I think evaporators, as a rule, are too small.

Mr. G. A. BRADSHAW : I should like to make a short remark about the author's statement regarding the presence of scale diminishing the efficiency of the boiler. He says that " one authority estimates that $\frac{1}{16}$ in. scale diminishes the boiler efficiency $\frac{1}{8}$ ; so that accepting the inverse square law, a $\frac{1}{8}$ in. scale reduces the efficiency to $\frac{3}{4}$ in." The firm I am interested in used to have all their scaling and cleaning done by their own staff ; but it was then found that the scaling was not done properly. At that time we used to find as much as 1 in. of scale on the back plates of the combustion chamber and the girder stays were blocked up solid. Subsequently we had the cleaning done by contract and by men accustomed to and expert at such work with suitable appliances, and yet we did not find any appreciable difference in the coal consumption, which is rather striking. We expected to find a big reduction in the coal consumption, the working conditions being similar. If $\frac{1}{16}$ in. scale makes a difference of $\frac{1}{8}$ in the efficiency, 1 in. of scale should make a very appreciable difference.

CHAIRMAN : Of course, it all depends upon the service in which the boat is engaged. In an intermittent service even with the most improved machinery you do not get the same results as in a long voyage ship. In vessels raising steam every day you do not see such a marked difference, and perhaps there are not the same facilities, under the two conditions, for making careful observations.

Mr. JAS. ADAMSON (Hon. Secretary) : In connexion with this matter of the oil, Mr. Henderson refers to there being no free oil found below the water line. It is somewhat difficult to see how he has verified that as we know that whenever oil reaches a superheated surface it changes its appearance. I am not quite sure but that the furnace did come down on account of the oil interposed between the water and the plate. If the furnace becomes so hot the oil would be burnt off and you might not be able to trace it. It would be very interesting if Mr. Shackleton could tell us what the oil merchant really might put into the cylinder oil to cheapen it. We get engine oil very much cheaper than cylinder oil, and I do not see how the mixing would not be to the apparent and temporary benefit of the oil-merchant.

Mr. SHACKLETON : Referring to that question, it is easy to see why the merchant would not use a good vegetable oil. Even cotton seed oil is worth, I suppose, about £20 a ton, and the merchant selling oil at 6*d*. is not going to use an oil worth 1*s*. 8*d*. to adulterate it. Olive oil is at about £40. Every marine oil contains a percentage of vegetable oil, but as far as cylinder oil is concerned a crude mineral oil can be obtained practically cheaper than the vegetable. Certainly if a vegetable oil were used it would be disastrous. Olive oil, even the purest, may contain higher than 20 per cent. of fatty acid. Even apart from olive, which is quite out of the question—it has long since ceased to be a marine oil—I think unless the advantages are very abnormal the average oil merchant would not think of putting into the cylinder oil anything in the nature of vegetable oil.

CHAIRMAN: It was at one time very common to use tallow. I do not know whether these cylinder oils are treated with animal oils. Possibly that might be more possible than that they are treated with vegetable.

Mr. SHACKLETON: That was the practice, but the same explanation covers the disuse of tallow for this purpose as all the best tallow nowadays is used to make margarine. Anything at all in the nature of fat is now an edible article. Mr. W. H. Lever called attention some time ago to the fact that a number of oils previously used for soap-making are now in use for making margarine. There is one matter a lot of research is required upon, that is the various changes certain waters have on oil in the boilers. For many years investigations have been made regarding the action of water on the enclosed crank chamber engine. It is surprising to what extent ordinary engine oil in a crank chamber engine is emulsified, and that is undoubtedly due to certain actions of the water which leaks in. That water has been softened, and my opinion is that the softer the water the more damage it will play in a boiler. If the water is hard it splits the oil up and carries it about in globules, whereas soft water tends to absorb it.

CHAIRMAN: I think Mr. Henderson speaks of the water being fairly hard in the instance he gives. I suppose there is some objection to the extensive use of soda as it eats away the boiler mountings very badly and spoils the valves. I do not think it is so much used as it once was, but of course there is a diversity of opinion as to the treatment of boilers. The general principles laid down in the paper are mainly on modern day practice. The feed water is heated generally, in one type of heater or another, and undoubtedly splitting up the water at high temperatures carries free air and other injurious substances out of it before it enters the boilers. A good many of the Transatlantic boats are now making round voyages without touching the boilers.

