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The Scientific Treatment of Feed Water for Ships' Boilers, introducing the Colloidal Aspect.

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READ

On Tuesday, February 3, 1925, *at* 6.30 *p.m.*

CHAIRMAN: F. M. TIMPSON (Chairman of Council).

The CHAIRMAN: The paper to be read to-night covers a very interesting phase concerning the treatment of boiler feed water. The joint authors are present. Mr. Lewis will now read the paper and Mr. Irving will give demonstrations to illustrate various points.

IN our lectures before Engineering Societies, we have dealt at length with the treatment of water for land boilers, and but passing reference has been made to marine problems. One point, however, was strongly stressed—the importance of water and engineering features connected with each particular case. Compared with land plants, marine boilers offer a more difficult proposition. There has to be taken into account the following features, which vary, of course, from the steam trawler to deep sea practice:—

(1) The source of water, which is rarely constant throughout the voyage.

(2) Foaming and/or priming, particularly in rough weather.

(3) Corrosion of boilers and other steam plant.

(4) The presence of oil in boilers.

(5) The high steaming rate at which the boilers work.

(6) The smallness of the steam space in the boilers.

(7) The troubles caused by leaky condensers.

(8) The cramped space for the plant.

(9) The difficulty of properly *scaling* the boiler.

(10) The varying load on the boilers.

With the time at our disposal, it is not possible to deal fully with all these factors, and it is, therefore, the intention to deal with *foaming, priming, corrosion, scale and oil*, with some comments on hydrological chemistry in general, together with the advantages of colloidal treatment.

Hardness of Water.—Temporary hardness, due to bicarbonate of lime and magnesia, is nearly all deposited on raising the water to 212° Fahrenheit.

The hardness left after boiling the water is called the permanent hardness, and consists chiefly of calcium and magnesium sulphates; also their chlorides. In addition, nitrates of lime and magnesia, some iron and aluminium salts affect the permanent hardness. The permanent hardness is usually regarded as of more importance than the temporary hardness. Permanent hardness, precipitated at high temperatures or on evaporation, increases the hardness of the scale formed by the deposition of temporary hardness.

Waters vary considerably in their hardness, soft waters being those of Liverpool and Glasgow, and fresh river waters such as the Amazon or Panama Canal. The hardness increases until we come to salt water of different degrees of saltness. Leaky condensers often introduce salt water into the boilers so that it is of primary importance to enquire into the chemical composition of each feed water.

The question of pollution of river water is an important one, and frequent analyses where pollution is likely to occur from industries situated on the banks of the river, are necessary. Decayed vegetable matter, and other matter in suspension, are a source of trouble. Slow rivers usually contain less suspension than fast rivers, but slowly moving water is likely to collect more dissolved impurities. Rushing water on the other hand absorbs more dissolved gases. At all times the question of river water being affected by sea water must be taken into account. Where there is a rainy and dry season then large rivers receiving drainings from large tracts of land vary greatly. The River Para varies from 76 grains of salt in November to 3 grains in March. Both per gallon. In sea water will usually be found magnesium chloride, magnesium sulphate, calcium carbonate and sulphate, sodium chloride, etc.; all undesirable salts for boiler feed purposes. Canal waters are objectionable and variation may occur as in the case of river waters. An excess of suspended matter is usually found in canal waters, and this helps to bind scale salts; it also facilitates priming. Town waters vary considerably in hardness according to the source. They are nearly all free from suspended matter. Those that are very soft are liable to be corrosive in boilers.

Salt.—Salt is not scale forming, unless the density is allowed to become high. Associated with salt, however, is always found the highly corrosive magnesium chloride. In connection with salt an analysis of the River Thames water at Egham may be of interest:—

Silica	0·23
Sulphate of Lime ...	0·22
$Ca\ Co_3$	17·20
Sulphate of Magnesia..	1·32
Nitrate of Soda ...	1·78
Sulphate of Soda ...	1·99
Salt	2·87

Grains per gallon.

Total hardness 18·50.

