NOTES ON THE TROUBLES RESULTING FROM THE USE OF IMPURE FEED-WATER IN BOILERS, AND SOME SUGGESTED REMEDIES.

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In bringing before the Institute some notes on this subject, I would like to say at once that I do not claim that any of my matter is original, but trust that the importance of the question justifies my bringing it to your notice, and hope that it may provoke a discussion which will lead to a useful interchange of ideas and experiences.

The subject being a very wide one, it is not intended to go into great detail, nor to describe any particular make of apparatus; the idea is rather to point out the impurities most commonly met with, and to indicate the general methods employed to remove them. They may be divided, roughly, under the following heads:

- Substances in Suspension.
- Salts in Solution.
- Free Acids.
- Air and other Gases.
- Oil.

The substances found in suspension mainly consist of finely divided particles of sand and clay which, if allowed to accumulate in a boiler, would ultimately harden, and cause overheating of plates or tubes. If the source of supply is always in this condition, it becomes necessary to remove these impurities either by mechanical filtration, or allowing the water to settle in some large receptacle. As a rule, however, this condition only occurs after heavy rains, and the only precaution necessary is to blow off more frequently at such times. There is probably less damage from this cause than from any of the others mentioned, and it is not proposed to deal further with it, especially as we have had some valuable papers on the subject of mechanical filtration. Organic matter can also be removed by filtration.
The question of Salts in solution is much more important, and one that affects a large proportion of boiler users. The troubles that result are either scale, or corrosion, whilst with some waters both may exist at the same time. The following Salts are those usually met with:

**Carbonates of Lime and Magnesia.**—The bi-carbonates of lime and magnesia are highly soluble in cold water, but when the solution is heated, either in an external heater or in the boiler itself, carbonic acid gas is driven off, and the mono-carbonates, which remain, being insoluble, are precipitated. This process is practically complete at 300 deg. Fah., which corresponds to 55 lbs. gauge pressure.

The deposit formed by these mono-carbonates is not in itself very troublesome, as it does not make a hard scale unless allowed to remain too long in the boiler. It can be removed by blowing off, and fairly frequent cleaning. In plants where a "Green's Economiser" is used, most of the deposit will take place in its tubes, which will require to be periodically cleaned, and the boiler will be relieved to a corresponding extent; in the same way the use of a live steam-feed water heater will save the boiler, but itself will need more care.

Where cold water is fed direct to the boiler (a barbarous practice which still exists in some otherwise civilised countries), it has been found a satisfactory plan to spray the cold feed water through a portion of the steam space; this raises the water at once to the temperature of the steam, and the mono-carbonates are deposited in a part of the boiler isolated from the main shell, and from thence removed by suitable blow-off cocks. This system has been adopted with success in many London plants where the water contains Carbonate of Lime.

**Sulphates of Lime and Magnesia.**—Both these Salts are very soluble in cold water, but are insoluble when water is raised to a temperature of about 300 deg. Fah. If this is done in the boiler itself, a hard scale results, which is very troublesome to remove; in addition, the deposited salts act like a cement, and bind together any previously precipitated carbonates there may be in the boiler.

Sulphate of Lime is more commonly found than Sulphate of Magnesia, but both act in much the same way. When these Salts are found in feed water, it is necessary to adopt some simple form of softener to remove them, otherwise they are certain to cause trouble, either in feed water heaters, economisers, or boilers. A great many people, including engineers, ask a boiler to perform this work in addition to its legitimate duties, but it is getting generally recognised that it does not pay to turn a boiler into a water softener except in very small plants, and there are now many firms who make a speciality of this work, and the
apparatus they supply is simple and efficient. It consists mainly of a vessel to hold the chemical employed, a mixing tank where the reaction takes place, a filter to remove the impurities thrown down, and a pure water tank from which the boiler supply is drawn. Very little attention is required, as a float in the soft water tank regulates both the feed and reagent supply. When dealing with water containing Sulphate of Lime, it is customary to add a certain proportion of Carbonate of Soda; this transforms it into Sulphate of Soda, which is very soluble, and may be highly concentrated before it will crystallise, and Carbonate of Lime, which is precipitated and removed in the filter.