Mr. MARTIN: I am an advocate of the use of soda in boilers. In my experience in various ships it is most beneficial if used judiciously, and after the use of carbonate of soda I have never found any trace of oil in any part of all.

CHAIRMAN : If it is desirable we might have a further discussion on the 29th of this month. Mr. Henderson has taken some trouble to put the subject before us, and it would be interesting to know the result of the analysis which Mr. Shackleton has kindly promised to have made.

It was agreed on the proposal of Mr. Rainey, seconded by Mr. Martin, that the discussion be adjourned till Monday, November 29.

Mr. JAS. ADAMSON : I rise to propose a vote of thanks to Mr. Henderson for his paper ; it is one which will bear a good deal of discussion. Obviously there was a big mistake made in allowing the ship to go to sea in the state Mr. Henderson describes, but having so gone apparently they did their best to overcome the difficulties. He remarks about density of the water which had already parted from its scale ; that, of course, is a practice well known to us all, although the old rule was to scum and blow off to reduce the density. One thing that struck me was the quaintness of the remark about the short memory of the owner, who forgot, when the ship came to Blyth, his promise to get the condenser put right. I think that is a point which might be dwelt upon with advantage by some owners who may be gifted with "short" memories in similar cases, although it might otherwise involve losses in a time charter. I do not suppose there are many wooden ferrules in use now for packing condenser tube ends. The spare ferrules are always made large and are reduced when required by compression in the machine provided for the purpose. With regard to this matter of oil in boilers, it has nearly always been a contested point whenever a survey has been called on collapsed furnaces as to the cause, but the consensus of opinion on the part of the surveyors is usually that oil often causes the collapse of furnaces, although no trace of the oil may be visible. In some cases the surface has been scraped, and the scrapings, on being analysed, showed that oil had been present, although it had been burnt up and was not distinguishable by the naked eye, so that the value of Mr. Shackleton's proposal is evident. As I have remarked, when oil does deposit itself on a hot surface, it alters its character and becomes a hard carbonized substance which has not the appearance of oil. Possibly one of the surveyors, in the case mentioned by Mr. Henderson, scraped a portion of the sediment from the collapsed furnace and in that way came to his determination. Of course, it is difficult for us to say anything about the case without having the whole of the facts before us, when surveyors, even with everything before them, are often unable to say what is the cause. I think that is a point worthy of discussion, especially as Mr. Henderson expresses himself as a young member desirous of getting the experience of those who have had more than he has had. I have pleasure in proposing that we accord to him a hearty vote of thanks. Mr. J. Martin seconded.

## DISCUSSION ON MR. HENDERSON'S PAPER.

*Monday, November* 29, 1909.

CHAIRMAN: Mr. J. G. HAWTHORN (HON. MINUTE SECRETARY).

CHAIRMAN: We are met to-night to continue the discussion on the paper by Mr. W. Henderson on "Some Experiences of Boiler Scale," a subject which is undoubtedly of great importance to the sea-going engineer. The introduction of sea-water into a boiler is to-day one of the greatest troubles an engineer has to contend with at sea, and anything that can be brought before the Institute which will enable our members to discuss the troubles arising from this source will be of great value. It is a subject we do not often get records of experiences of; we are dependent to a great extent upon books, notably by Professor Lewes and others, and have to rely a great deal on the theorizing of these gentlemen, so that to have before us, as we have in this paper, a record of practical experiences, must be of great value to all of us. I will now leave the meeting open for the discussion to be continued.

The HON. SECRETARY: At our last meeting we had before us a number of samples of scale which Mr. Henderson was good enough to send. These have been analysed and the results of the analyses are now in our hands. I have also one or two letters from the gentlemen who have been good enough to get the analyses for us. These I shall now read.