The average amount of salt in sea water may be taken as 2,140 grains per gallon. The Gulf of Mexico—Mediteranean water and Falkland Islands, give as an average:—

Sulphate of Lime ...	100·00
Carbonate of Lime ...	7·00
Chloride of Lime ...	250·00
Sulphate of Magnesia..	150·00
Salt	2140·00
Total	2647·00

Grains per gallon.

The Thames at Vauxhall, like most other rivers, varies according to the ebb and flow of the tide. As an instance:—

High Tide.

Total Hardness	15·80
Salt	8·60
Sulphate of Magnesia	2·52

Low Tide.

Total Hardness	16·35
Salt	3·27
Sulphate of Magnesia	1·86

Where there is a rainy and dry season, then large rivers receiving drainings from large tracts of land, vary greatly. As already noted the River Para varies from 76 grains of salt in November to three grains in March. Different analyses at suitable intervals of the various sources of water used on a ship is a necessity in advising as to the most efficient treatment, and what variation in it should be made from time to time. When all salt feed is used, or where there are leaky condensers this involves the blowing off of a large volume of boiler water daily, which must be compensated by increased amounts of chemical softening materials used for treatment. This point is often overlooked.

Every ton of sea water of the average composition given above allowed to enter the boiler, means the introduction of about 75 pounds of solids, and to render such water non-corrosive, about eight pounds of quicklime or 45 pounds of soda would be required per ton, quantities which are prohibitive when there is any considerable leakage of sea water into the feed. The use of lime has the further disadvantage that out of the eight pounds mentioned above, 5¾ pounds would be deposited as scale. Sea water itself has sufficient calcium sulphate to produce 3½ pounds of scale for every ton, so that if the proper proportion of lime be added the total quantity of scale which will be deposited is 9¼ pounds. Although this scale, when evenly coated over the boiler surfaces, may protect them from the corrosive action of the magnesium chloride, it is at best only an expensive and unsatisfactory remedy, since it increases the consumption of fuel, and when accumulated, may damage the boiler by overheating. Scaling is also necessary.

Concentration of Boiler Water.—The maximum permissible density for a boiler water is dependent on its salt content and alkalinity. Too great an alkalinity causes the boiler to prime.

An alkalinity of 50 to 70 degrees, with a density of about four degrees Twaddell, in Babcock and Wilcox and other water-tube boilers, is safe. For marine boilers a Salinometer is used. The permissible density is determined by the type of boiler, amount of water evaporated per hour, the load per unit grate area, and the manner in which the water is treated.

Evaporators.—Evaporators are essential for making up the loss of water due to leakage from the glands and joints, but they must be blown down before the brine becomes too concentrated; otherwise the magnesium chloride will be decomposed and give off hydrochloric acid, which will pass over into the boilers with the distilled water, and thus render the 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 is not immediately destroyed by re-uniting with the magnesia, but is carried in with the fresh make-up water and is held in solution throughout the entire volume of boiler water. It is thus in a position to attack all parts not protected by adequate treatment.

A small amount of salt water is sure to get into the boilers even under the most favourable conditions—through priming of the evaporator or leakage from the condenser.

Condensers.—About 95% of the condensed steam is returned to the boilers by means of the condenser. Unfortunately this condensed water contains a large proportion of the dissolved gases coming from the boilers, and this applies whether an open or closed system is in use.

When the tubes leak seriously it is necessary to pump the excess water overboard, and it consists of mixed condensate and cooling water. When the latter is salty the density rapidly goes up in the boilers with a greatly increased risk of scale and corrosion which latter is accentuated by the dissolved gases, oxygen and carbonic acid.

Magnesium Chloride.—This is a very common component of waters, and under boiler pressure it splits up giving free hydrochloric acid, which attacks plates and tubes, causing pitting and grooving. The iron attacked, forms iron chloride. This splits up, giving black oxide of iron and acid back again; the corrosion thus becoming a cycle. If oxygen is present, red iron rust is formed. Magnesium chloride is a soluble salt, occurring in most natural waters, and it is also formed in a water containing a magnesium salt and other chlorides. Its effect may at times be found in superheaters and turbines. Certain chemicals can be introduced into a colloidal treatment for dealing with such substances.