Of course this operation can be performed in the boiler itself, but it will necessitate frequent blowing off and careful cleaning, otherwise trouble is certain to result.

CHLORIDE OF MAGNESIUM.—This is one of the worst Salts to deal with, and one commonly found in Australian waters, yet very little attention seems to have been paid to it.

Although its action is corrosive, the water containing it, even if taken from the boiler, will not give an acid reaction, and the trouble is only revealed by an examination of the interior of the boiler. Its action is as follows:—

When water containing Chloride of Magnesium becomes saturated, as happens in time in the boiler, the crystals that form are not pure Chloride of Magnesium, but are what is called Hydrated, that is, they contain a certain percentage of water, and when heated, split up into Hydrochloric Acid and Magnesia; the former attacks the iron of the boiler surfaces, forming Chloride of Iron, but as soon as this is formed it is decomposed by the Magnesia already liberated, precipitating Oxide of Iron and reforming Chloride of Magnesium. This action is quite local, the acid that is formed being almost immediately neutralised, consequently the boiler water, if tested, does not appear to be Acid, and it is quite possible, if the water used also contains Sulphate of Lime, for scale to be formed in one part of the boiler whilst corrosion is going on in another.

The remedy is the use of a sufficient amount of an Alkali, such as Carbonate of Soda, to render the whole water in the boiler so alkaline as to neutralise the acid directly it is formed and before it can attack the boiler plates. This amount can only be determined after a proper analysis of the feed water has been made. In the case of sea water, which contains 8.1 lbs. of Magnesium Chloride per ton, it is necessary to add 45 lbs. of Soda Crystals to completely neutralise it. Another remedy is the use of Lime, but it is not so satisfactory as Soda, as it will coat the heating surfaces of the boiler, and may require more fuel to be burned.

In Kalgoorlie, before the present water supply scheme was completed, the only feed water available contained a larger percentage of solids than sea water, rendering distillation necessary;
notwithstanding the fact that this was done, and the supply therefore presumably pure distilled water, almost all the boilers on the field were pitted, and although this may have been caused by air, as will be explained later, it is more probable that it was due to the fact that distillation was carried on too long, the whole of the water in the still becoming so saturated that the Hydrated Crystals of Chloride of Magnesium were deposited at and above the water line. These were decomposed by heat, and free Hydrochloric Acid was carried over, rendering the distilled water acid. This water, being fed to the boiler, attacked the tubes and plates, but in this case, there being no Magnesia present to neutralise the Acid, the whole water in the boiler would show an acid reaction, and would attack all surfaces not protected by scale, or otherwise. To remedy this, it was the custom to use zinc blocks in the boilers, and also add Milk of Lime to the make-up.

Although this paper is intended to apply only to land practice, another impurity may be mentioned—Common Salt, as it is also found in some feed waters on shore (in fact, the new supply to the W.A. goldfields contains 17.6 grains per gallon). So far, no satisfactory remedy has been found, and one of two courses is open to the engineer compelled to use salt water: First, to distil all water fed to the boiler by means of an evaporator; second, to use the salt water in the boiler, and by frequent blowing down prevent it becoming too nearly saturated.

The Salts I have mentioned are those most commonly met with, and the remedies suggested those which have been found efficient, but there are, of course, many other substances used for the prevention of scale, such as tan-bark, potatoes, petroleum, molasses, eucalyptus leaves, and many patent boiler compounds of which every engineer should beware unless the vendors will furnish an analysis of what they contain. The value of potatoes, starch, molasses, and similar substances, depends on their depositing on the scale-forming particles as they are precipitated, a sticky covering which prevents them from uniting into a compact hard scale, and allows them to remain in such a condition as will permit them to be removed through the blow-off cock. These substances are seldom used now, as they tend to foul the water and heating surfaces of the boiler. Tan-bark, oak-bark, and logwood are used with water containing Salts of Lime and Magnesia, the tannic acid in them acting on the scale formed, but care has to be taken to prevent an excess of tannic acid, which readily attacks iron. Petroleum acts in two ways—preventing the formation of hard scale, and also rotting scale already existing. It is more frequently used to clean boilers in which there is a large quantity of Sulphate of Lime, but great care must be taken when using it to prevent any possibility of a naked light coming near the boiler, otherwise a serious explosion might result.