Mr. J. Veitch Wilson writes as follows:—

"I have read and re-read Mr. Henderson's paper with interest, and the more I read it the more I sympathized with him in the difficult position in which he was placed. The pity of it all is that despite all Mr. Henderson's sufferings, and despite the careful and exhaustive analysis which our chemists have made of Mr. Henderson's samples, I fear that no great light will be thrown on the questions involved, since the data is so irregular—leaving Barry with fresh water, filling up with salt water, river water at Genoa, salt water on the voyage to Antwerp, then a charge of the fine rich muddy water of the Scheldt; what do you wish for more to 'make up' a boiler!! Of course you may say that such cases occur as this one occurred; I trust, however, that British shipowners know their interests better. But be that as it may it is impossible to draw definite conclusions from such indefinite data. I enclose two reports by our chemists on the samples sent me, my own views are:

"*A*. This deals mainly with the oily deposit which, in this case, is very much what we are occasionally privileged to see from steam cylinders and from gas engines. What happens in these, as it seems to have happened in the case you are considering, is that, unless there is a strong scavenging action, a little oil is left in nooks or crannies of the cylinders or valves, gets slowly reduced in bulk by the heat of the cylinder, seizes any dirt which may come over with the steam, seizes also any abraded or oxydized iron, and gives us, as our chemists say, 'Ash, principally iron with some copper and silica,' the silica, I suppose, from the river or dock water.

"*B*. Deals with the scale found in the boilers. The nature of this scale would depend greatly on the water used in the boilers, and in the case of the mixed water used in this boiler it must be hard to say what is responsible. I am, unfortunately, no chemist, but it seems that this scale is much richer in sulphate of lime and lower in magnesia and carbonates than one generally finds from an unmixed sea-water, and it is therefore fair to assume that much of this has come from the river or dock water which Mr. Henderson picked up on the voyage. As it occurred to me that you might like to have the opinions of a boiler expert on the question, I sent copies of our analysis to my old friend Mr. Crosland, of the Vulcan Company. I enclose his replies which you are at liberty to read to the meeting if you think them of sufficient interest."

The letter referred to, from Mr. J. F. S. Crosland, is as follows:—

"I am in receipt of yours of the 23rd with enclosure, regarding which I have to say with regard to the analysis furnished of the balls of deposit from the valves, it would have been more interesting had more information been given, which would have been helpful to arriving at the cause of their formation. One hypothesis accounting for them would be that the oil, which is an important constituent of them, contains some saponifiable matter, which, in presence with lime and magnesia, would form a substance analogous to putty, which would act in attracting the adherence of other matter sent through the valve. It would therefore appear highly interesting to get some further information with regard to the oily matter and also with regard to the constituents of the ash. With regard to the sample of deposit formed from sea-water, it has been proved, I think, beyond doubt that such deposits vary according to the position from which they are taken from the boiler. The sodium chloride we would hardly think would be a constituent of the scale *per se*, but would be left on the scale when the concentrated water is blown from the boiler. The most important question at present affecting the constituency of scale from the sea-water is whether the magnesia comes down to any great extent as hydrate or as carbonate. As the boiler has been worked with sea-water as well as land water, presumably containing some fair amount of temporary hardness, an investigation as to the state of the combination of the magnesia would be additionally interesting."

Mr. Crosland writes again as follows :—

" With a desire to help you in explaining the formation of such like bodies as the deposits found in the valves, I may mention that we do find what, for want of a better term, we may call a mechanical affinity between amorphous substances and oil or greasy matter, quite independent of whether it is saponifiable or not. It is this fact which makes us so suspicious of the presence of any "floury deposit," because of its tendency to attract and make a constituent of any scale of any emulsified oil occurring in the feed water. With regard to the further information furnished me in reference to sample 3, it is quite in keeping with the remarks of my previous letter that there is a tendency for the deposits formed from sea-water to select different parts of the boiler for their aggravation."

The following is a copy of the analyst's report :—

*A.*

INSTITUTE OF MARINE ENGINEERS.
*Nov.* 10, 1909.

DEPOSITS.

(1) Ball of deposit from valve.
(2) Unmarked, apparently similar to (1).
(3) Boiler deposit.

| | No. 1. | No. 2. |
|---|---|---|
| Oil and volatile matter | 24·1 | 39·8 |
| Coke | 1·3 | 0·1 |
| Ash | 74·6 | 60·1 |
| | 100·0 | 100·0 |

Ash principally iron with some copper and silica.

No. 3 principally sulphate of lime with some sodium chloride. Traces of iron, alumina and magnesium salts.

*B.*

*Nov.* 24, 1909.

DEPOSITS.

