Notes on Corrosion: Causes and Preventive Measures.

The principal causes of corrosion in marine boilers are:—

(1) Sea water.
(2) Animal and vegetable oils.
(3) Air.
(4) Galvanic action.

(1) Sea Water.—Sea water varies in composition to a very considerable extent, but the following analysis may be taken as giving about the mean average quantities of the various constituents:—

ANALYSIS OF SEA WATER.

Carbonate of Lime	9·20	grains per gallon.
Sulphate of Lime	112·45	,, ,,
Sulphate of Magnesium	160·26	,, ,,
Chloride of Magnesium	261·91	,, ,,
Chloride of Sodium	1,870·86	,, ,,
	2,414·68	grains per gallon.

Under certain conditions, sea water in immediate contact with heated iron or steel surfaces becomes acid, by the conversion of the chloride of magnesium into hydrochloric acid and magnesia. The hydrochloric acid dissolves a certain quantity of iron from the boiler surfaces, forming chloride of iron; as soon as the chloride of iron is formed it is decomposed by the magnesia already liberated, precipitating oxide of iron and re-forming chloride of magnesium. In other words, the acid formed in the boiler is merely developed locally whilst the water is in contact with the hot tube, and is immediately afterwards destroyed by reuniting with the magnesia. Hence iron is never found in solution in the boiler water, and the water which is being evaporated in the boiler itself would, if no acid were introduced with the feed-water, never be found acid when tested. The oxide of iron deposited is ferrous oxide and is black, and remains so unless air is allowed to get into the boiler, when it becomes ferric oxide and changes in colour from black to brown or red.

If corrosion is to be prevented, sea water must be kept out of the boilers, and this can only be attained by making and keeping the condensers tight. To deliberately install expensive and well constructed boilers and as deliberately to use in connection therewith condensers known to be subject to leakage, and so constructed as to make quick and efficient repair extremely difficult, is commercially unsound.

Every ton of sea water allowed to enter the boiler means the introduction of:—

Carbonate of Lime	·285 lb.
Sulphate of Lime	3·478 ,,
Sulphate of Magnesium	4·957 ,,
Chloride of Magnesium	8·101 ,,
Chloride of Sodium	57·871 ,,
	74·692 lbs., say 75 lbs., solids.

Evaporators are essential for making up the loss of water due to leakage of glands and joints, but they must be blown down before the brine becomes too concentrated; otherwise, the chloride of magnesium will be decomposed and give off hydrochloric acid, which will pass over into the boilers with the distilled water, and thus render the fresh make-up feed-water acid. The action of the acid formed in this way differs from that formed in the boiler by the decomposition of sea water, inasmuch as it does not immediately afterwards become destroyed by reuniting with the magnesia, but is carried in with the fresh make-up feed, and is held in solution. It is thus in a position to attack all parts not protected by scale or otherwise. This is a point which demands careful attention. On no account should the brine be allowed to get above $\frac{5}{32}$, and when this point is reached, the evaporator should be blown down and refilled with fresh sea water.

It is undesirable to start boilers with dock water. Dock water is a tidal water, and always contains a certain percentage of sea water and other impurities.

The following example is from actual practice, and occurred in the boilers of a steamer trading between this country and the Mediterranean:—

	Boiler water on starting. Grains per gallon.	Boiler water at end of voyage after 15 days' steaming. Grains per gallon.
Magnesia	3·32	·92
Sulphate of Lime	72·42	28·22
Sulphate of Magnesium	39·84	332·82
Chloride of Magnesium	99·62	497·40
Chloride of Sodium	695·52	4,710·91
	Total 910·72	Total 5,570·25

The boilers on starting were filled up with dock water which contained 30 per cent. of sea water, and at the end of the voyage, which was of fifteen days' duration, although provided with evaporators, the total solids had risen to 5,570 grains—that is, the density had risen to 12·7 ozs. or $\frac{2\cdot54}{32}$. Assuming that each of her two boilers held 2,000 gallons, this means a total leakage of sea water into the boilers of 8,120 gallons, thus introducing:—

Scale forming Sulphate of Lime	=	131 lbs.
Sulphate of Magnesium	=	186 ,,
Chloride of Magnesium	=	304 ,,
Chloride of Sodium	=	2,170 ,,

These quantities are such that in practice ordinary remedies cannot neutralize their detrimental effect.

It is the system that is at fault; condensers should be made tight, and sea water kept out of marine boilers if they are to be kept free from corrosion. Failing this, all types of marine boilers will always be liable to corrosion. The addition of milk of lime, or alternatively soda, will neutralize the corrosive effects of sea water.

It is difficult to give any definite instructions as to the extreme limit to which it would be wise to use either, as so much depends on the circumstances of each case, such as the density of the water, rate of working, and the time which must elapse before the boilers are next cleaned.

Experience points to the use of lime as being the more generally satisfactory on a voyage, while soda may be used in cases where the boiler water is acid through the density of the brine in the evaporator being excessive, and where no vegetable oil has been allowed to enter the boilers, and on entering port at the end of the voyage, or before blowing off.

A small amount of salt water is bound to get into the boilers, even under the most favourable conditions, and it is an excellent plan to continually use a small quantity of milk of lime to neutralize it. One lb. of lime dissolved in fresh water per 1,000 indicated horse-power fed per day, in the manner below mentioned, may suffice.

The lime used is the ordinary unslaked lime of commerce, and it should be finely powdered and kept in a dry place—for instance, on the stokehold gratings.

Milk of lime is a mixture of about 1 lb. of lime to a gallon of water, and this should be strained through wire gauze before use, in order to get rid of any lumps or solid impurities.