Colloidal State.—This is not a case of super-saturation. A liquid containing a very insoluble substance in solution, beyond its usual degree of solubility, is said to be in the colloidal condition. Matter is divided into three states, *i.e.*, solid, liquid, and gaseous. Modern discoveries call for further division of the solid state. It is now possible, with many substances, to so reduce the size of their particles that when added to water the solution looks clear or only faintly opal. These can be filtered unchanged, but colloids are not capable of passing through an animal membrane.

Colloid means "glue-like," and a colloidal solution is one in which a finely divided substance does not coalesce. A colloid in solution is said to be in the "Sol" form, but if it jellifies, coagulates, or is precipitated, it is said to be in the "Gel" form. When a colloid is precipitated it changes from the "Sol" to the "Gel" by virtue of losing its electric charge. This is a purely physical process, and not a chemical one.

Ultra-Microscope.—Since most colloidal suspensions reveal little under an ordinary high power microscope, an ultra-microscope is used. The particles appear as tiny cones of light on a black background, and most of the particles are vibrating. This movement is observed when extremely small particles of substances are suspended in a liquid. After the lecture you will have the opportunity of viewing a colloid through an ultra-microscope.

Colloids are larger than molecules, but very small compared with visible particles, *e.g.*, dust in the air. They are smaller than particles visible under the microscope. The majority of colloidal particles have an electric charge. The determination of the source of the electrification of any colloid has not yet been made, but research would point to *ad*sorption of either positive or negative ions. The conducting power of electrolytes, *e.g.*, salt, soda, etc., is well-known to be due to their dissociating in solution into positive and negative ions, and in passing, perhaps it should be explained that the word "ions" refers to an atom possessing an electric charge. The difference between a colloidal particle and an ion is that in the former the molecules carry the electric charge, and in the latter, the atoms. The difference between absorption and adsorption may be illustrated as follows:—

Imagine a thick piece of blotting paper on to which is poured some dirty water. The water is *ab*sorbed by the paper—the dirt only partly penetrates the surface or is *ad*sorbed. So long as the charge remains on the colloidal particles, they repel one another, and do not coalesce. Positive ions precipitate negatively charged colloids, and negative ions precipitate positively charged colloids.

The electrical methods which are employed for the removal of oil from condensates consist in an application of colloidal chemistry. The oil particles have on them an electric charge due to adsorption of inorganic salts present in traces, and when a current of electricity is passed through them they travel to the pole opposite to their charge.

A colloid is precipitated by passing an electric current through a solution of it. The colloid is precipitated at the wire, having an electric charge opposite to that on the colloid. Colloidal iron is a yellowish brown solution, and is a convenient substance for demonstrating how the electric current deposits it on the negative wire, changing it into ordinary hydrate of iron. We also show at the same time, a substance called algor, which is used in the Colloidal treatment of feed waters. This is deposited as a jelly (or gel) on the positive wire, showing it has a negative charge. If soda is put through a similar test it will be found to be non-colloidal.

DEMONSTRATION.

Salt, sugar, soda, etc., are crystalloids. Glue, starch, albumen, gum, etc., are typical colloids. A substance may be colloidal in some states and crystalloid in others—soap for example.

Colloids in Everyday Life.—For a cut finger, alum is used to stop bleeding. Blood is a colloid. Alum neutralises its electric charge. The blood coagulates or gels. The curdling of milk with fruit juice is another example.

Colloidal clay is introduced in the pencil and crayon trade—the clay for the leads undergoing prolonged grinding. Such clay is used in the manufacture of printers' inks, soaps and detergent preparations. Prepared colloidal silica has antiseptic properties and can be used in the treatment of wounds.

Application of Colloidal Chemistry to Feed Water Problems.—Before proceeding, it is necessary to explain what is meant by "protective colloids." Gum and gelatine are often used to stabilise emulsions, especially in pharmacy, such as cod liver oil emulsion. The gum acts as a protective colloid around each particle of the oil, and prevents it from separating out. Ice cream made with gelatine is smooth and rich in appearance and taste. Without gelatine or eggs, it is granular and gritty.