Referring to our report of 10th instant, we have made a further examination of sample No. 3 and find it to be composed substantially of :—

| | | |
|---|---|---|
| Sulphate of lime, $CaSo_4$ | 90·0 | per cent. |
| Sodium chloride, NaCl | 5·0 | ,, |

Remainder water, trace of magnesia and undetermined substances.

Analysis shows these to be common and ordinary types of cylinder balls and of boiler deposits.

The latter has not been produced in presence of any efficient quantity of soda as it has little carbonate and is practically all sulphate of lime. The salt in it is moderate in amount, showing that the last water has not been too dense.

There is no oily matter in this scale, showing that no great quantity of oil has been in the boilers. If this sample of scale has been taken from the furnace crown which collapsed, or near to it, the absence of oil does not agree with the conclusion come to after survey that oil had caused the collapse.

Mr. F. M. TIMPSON : Mr. Henderson seems to want an opinion on the specimens of scale sent, more particularly on that on the furnace which collapsed. His contention that there was no oil in the boiler seems to be borne out by the results of the analyses Mr. Shackleton kindly obtained for us. I do not think scale is quite so common nowadays in marine boilers, but in land boilers where very chalky water is used scale is found in heavy quantities, but in speaking to a boiler surveyor of very wide experience he mentioned to me that he had never known a case of collapse owing to scale in any of the boilers under his inspection. It is very hard for members of the Institute to pass an opinion regarding the collapse of this furnace without having been there to inspect the case for themselves, but to all appearance the result of the analyses seems to bear out Mr. Henderson's assertion that oil had nothing to do with the collapse of the furnace.

Chairman : This subject of the formation of scale in boilers is one not properly understood by most sea-going engineers. At a temperature of 287° F., equal to 35 lb. pressure by gauge, 500 lb. of water are required to dissolve 1 lb. of sulphate of lime ; at 200° F. 400 lb. of water are required to dissolve 1 lb. of sulphate of lime. The molecules of sulphate of lime are crystallized out at 287°, and one can easily understand the dry scale being wholly and solely composed of sulphate of lime, or at least 90 per cent. of it. Feeding with sea-water and keeping the density at 20 oz., there should be magnesia in the scale, because the whole of the magnesia is deposited due to concentration, not crystallization; that is, in relation to deposition taking place due to the density rising from $3\frac{1}{2}$ to $4\frac{1}{2}$ 32's. Salt itself will crystallize when $\frac{6}{32}$ is reached. The presence of salt leads one to infer that the collapse had taken place in that part of the boiler where the circulation was bad, where the density had increased much beyond that at which they had tested the boiler. In my younger days I have seen boilers working, using the auxiliary feed water, at a density of 10 oz. to the gallon ; below the furnace, 16 oz. to the gallon, and at the back of the combustion chambers up to 22 oz. per gallon. But in the case Mr. Henderson speaks of we cannot say that the density was too high, because, as the analyst's report says, "the salt in it is moderate in amount, showing that the last water has not been too dense." Now, probably, had that sample been taken from another part of the boiler it may have been found to contain more salt. Salt is never found in the lime, it is always on the outside of the scale, the lime playing the part of binding material. In the crystallizing process the effect in the vicinity of each molecule is a tendency to draw these other matters into it. The first layer is clean dry scale, sulphate of lime, the middle strata contains a certain amount of magnesia, and the outer strata chloride of sodium ; so that the fact of the scale being purely sulphate of lime leads one to infer the collapse was not due to the density, but that the density was really lower than that stated in the paper. To use the sea auxiliary up to 20 oz. is not the correct thing; 15 oz. is as much as one should have. The Admiralty Boiler Committee recommended 35 to 40 degrees, and never to exceed the $3\frac{1}{2}$ to 4 32's when working with jet condenser. There is no difference between that and using the sea auxiliary feed. Then there is the question of the oily matter which will find its way into the boiler if we have internal lubrication. Professor Lewes, at the Institution of Naval Architects, showed that the saponification which takes place forms what he terms "fatty pancakes," which become heavier and eventually settle down on the tops of combustion chambers, furnaces and other parts of the boiler, thus getting the force of the jet of flame striking that spot. It is known to be a bad conductor of heat, and as a result the temperature of the plate goes up; when it reaches 650° it loses in tensile strength, and at 900° it loses 30 per cent. in tensile strength—that is, say, the combustion chamber. Under extreme circumstances this extreme heat concentrated in one spot not only raises the temperature of the plate but actually melts it, so that collapses due to oily matter are easily understood. My experience at sea is this, that as the temperature begins to rise the dry clean scale becomes cracked off long before the temperature at which the collapse occurs is reached; but in this case the scale remained on the plate after the collapse occurred which makes the matter all the more difficult to explain. I have been with the old jet-condenser boilers—sea-water feed and boilers working only at 10 to 12 lb. pressure by gauge—where the deposit was right up to the top of the furnace, not hard scale, but a substance like dirty pipeclay. These deposits were due to the rise in density; scale cannot be formed under 35 lb. pressure. The sulphate of lime is that which binds up the other substances; without it there would be no scale, but when it is present in the proportion of 3 to 5 per cent. it is capable of binding up the other deposits, the process being greatly accelerated by the presence of oil, and thus one can easily understand a big percentage of sulphate of lime in the scale. There is about $\frac{1}{8}$ oz. of sulphate of lime in a gallon of sea-water, about $\frac{3}{8}$ oz. magnesia and $4\frac{1}{2}$ oz. salt, yet the $\frac{1}{8}$ oz. of sulphate of lime causes the greatest trouble throughout in binding up the others. It will be seen, therefore, how necessary it is to get the density at that particular point where the danger is greatest, the furnace crown. In reading the Board of Trade boiler reports I noted one case arose out of a broken salinometer cock, owing to which the water was drawn from the gauge glass for testing. They were not sure whether the water in the column was the same as that in the boiler; evidently they were getting fresher water, and this led them to go on until the density was such that deposition took place and the furnace collapsed through the formation of scale.