When starting with new boilers on a voyage for the first time, 5 lbs. of lime should be put into the boilers for every 1,000 horse-power (dissolve in water, strain and put in through man-hole), and 2 lbs. of lime per day for every 1,000 horse-power should be passed through the hot-well, as milk of lime, for about six days, and for the remainder of the voyage about 1 lb. per day per 1,000 indicated horse-power. At the end of the voyage the boilers should be examined to see if they have a thin coating of lime scale on their internal surfaces. If this is not the case, and the water shows an improper colour, black or red, the use of lime should be continued.

The boiler water should be tested daily, and if found to contain a larger amount than about 100 grains of chlorine per gallon, the amount of lime used should be increased.

If the boiler water at any time be found acid, a solution of carbonate of soda should be added to the feed at the rate of a bucket of soda solution per hour until the water just turns red litmus paper blue, after which daily additions of soda or lime should suffice to keep the water in a safe alkaline state.

Carbonate of soda is effective in changing sulphate of lime into sulphate of soda, which is soluble and therefore harmless.

In all cases on entering port, soda crystals dissolved in fresh water should be added to the feed, as this will tend to soften any scale and render the boilers more easily cleaned.

The use of soda *at sea* in boilers into which vegetable oil has been allowed to enter, is sometimes attended by trouble on account of the soapy scum which forms on the surface of the water being carried over by priming into the high-pressure cylinder, and in such cases lime alone should be used.

(2) Animal and Vegetable Oils.—Another cause of corrosion is the introduction of animal or vegetable oil with the feed-water by using such oils in the steam cylinders, the exhaust steam carrying it to the condensers. Such oil, containing fatty acids, will decompose and cause pitting wherever the sludgy deposit can find a resting-place in the boilers.

Preventive.—Only the highest grade of hydrocarbon oil should ever be used in the steam cylinders, and of this the least possible amount. Also, in lubricating piston rods and valve stems, the same oil should be used. The reason for limiting the quantity of such oil to the utmost extent is that the hydrocarbon deposited upon the heating surfaces is most harmful, as a thin film of this deposit forms a complete non-conductor, thereby preventing the heat from passing through to the water, and causing the surfaces to burn, blister, and crack.

The feed-water should be purified on its way to the boiler by passing it through an efficient filter, which must be kept clean. A large proportion of oil and impurity may be thereby caught, and the condition of the feed-water improved.

Graphite can be used in place of oil as a cylinder lubricant with equally satisfactory results. In fact, graphite is generally superior to oil, and especially so when the steam pressure is as high as, say, 275 lbs., which corresponds to a temperature in the neighbourhood of 400° Fahr.

Many steam vessels are running without a particle of internal cylinder lubrication, save that brought in by the swabbing of the piston rods with pure hydrocarbon oil.

(3) Air in the Feed-Water.—Air has been a well-recognised cause of corrosion for many years, and many instances of rapid corrosion have been proved to have been caused by the feed pumps sucking air from the hot-well, and the feed being delivered at a level considerably below the water line of the boilers.

Small bubbles of air expelled from the water on boiling, attach themselves tenaciously to the heating surfaces. The oxygen in the air at once begins war on the iron or steel and forms rust, making a thin crust or excrescence which, when washed away by the circulation or dislodged by expansion and contraction, leaves beneath a small hole or pit. "Pitting" once started, progresses rapidly, as the indentations form ideal resting-places for the bubbles of air, and at the same time present increased surfaces to be attacked.

Preventive.—Where possible, the hot-well water should be pumped to a filter tank situated 8 to 10 feet above the feed-pump suction valves. By this means, a large amount of air rises and is liberated from the surface of the water, and a head of water at the suction valves of the pump is assured.

In the design of the piping, care should be taken to avoid any spraying of the water discharged by the air pumps, or any possible spraying of the water in the feed system before it is pumped into the boiler. All delivery pipes should therefore be carried well down into the tanks, so as to be water sealed.

All tanks containing feed-water should be kept closed in order to prevent any avoidable access of air to the water surface and vapour pipes fitted to allow of any air which frees itself to escape.

As a means of freeing air from the feed-water, it is desirable to fit a large air escape pipe on the air pump discharge, as very frequently, owing to the action of the air vessel on the air pump, large quantities of air are forced into solution in the feed-water which, to a considerable extent, can be got rid of.

Care should be taken to keep the pump glands tight and to efficiently entrap free air in air vessels.

(4) Galvanic Action.—Formerly, nearly all corrosion in boilers was attributed to this cause, and zinc slabs were suspended wherever possible within the water space. The position of zinc relative to that of iron in the scale of electro-positive metals, causes it to be attacked instead of the metal of the boiler when galvanic action takes place; but, as zinc is only attacked when the boiler water contains salt—that is, the galvanic action is set up by two dissimilar metals in a highly exciting saline liquid—this is merely another evidence of the presence of sea water, and the fitting of zinc is only an expedient to minimise the action of the objectionable sea water. If the sea water is prevented from entering the boiler, the zinc will not readily act, and there will be little necessity for using it in large quantities, thus lessening a very expensive item in the working of marine boilers.

Preventive.—To afford efficient protection by the use of zinc, however, there should be metallic contact between the zinc and iron.

Its suspension in drums, and at points within the boiler near the entrance of the feed, is recommended as of positive benefit, and, indeed, as long as zinc slabs continue to disintegrate and oxidize in a boiler, they are active in lessening corrosion.

Testing the boiler water at frequent and regular intervals for contents in chlorine is of the greatest importance.