To treat the water with soda or the like is to produce a chalky deposit in the boilers. It is much the better plan to allow the scale salts in the water to form a colloidal jelly by the addition of a protective colloid, especially if the gel so formed is capable of absorbing suspended matter, and retaining moisture at elevated boiler temperatures. Instead of crystalline deposit, there is a flocculent precipitate with this colloidal treatment, resulting in that deposit being easier to deal with.

A demonstration will be given in connection with the previous remarks on colloidal treatment. A hard water containing calcium chloride—will be used, and the colloid added to it. You will observe the precipitation of the jelly or gel. The demonstration will be repeated, but with the addition of powdered charcoal. Observe the absorption of the charcoal and the clarifying of the water. You will also note the large amount of water retained by the colloid. You will observe the precipitation of the jelly or gel, *i.e.*, change from the "Sol" to the "Gel" form. Observe the absorption of the charcoal and the clarifying of the water. You will also note the large amount of water retained by the colloid.

DEMONSTRATION.

Boiler Corrosion.—There are many theories relating to the corrosion of iron and steel. It does not matter how the corrosion takes place, if we can state a limit for boiler waters in which it will not take place. This is very conveniently and accurately done by stating its "hydrogen-ion-concentration" in terms of what is known as its Ph value. Pure water has a Ph (hydrogen-ion-concentration) value of seven, alkaline solutions having higher values, and acid solutions lower values.

Modern practice tends to the use of higher and still higher pressures. For pressures over 300 lbs. to the square inch, efficient treatment of feed water is of paramount importance if corrosion is to be prevented.

A feed water for use in a boiler should have its Ph value over nine. Litmus is not a sufficiently sensitive indicator. A "special" indicator has been invented, and this gives over seven different colours, which are in the correct spectrum order from the strongly acid to the strongly alkaline side. In all cases the water should be tested for total hardness and then with the indicator.

I have here an indicator which gives all the colours of the rainbow, and it will be observed from the demonstration following these remarks, this enables one to determine instantly, the reaction, even with waters which have but a faint reaction with litmus.

DEMONSTRATION.

Oxygen.—Oxygen (O) and carbonic acid (CO_2) gases are liberated in boiling, and rise in bubbles to the surface of the water. In some cases these bubbles cling for some time to the lower sides of furnace tubes and to the sides of boilers at the water line. They may adhere to stays. The oxygen, in the presence of CO_2 attacks the hot boiler plates or tubes, producing ferrous carbonate, and this with more oxygen and water form ferric hydrate. When in contact with iron—this is reduced to black ferrous oxide and oxygen is liberated. The oxygen and carbon-dioxide further attack the metal with a similar cycle of events.

A water rich in alkaline salts retains more oxygen at a high temperature than does raw water. The more gas and moisture, the greater the corrosion. A water such as rain water, practically free from dissolved solids, is an instance of where under such conditions corrosion is more likely to occur. Dr. Newton Friend has stated that as a general rule, the presence of a dissolved salt increases the rate of corrosion, and it may be of interest to quote a paragraph in the *Railway Gazette* for August this year, containing an extract from a paper read before the Institute of Locomotive Engineers. The article, summed up briefly, states, that oxygen plays an even more important part in the presence of concentrated salts. An iron plate is rapidly eaten away with a solution of salt, when exposed to air, but the same plate when subjected to a similar solution, and the oxygen carefully excluded, does not show corrosion.

Lime soda does not wholly deal with dissolved gases of this nature. As a safeguard the introduction of an oxygen absorbing reagent into the feed water is a wise plan, and it is essential to compound this into the reagent introduced into the feed water.

Scale.—The undesirability of scale, even in a thin film, is generally recognised. It is sufficient to say that a thin film of scale which is sometimes accepted by engineers as a preventive to corrosion is unnecessary, and is but the substitution of one evil for another. If the water is efficiently treated, neither hard scale nor corrosion need be present. In addition to fuel loss there is the possibility of overheating, bulging and burning of tubes with repeated scaling charges and more frequent boiler cleaning.