Mr. A. Robertson: After looking at the sample submitted it hardly seems to me that the collapse took place through the formation of scale in this instance, because I have often seen scale quite as thick on furnaces and no trouble ensued. I believe it is the case at times that the scale forms on the surface of the furnaces and the water is held up from the crown, in which case, of course, there is very often local heating and collapsed furnaces. It is very difficult, under the circumstances, not having seen the furnaces, to give any opinion as to the exact cause of the collapse.

Mr. F. M. Timpson: Mr. Hawthorn's remarks may help to throw some light on the subject. I remember a case some time ago of a small launch in which the furnace came right down on to the fires. The boiler was practically solid with salt. I do not suppose they tried the density or ever cleaned the boiler out, but in that case there was no oil to cause the trouble. It is probable that they were dealing with a higher density than they had any record of, and in that case the high pressure steam, which I presume was used, would bring about the collapse all the quicker. Scale similar to that as shown from the furnace crowns is not altogether uncommon—at least, it was not uncommon a few years ago—but in a properly equipped ship one would never anticipate such a deposit as shown in the sample.

Chairman: Some years ago Sir John Durston carried out experiments at Portsmouth on the subject of the conductivity of plates with the scale on them. I am hardly sure of the data, but I think, if I remember correctly, he said there was a 15 per cent. rise of temperature for the first $\frac{1}{16}$ in. of scale on the plate, taking a $\frac{1}{2}$ in. plate. There was a difference of temperature of 40° between the fire side and water side with both in a clean state, and then with $\frac{1}{16}$ in. of scale on the water side the difference of temperature rose 15 per cent. ; for the next $\frac{1}{16}$ in. it rose 40 per cent. on that again. Supposing we take the temperature on the water side at 420° with both sides clean, with $\frac{1}{16}$ in. of scale this would mean an increase of 15 per cent., or 60°, making the temperature 480° ; if another $\frac{1}{16}$ in. of scale were added, the temperature would be increased by 40 per cent., or 190°, giving the critical temperature of 670°. I hardly think that $\frac{1}{8}$ in. scale brought down the furnace crown under these conditions, unless there was a deposit on the outside. The black appearance would suggest the presence of oil.

Mr. TIMPSON : The chemist's report says that there is no trace of oil whatever.