With regard to boiler compounds, these are mainly composed
of either Carbonate or Tannate of Soda, more or less adulterated and coloured, and I would like to quote from a circular issued by the Magdeburg Steam Boiler Society on the subject, which says:

"No patent remedy against boiler scale is more effective than Soda, and all are dearer."

**Free Acids.** May occur when feed water is drawn from a source polluted by the discharge into it of the refuse of manufacturing concerns, or in a highly-mineralised country. If nothing else exists in the water, it is only necessary to add a sufficient quantity of some Alkali to entirely neutralise the acid; the amount can readily be ascertained by obtaining a given quantity of the water, and adding the Alkali until litmus paper shows neither an acid nor alkaline reaction. From this the quantity to be added in practice can be determined; the addition should take place in the suction tank, so as to save damage to feed-pump and pipes.

In cases when free acids are found along with other impurities, the problem is more complicated, and the advice of a chemist should be sought, so that he can determine the best solution to the difficulty.

**Air.**—This impurity, for we must term it so when it is found in water which is to be used in boilers, is a fruitful source of corrosion. The purer the water the more readily will it absorb air; so that it is in surface-condensing plants we oftenest meet with this trouble. It is liberated on the water being heated, and the bubbles attach themselves to the tubes or plates, rapidly oxidising the iron (forming rust); this is washed away by the circulation in the boiler, or removed by the expansion and contraction of the plates, leaving a small hole or pit. "Pitting" once started progresses rapidly, as the small holes form ideal resting places for the bubbles, and further oxidation occurs. It is most severe, as a rule, just where the feed-water enters the boiler, and about the water-line; and where wrought-iron feed-piping is used, it eats its way through very rapidly. I know cases where this has occurred in nine to twelve months' work.

Some waters, amongst them Yan Yean, have a considerable percentage of air in them; in fact, I believe Yan Yean water is purposely aerated to make it palatable; in other cases air is drawn in through feed-pump glands, and is also found in hot well water. It is desirable, where possible, to pump the latter into a tank some feet above the level of the feed-pump suction-valves, so that the air is liberated before it gets into the pump; care should also be taken to have all glands and joints tight, especially the low-pressure piston-rod stuffing-box, and see that the air-vessel on the feed-pump is of sufficient size and is really efficient.

When corrosion has already begun in a boiler, the affected parts may be given a thin cement-wash, which will prevent further action, or a small quantity of lime-water may be added to
the make-up, which will have the same effect. Instead of using a cement-wash some engineers prefer to use a zinc-paint, for the same purpose, and it is more readily applied.

Zinc-blocks should also be placed in the boiler, close to where the feed water enters; they can simply be suspended, and need not be in close metallic contact with the plates, as is necessary if galvanic action has to be guarded against. The air will attack the Zinc in preference to the iron, and, as long as it wastes away, it is a proof that it is doing the work for which it is intended.

Oil.—The question of the efficient removal of oil from either exhaust steam or the hot well discharge has received more attention from engineers and chemists during the last two or three years than it has ever received before, and it has become one of the most important problems that the engineer in charge of a surface condensing plant has to deal with. It may be argued that until recently little was heard of this trouble, and that on board ship no difficulty was experienced in removing any oil that might be in the hot well discharge. This is so, and the long immunity from trouble enjoyed by marine engineers may have misled engineers in dealing with land practices. As a matter of fact, very little oil is used on the main engines, and in many cases, after a vessel leaves port, no oil whatever is fed into the cylinders, the piston and valve rods merely being swabbed. The little oil that does get into the condensers is entrained in the water, and is easily removed by means of a mechanical filter placed in the pipe line between the boiler and pumps. The general use of lime on board ship also tends to prevent any trouble, as will be explained later.