Sodium Sulphate.—Tubes have been known to fail without visible cause, but eventually the trouble has been traced to a scale at one time existent composed of sodium sulphate (Na_2SO_4). In high pressure boilers the salt is rendered insoluble and it settles to form hard scale. Under the diminishing temperature of the water the scale is dissolved and sodium sulphate re-enters into solution. When inspecting a boiler, scale would not be apparent.

Mechanical scaling tools should be avoided whenever possible, because by their use the surface of plates or tubes is roughened, facilitating the formation of new scale. There is also a danger of destroying the skin of the metal rendering it more liable to attack from corrosive influences.

Mechanical scaling is a temporary remedy only. Between scaling periods fuel losses are steadily increasing.

Demonstration.—An interesting demonstration showing the disadvantages of internal soda ash treatment will now be given.

Priming and Foaming.—Impurities in a water which *increase* the surface tension facilities priming, such as oil, salt, some organic matters, as for instance, proteinous and humic substances. Evidence of priming or foaming is found when there is scale or deposit above the water line. Excessive scale disintegration facilitates priming, and varying thicknesses of scale in different parts of the boiler may cause priming due to pressure differences. In all cases where steam cannot escape freely from the water, there is a likelihood of priming. If a dirty river water is being used foaming is more likely to occur, and scumming is necessary. Where an excessive amount of salt becomes concentrated, the water subsequently becomes superheated and the next stage is violent ebullition; thus a fairly large volume of water may be carried forward. Wet steam is particularly objectionable as being likely to cause corrosion. Another factor not given the importance that it merits, is the fact that salts being carried forward with wet steam are deposited on bearing surfaces, increasing friction. The addition of more oil is again necessary, and altogether, priming is a very wasteful trouble.

Zinc Plates.—The practice in marine circles is well-known. The general idea is that electrical contact is made between the zinc and the metal of the boilers. The corrosive substances, theory states, result in the solution of the zinc with a consequent protection of boiler plates and tubes. When the zinc becomes covered with deposit, either from the material itself corroding or from scale forming matter, the electrical circuit is broken and the object defeated. Renewals of zinc plates are usually frequent and expensive. A somewhat similar idea so far as electrolysis is concerned is carried out in various systems. Once the circuit is broken, however, the system ceases to operate. Zinc, according to experience, acts locally to some extent as a deterrent to corrosion. The difference in the material of which plates and tubes are made must account for the fact that metal close in texture and free from slag and air bubbles is not liable to be affected by the ordinary conditions creating corrosion. Lowmoor iron is famous for this reason. With this colloidal treatment zinc plates are eliminated.

Turbine Corrosion.—In a number of cases where we have been called in, superheaters were installed, and no wet steam was allowed to get through to the turbines. What, therefore, was the cause of the corrosion? When the feed water was analysed it was found to contain magnesium chloride and nitrate. Under the influence of heat, hydrochloric acid and nitric acid respectively were evolved, and these acids are volatile. In this form the acids were carried along with the superheated steam to the turbine blade. As the steam meets the blades it loses velocity and temperature, and eventually condensation takes place. The acid gases on condensation resulted in corrosion, which was noticeable chiefly on the blades at the low pressure end. Corrosion in turbines is principally due to dissolved oxygen, and secondarily to volatile acids.

Moisture and gases are essential to corrosion of the blades, and it will usually be found that corrosion is greatest at that point where the steam is becoming saturated.

Oil.—It is very dangerous in a boiler as it leads to intense overheating of the plates. Oil eliminating filters should be carefully watched. The alumina-ferric process of oil removing is a colloidal one.

When water is heated by exhaust steam *oil* may be present. Animal or vegetable oils are easily split up by heat into glycerine and free acid—the liberated acid attacking boiler plates and forming a black greasy compound that requires mechanical removal. Mineral oils having a different base, are not usually decomposed to acids, but may cause considerable rise in the temperature of plates.