The HON. SECRETARY : Mr. Henderson says : " On opening the boilers we found scale all over the furnaces $\frac{1}{4}$ in. thick, with an even surface, except in the case of the injured furnace. Here, in the first four grooves from the back, were found fine small crystals which were fused or burnt on the $\frac{1}{4}$ in. surface scale, making a total scale of over 1 in. That was found on the other furnaces which did not collapse. There is one piece of scale which has a good deal of carbonized oil in it. One of my first experiences with a boiler scale was when serving my apprenticeship. I was sent with a journeyman to overhaul the vertical boiler and two cylinder engine of a small coasting steamer. When we reached the scene of operations, we found the fire box plates with pockets, due to the heat buckling, the worst one being cracked. This we cut away and fitted a patch. We found the scale inside the boiler to be very heavy—in some portions of the heating surface it was about $1\frac{1}{2}$ in. thick. I preserved an unique sample for many years, but being latterly lying in a position exposed to weather conditions it melted away. The peculiarity of this scale was that the first layer was white, the second black—coal dust—and the third a compromise between these. There had been three drivers, each of whom had apparently left his witness on the scale.

This photograph shows a furnace which collapsed abroad, and when discussing the possible cause I was informed that some South American waters were very bad for boilers, and possibly the collapse had been due to filling the boiler from such a source, as the collapse occurred in that neighbourhood. We have in the museum sealed bottles of boiler water from 25 to 30 years old of high densities from boilers which worked at

60 lb. pressure, the duration of the voyage in some cases being five months without emptying the boilers. There was comparatively a good deal of scale in the boilers, particularly about the tube plates and tubes, but no trouble was experienced. A furnace may collapse and the cause be attributed to the presence of oil, yet no trace of oil appear on the furnace or in the scale found near ; yet by scraping the plates a sediment is obtained which on analysis has been found to contain oil changed in appearance and carbonized by the abnormal heat ; hence it is a pity we had not any of the scrapings from the furnace in this case, so that we might have had them analysed as well as the scale. There are samples of scale which undoubtedly contain oil, although this particular piece of scale which was on the furnace does not seem to have any trace of oil in it. Mr. Henderson's point is that he would like if we could indicate how that furnace collapsed if it were not due to the presence of oil—and he himself does not believe that the oil caused the collapse ; but as Mr. Veitch Wilson pointed out, it is almost impossible for us, with the small amount of data we have, and without seeing the furnace and the design of the boiler and stays, to attribute the cause to either oil or scale. The collapse is usually due to abnormal heat and expansion in the direction of least resistance.

CHAIRMAN : There is another point with reference to oily deposits pure and simple. Oil, to be a good internal lubricant, would contain two essential properties. The first is a good gravity and the second a high flash-point. As Professor Lewes pointed out before the Institution of Naval Architects these two properties are undoubtedly good for the cylinders but bad for the boilers, for a light oil is easily carried round by the convection currents, creating saponification ; then after a time it becomes deposited. The question is the temperature of the collapse ; at what temperature does the furnace come down ? Of course, the pressure is independent of the temperature. The furnaces would not be brought down at 900° with a pressure of 60 lbs., but may at 180 lb. with a lower temperature, so that the question is, whether, when the temperature of the furnace is raised, the oil would not be melted off, because it is quite possible that the temperature which caused the collapse is the temperature at which the oil is melted off. That would account for many cases of collapse due to oil, although no oil was present afterwards, yet if some of the deposit in the bottom of the boiler were examined a certain trace of the oil would be found. When the oil is mixed with the scale it cannot be melted off. It would be very interesting to know at what temperature this furnace did come down. As I said, the critical temperature is about 600°. At 900° the material loses 30 per cent. of its tensile strength and with a reduced tensile strength of 30 per cent. 180 lb. pressure may collapse it. One can easily understand very dense water being used in a very low pressure boiler. If the boiler is red hot, and there is no pressure there would be no collapse. With a pressure of 160 lb. in the boilers and a rise of temperature approaching 700° to 800°, we can understand a collapse taking place, and the probability is that if the collapse were due to the presence of oil, that temperature would have melted the oil off.

Mr. A. ROBERTSON : In the case Mr. Henderson gives they seem to have started in a very bad manner—that is, in feeding the boilers right up with dock water. That would not be of the best in any case, but Mr. Henderson goes on to state :—

"The surface scale here was comparatively soft and easily removed. The only hard surface scale met with was that over the injured furnace, which seemed dried or burnt and essentially changed in character, thus apparently giving it a heat conductivity of inferior character and bringing about a softening of the iron of the furnace crown."