The trouble in land plants has, however, been very acute, and has affected boilers in two ways, viz., corrosion and overheating of boiler flues and tubes. Corrosion is caused by the use of either animal or vegetable oils, or compounded mineral oils, containing either of these, that decompose in the boiler, liberating acids which attack the heating surfaces.

Nowadays most people take care to secure a pure mineral oil, which obviates this trouble, at any rate.

The overheating of plates and tubes is a far more serious cause of damage. Although the exact action of an oil film is not determined, there is no doubt that it prevents the rapid transmission of heat from the furnace gases to the water in the boiler, causing a rise of temperature in the metal through which the heat passes.

Some engineers simply say that oil is a bad conductor; others have propounded a theory that the oil acts as a kind of buffer which deadens the molecular vibrations, by means of which heat is transmitted. The writer is inclined to think that a thin layer of steam is formed immediately above the oil film, and tends to cling to it, preventing the direct transference of heat to the water; but whatever may be the cause, we are more concerned with the results,
which are only too well known, and the best methods of preventing the oil getting into the boiler.

Formerly the usual method was to follow marine practice, and pump the feed water through some form of mechanical filter containing either charcoal, sawdust, towelling, or fibre, and also to remove some of the oil by means of settling tanks. This was good enough with slow-speed low-pressure engines, but with the advent of high pressures, superheated steam and quick rotation engines, an entirely new set of conditions was created, and it was found that the oil formed an emulsion with the water, and was not removed by any of the filters already mentioned, nor did the oil rise to the surface, no matter how long the feed water stood, with the exception of the small amount that was held in suspension.

The particles of oil seem to be so finely divided and so elastic that they pass through even the filtering paper used by chemists.

The next step was to try to remove the oil before the exhaust steam reached the condenser, and many different types of apparatus were placed on the market, all based on the same so-called steam separator principle, though it might more properly be termed water separation. These were found to be fairly efficient under certain conditions, provided the velocity of the steam was sufficiently reduced when passing through the separator.

Different makers claim to remove 80 to 90 per cent. of the oil in the steam, the remainder being removed in an ordinary filter. The use of this apparatus had the advantage of not only keeping the boiler clean, but also the condenser surfaces, but it had the serious disadvantage of removing a considerable percentage of hot water, amounting in some cases to 7 to 8 per cent., all of which had to be made up.

It was found by longer experience that even this type of apparatus occasionally failed to do the work for which it was intended, and mainly when used in plants where quick-rotation engines were employed.

The cause of the failures does not appear to be exactly known, and may have been due to some defect in the particular type or its arrangement, or it may have resulted from the use of more oil than would be necessary with slow-speed horizontal engines. Then, again, the oil may have become still more emulsified by the frequent changes in the direction of the flow of steam. At any rate, the result has been that an entirely different method of treatment is being adopted in many large British plants, and one that aims at the complete purification of the water after it leaves the condenser and before it is fed to the boilers. It was found by experiment that it was possible to add some substance to the hot well discharge which would entangle the particles of oil so that they could be removed in a mechanical filter. Lime water was found to do this, but the process was slow. The addition, however of a little Caustic Soda completed the action quickly, Lime
being deposited as a thin skin round the particles of oil, and apparently rendering them inelastic, or else entangling them so that they were caught by the filtering medium instead of passing through it, as before. Another substance used is alum, either in the form of Sulphate of Alumina, or a bye-product in the manufacture of alum called alumina ferric. It acts as a coagulent, but it is still necessary to use a little lime.

Particular makes of apparatus (of which there are several on the market) will not be described, as the columns of the engineering papers are available for members, but it may be said they have proved capable of removing the whole of the oil, cheaply and efficiently, whilst the attention required is practically nil. It has been claimed for one make that the cost of purifying (in Britain) is only a fraction of a penny per 1,000 gallons. The only drawback the writer sees to this system is the fact that it still leaves the condenser with its efficiency reduced, by having grease deposited on its cooling surfaces.

In conclusion, the author would apologise for the somewhat superficial way in which he has dealt with this important subject, but trusts that the paper may provoke a discussion that will justify its presentation.
Notes on the troubles resulting from the use of impure feed-water in boilers, and some suggested remedies (Paper)

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