Superheaters.—When priming occurs these are liable to become choked up or scaled with chalky matter and salt, or corrosion may take place. Corrosion of superheater tubes is due to oxygen or volatile acids, and the corrosion will be confined to the wet ends.

In conclusion.—There are many other interesting points about feed water treatment. In regard to priming, the colloid we are demonstrating with, lessens this evil by lowering the surface tension of the water. The colloid demonstrated also deals with suspended matter by absorption, as in the case of the charcoal. It is also applicable to sea water.

Time will not permit of detailed explanation, but we would like to stress the fact that correct treatment of boiler feed water demands a proper examination of it, and a close investigation into boiler conditions under which the water has to operate. There is no such thing as an universal specific. In considering the line of treatment, it is not a matter purely for the laboratory. There are engineering features needing careful consideration, and which, therefore, necessitates the combined services of the chemist and the chemical engineer.

Here are some interesting specimens of scale, corroded tubes and plates for your inspection. Also some lantern slides will now be shown, when the meeting will then be open for discussion.

The Chairman: The paper which is now open for discussion does not require much comment by me, as it is of general interest. It applies to boilers, superheaters, etc. It is not often that we have a chemist and an engineer co-operating in the preparation of a paper, and the demonstrations we have seen have added considerably to the value of this paper.

Mr. J. Thom: Surely the locomotive engineers must have great difficulty in keeping their boilers clear of scale. I do not think it is common practice among them to treat their boilers specially in the manner suggested by the authors. The Ramsbottom troughs in use on the railways have to use the water available in the districts in which they are placed. The locomotives have to evaporate a larger quantity of water in comparison with boilers of the marine type, as the latter have the same water going back again in the distilled state, except for gases, etc., which possibly get eliminated. A locomotive is perhaps 2,000 h.p., and when you refer to the size of boilers at sea for the same horse-power there is a marked difference. The boiler with which you have to do the same amount of work at sea is twice as large.

The speaker mentions the effect of alum on the boiler plates. Can he say what effect alum has on the boiler water? There used to be instances in different parts of the world where in order to precipitate sand and mud in river water it was the practice to pump this water into a tank and to take a bamboo rod with one of the cavities filled with alum. This cavity had small holes drilled in it to allow the alum, when melted, to mix with the water. The water in the tank was stirred with the bamboo and allowed to stand for a short time, when it became quite clear, and the clear portion was used for the boilers. Would this small amount of alum have any effect on the boilers afterwards?

The lecturer also spoke of the life of the boiler. I think the average marine boiler is quite equal to its duty, and I think it is about the steadiest and most reliable unit you can find anywhere. If it has any fault, it is that it is nearly always too small for its work, but this is also applicable to the locomotive boiler.

I quite understand the necessity for the use of the chemical indicator shown by the Author, which I think is an improvement on anything of the kind I have seen before. It affords greater fineness and gives better results than one could obtain from litmus paper. With the lower pressures in the old days we were able to keep the boilers fairly free from scale, much better than the examples shown on the screen. I have never seen boilers at sea as bad as those. Of course oil may get in, but if the water is carefully filtered and air and gases are got rid of, the results obtained may be considered as wonderful from the point of view of purity of the water. I think this is a most interesting lecture, and I congratulate the authors.

The CHAIRMAN: Superheating and priming have been the subject of a good deal of research. I understand that in some cases, if priming occurs the superheaters are turned off immediately. I do not know whether that is general practice.

Mr. J. H. Graves: As I am neither a chemist nor a chemical engineer, I am rather at a loss to understand fully some of the points described to-night.

A question occurred to me with regard to one remark of the lecturers, in which they referred to the use of scaling tools, which they stated should be avoided wherever possible. I should like to know whether this recommendation applies irrespective of the material of which the boiler tubes are made. Does it apply to copper tubes as well as steel?

With reference to Mr. Thom's remarks, I think he is rather in error as regards the horse-power of modern locomotives. I believe the average express locomotive at a speed of 60 m.p.h. only requires about 400 h.p.