I can easily understand that the hardening of the scale would be due to the very fact of the burning of the furnace, without accepting the explanation that the hardening of it caused the furnace to come down. I should think it was the reverse; the scale was the same all over and at the particular point the intense heat hardened it.

CHAIRMAN : Another point lost sight of is the introduction of soda. Many of us do not take into consideration the fact that when soda is put in it raises the density. Engineers take the density with the salinometer and blow down and find a rise of 20 oz., perhaps 10 oz. of which is due to the presence of soda in the boiler. Anything which water will dissolve increases its weight.

Mr. F. M. TIMPSON : I have seen a scale formed of soda. in one instance, in one of the Dublin boats sailing out of Glasgow, They were troubled with corrosion and started feeding in with soda. The scale was absolutely soda scale. If running on ordinary conditions with sea-water at a reasonable density, and if the boiler is then allowed to cool down, usually the scale does not get very hard. I think one authority recommends allowing the boiler to cool right down and then the deposit may be washed off.

CHAIRMAN : The practice used to be to run the boilers right out and then light fires in the furnace to crack the scale off.

Mr. TIMPSON : If it were washed away first it would take away a good deal of the soft deposit which would otherwise require to be chipped off. Mr. Adamson spoke of the different effects observed in the scale. In one instance of a vertical boiler in a vessel running out of this port they could not get steam on the donkey boiler. One day it stopped altogether, and they had to turn over to the main boiler. When they went to knock open the doors they could not get in and found the boiler solid right up to the crown with mud. That was the effect of feeding with Thames water.

Mr. A. ROBERTSON : I have seen River Plate water put into boilers frequently with a very slight rise in density, and on opening the boilers a considerable amount of mud was found. The practice was to fill up the tanks and allow the mud to settle, and the water was used for the boilers for a considerable distance of the way home. I think Mr. Stromeyer advises giving a dose of soda just before stopping the boilers and then blowing down and getting a man in as quickly as possible to brush the deposit off when warm.

Mr. TIMPSON : What causes most of the trouble is pitting from the free acids ; but in regard to collapsed furnaces, although some of them have a thickness of mud, collapse or buckling is very rare with 120 lb. maximum pressure. It seems to me to be peculiar that in this instance there is a much thicker scale than is usually found if this has been detached as the author suggests. In modern boats the tubes seem to be particularly affected.

CHAIRMAN : The contour seems to suggest that the scale is from the corrugations.

Mr. TIMPSON : It does not generally drop clear, although the different classes of water might have detached it from that one furnace.

Mr. ADAMSON: I saw a case of a steam launch boiler not long ago where the tubes were pretty close on to the furnace, and evidently the scale had dropped from the upper tubes and gradually filled in between the lower tubes and the furnace crown towards the wings. Fortunately, no damage was done, but it was not far off.

Mr. TIMPSON: The conditions might have been similar in this case.

CHAIRMAN: The subject of the treatment of boilers will again be before us in the course of the next month or so, when the discussion on Mr. Ruck-Keene's paper takes place, and if it is your wish I shall now declare the discussion on this paper closed. The paper itself is worthy of a place in the Institute Transactions. It is one of the few papers which has come from the actual experience of a sea-going engineer, and many experts on such subjects are requiring just such records to enable them to arrive at their conclusions. I am sure the Institute can do no less than accord to Mr. Henderson a very hearty vote of thanks for the way in which he has put this subject before us.

Mr. ADAMSON: Before we close I should like to propose that we accord a very hearty vote of thanks to Mr. Veitch Wilson for the trouble he has taken, and also for having these analyses made.

The motion was seconded by Mr. A. Robertson and carried, and the meeting closed with a vote of thanks to the Chairman.

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Mr. ANDREW HENDERSON: The points of the present paper relative to the furnace collapse present a similarity to the points in a paper (Vol. X, 76) by Mr. J. G. Hawthorn. In a very nice way he points out wherein lies the danger of deposits (inorganic and organic) on the heating surfaces, and mentions two sources of furnace collapse.

(1) Thickness of Scale. Here $CaSO_4$ is the dangerous constituent as it is not only a bad conductor of heat, but binds together comparatively harmless deposits into a thick non-conducting scale.

(2) Oil settling out with $CaSO_4$ as mixture or as a lime soap. This is a worse conducting scale than the first named, and binds other deposits better.