I have received some written remarks on this paper from a friend of mine, Mr. C. A. Packer, of Glasgow, and with your permission, Mr. Chairman, I would like to read them. They are as follows:—

"In the paragraph 'Evaporators,' the authors convey the impression that these are liable to pass over H.Cl. to the feed water. This is not the case, because the conditions in the evaporator shell never approach those necessary for the decomposition of $MgCl_2$.

Modern evaporators have a shell pressure of only a few pounds (from 5 to 7) per sq. in. and are fitted with 'continuous brining' equipment, which prevents high concentration of the brine and eliminates the necessity for periodic blowing down. There is, therefore, no acid from this source nor any $MgCl_2$ introduced into the feed water.

I agree that HCl may be formed under boiler conditions, but why not prevent this by keeping the feed free from $MgCl_2$? *i.e*, by evaporating all make up feed water.

In the paragraph 'Condensers,' the authors state that the condensate contains dissolved gases which are responsible for corrosion, and that it does not matter whether an 'open' or a 'closed' circuit is adopted, these gases are still absorbed by the condensate.

This entirely depends upon the condition which prevails in the condenser. If the condensate is 'overcooled,' then gases will be dissolved, but if the condenser is designed to eject its condensate at the temperature corresponding to that of the steam within it, then the water will be free from gases and chemically inert.

Such a condenser has been designed by Messrs. G. and J. Weir, who, no doubt, would be willing to provide to persons interested, a pamphlet describing it and also the method of fixing to an ordinary condenser, an arrangement whereby it will function as stated above.

If a closed circuit is fitted with this type of condenser, corrosion within the circuit will be practically eliminated."

Engr.-Lieut. A. MARSDEN, R.N.: I would like to ask the lecturer whether the colloids offer any resistance to the circulating currents of the boiler; further, I have always considered that the suspended particles in a boiler were a considerable help to free steaming, since they act as nuclei upon which the steam bubbles have birth. I think these are the only objections I can see to the use of the colloidal process in boilers. The removal of these particles by the colloids might impede free steaming.

Mr. R. J. GIBBS: Will the lecturer say whether the colloidal solution is put into the boiler or into the feed water beforehand? If it is put into the boiler, what becomes of the jelly which is produced from the colloidal solution?

Mr. E. A. FLINT: Referring to the table on Proof Page 1, I have totalled the grains per gallon, and it does not agree with 18·5, total hardness shown. It is usual for chemists to speak of parts per 100,000, and possibly the discrepancy arises from this.

Referring to the rate of steaming having an influence on the formation of scale, a paper was read some time ago by Professor Bone at the Royal Society of Arts, who gave some results based on a rate of steam production at 33 lbs. per square foot of heating surface. While not dealing with scale formation (his paper was in fact on "Surface Combustion,") he mentions that no scale was formed, and he attributed this to the very high rate of steam production.

Referring to the lecturer's remarks on lime and soda plants. It has been the practice of manufacturers in the past to design their plants on too small a scale, to enable them to put in lower tenders, and they very seldom allowed for a time of reaction in these plants of 2½ hours, whereas, when using London water, in my opinion, not less than three hours is required. If the lecturer could give us any methods whereby the action of lime and soda could be hastened, it would be a great help.

Further, it would be of interest and assistance to have reliable figures relating to the loss of efficiency in boilers due to the formation of scale. The figures available at present vary very much, and as practical engineers we are faced with this difficulty. One or two boilers of a battery are undergoing cleaning. One or two more have just been cleaned. Another group is due for cleaning. So that a regular routine work of cleaning boilers is carried on and we never have a complete set of dirty boilers to compare with a complete set of clean boilers, and it is therefore difficult in practical work to obtain a figure representing the loss of a boiler scaled up to say 1/16th in.

A previous speaker made a comparison between marine and locomotive boilers. I think he is mistaken, and it is becoming a practice more and more to instal water softeners for locomotive work. Furthermore, a locomotive might begin its journey on London water and finish on Manchester water, which seems to me to facilitate the prevention of scale, but not to prevent it entirely. So far as scale in a locomotive type boiler is concerned, I do not know of any method of scaling these boilers, and the only time when these boilers can be properly scaled is when the tubes are renewed, which of course does not occur very often in the life of the boiler. So that, for locomotive type boilers we are practically compelled to rely on washing out.