Cases are mentioned of collapse under banked fires, and Mr. McLean notes an instance of collapse where there was no scale at all but merely a thin oily deposit on the furnace sides from the bars upwards. It would therefore appear that in cases intermediate between (1) and (2), the critical thickness of scale would in a sense be inversely as the amount of oil present. Mr. Hawthorn shows how to prevent deposition of $CaSO_4$ and seems to hold that if that is prevented oil will not settle as a dangerous deposit. Still what about Mr. McLean's instance?

Mr. Martin states that the judicious use of soda ought to prevent all boiler troubles. He therefore agrees with Mr. Hawthorn that the oily scale ($CaSO_4$—mixture or soap) is decomposed or not allowed to form at the temperature of steaming if a certain amount of soda is used.

Before discussing the scale at all, one's attention should be directed to the oily residues in the cylinders, which analysis discloses to be oil, coke, and ash. The steam passing into the cylinders would in the case in question carry over a little soda. Consequently the oil in the cylinders would be subjected to (1) steam distillation and (2) saponification (saponification would be confined to the esters, etc., in the oil). Now many oils in distilling char somewhat, and consequently in the case of a non-homogeneous oil we might expect a greasy residue containing heavy oil and carbon. I don't know that this can really account for all the coke found in the samples, but if we assume that the oil in question carbonizes under the temperature of the cylinders, what ought to happen when the same oil is present in the $CaSO_4$ scale?

One may take it for granted that the scale over the collapsed furnace caused the breakdown independent of what scale existed elsewhere. Chemical analysis discloses no oil whatever, whence "the absence of oil does not agree with the conclusion come to after survey that oil had caused the collapse."

Mr. Adamson probably had the cylinder deposits in mind when in the first discussion he opined that probably the surveyor had scraped the plates below the scale and satisfied himself that oil had been present. A similar doubt occurred to me, but I asked the author if he saw the plates under the scale. He assured me, however, that the plates were quite clean and free from anything like an oily residue. Again, supposing the oil to have been deposited as a lime soap and subjected to the heat in question, a fair amount of Carbonate of lime should have been left in the scale, and according to Mr. Hawthorn have been bound by the $CaSO_4$ and revealed by analysis.

One seems to be driven to attribute the collapse to Mr. Hawthorn's first cause—thickness of scale. I myself would not venture an opinion on such a point. However, Mr. Robertson thinks the scale is not thick enough. Mr. Timpson, on the other hand, seems disposed to accept the chemist's view ; but the Hon. Secretary seems doubtful. He maintains that the ways of oil are rather mysterious. Besides, many of the speakers think that the data is not sufficient. I think therefore that the cause of progress will be served if the present case is merely recorded as APPARENTLY *not due to oil* and the *verdict of the survey as* APPARENTLY *incorrect.*

In the first discussion Mr. Shackleton gives a very interesting discussion of oils. It would be interesting if he would explain whether a pure paraffin with water would damage packing by chemical combination or by its solvent properties. His remarks about sal-ammoniac are most appropriate.

Mr. Bradshaw seems amused at the authority who gives the rule regarding diminution of boiler efficiency with increasing thickness of scale. I suppose, like most approximate rules, it becomes absurd if pushed too far. Mr. Hawthorn's mention of Sir John Durston's data, and his deductions therefrom are most interesting.

Mr. Timpson, Mr. Ross and Mr. Rainey voice the plea of the author that prevention is better than any cure, and that an efficient and sufficient number of evaporators should be installed in every ship.

One would like to hear the properties of a good cylinder oil discussed by such practical men as attend the Institute. Analysis of oils is not all easy, and apparently even dealers are ignorant of what constitutes a good oil for a given purpose.

I had a discussion this morning with an authority on oils, and he admitted my contention that a mixture of pure paraffins was the ideal oil as it contained no saponifiable oil, but he asserted that cylinder oils were such mixtures sophisticated with either cottonseed or whale oil. This varies somewhat from Mr. Shackleton's view. For my own part I am prepared to accept Mr. Shackleton's statement as quite correct; but I quote this opinion to prove to the members that even authorities on oils may err, re adulterants.

On behalf of the author, I should like to convey thanks to Mr. Shackleton and Mr. Adamson for their enthusiasm over the deposits, and to the members present for according the vote of thanks.