With regard to the slides which showed the effect of scale deposit in land boilers, it should be remembered that no qualifications are laid down by the Board of Trade for persons in charge of such plant, and when we reach the stage when some qualification is required in engineers who are to take charge of land boiler plants, such a state of affairs will not occur, and the ex-Marine Engineer will then perhaps come into his own.

Mr. A. Jobling: I rather think that the formidable array of chemical formula is against general discussion. It would be interesting to know how "Algor" is to be used. Is it to be injected into the boilers direct, or into the hot-well?

As a practical engineer, I am not yet able to differentiate between the various apparatus for reducing scale deposits, which we have had placed before us during the last few years; although "Algor" from the experiments shown us this evening seems to be based on very sound principles and should give excellent results. We have had circulators, a mechanical device for circulating water in the boilers at a rapid rate, which is alleged to keep the sediments from depositing on the heating surfaces; we also have the "Atlas fluid," which acts chemically, likewise the D.M. mixture which has to be applied to the heating surfaces, and now we have the latest scale remover called "Filtrator," a device for supplying the boilers with the emulsion of Linseed. This method, although used in a very crude manner years ago, seems to have assumed a prominent position in the marine world.

Regarding the slides shown us on the screen, which refer to land boilers, these are merely examples of the ineptitude of the management of the class of personnel, and such results could not possibly happen at sea with the intellectual supervision as provided by the Marine Engineer.

Mr. R. H. MacKillican: Could the authors give us any information relating to actual results obtained by the application of this treatment to boilers under normal conditions of working? We have seen how the impurities are absorbed in the test tube demonstrations, but one wonders whether the same thing happens in a boiler under the different temperature and circulation conditions.

The Chairman: Before calling on Mr. Lewis to make his reply, I cordially echo Mr. Flint's views regarding the way in which some boilers are run in land practice. Such results as those shown on the screen are not to be wondered at when one considers the lack of qualification permitted by some firms in the men to whom they give charge of their plants.

I believe there is no real, specific remedy for scaling and corrosion, and each case has to be dealt with separately. The important point is to keep air out of the boiler and, of course, salt if you can, condenser leakage being one of the greatest troubles we have had to contend with in marine practice.

Mr. Carpenter (Visitor): The question has been raised regarding actual experience in the treatment of water by this process in marine practice. I have had three years' experience with marine firms and I may say that the ships to-day are returning not only free from scale but the boilers are quite clean. Throughout a 3½ months' voyage out to South America and back, the corrosive troubles have been eliminated. One firm, after about 12 months' running on fresh water, decided to run their ships through the Mediterranean on salt water. These ships came in free from scaling. In this case, of course, special treatment had to be devised.

The CHAIRMAN: Perhaps the last speaker could amplify his remarks to give a better idea of the method of working.

Mr. LEWIS: I agree, and this will be embodied in my revised reply. I would like to say that this system is not an experiment by any means, and it has already been a great success in its practical application.

The CHAIRMAN: The treatment of boiler feed water is a most interesting subject, and there are several phases which have not been touched upon to-night, more particularly in connection with superheat. The boiler is well in hand, but the addition of superheaters brings in new problems.

A vote of thanks to the lecturers was carried unanimously.

The AUTHORS, replying to the Chairman, regarding the use of superheaters, as far as we are aware this is not a general practice. Priming and also scaling and corrosion of superheaters can be prevented by efficient treatment.

Referring to Mr. Thom's remarks we may say the "Algor" treatment is being successfully used for treating locomotive water on a number of the railways. Dealing briefly with the questions raised, the first was that in connection with alum in boiler water causing corrosion. The reason is that alum is a compound of potassium and aluminium chemically combined with sulphuric acid, and when it is added to the boiler water, unless something else is used (some alkali), the alum when it gets into the boiler splits up, liberating sulphuric acid, and causes a great deal of corrosion and damage. As fast as it attacks the boiler, it splits up again and goes on attacking the boiler, so that alum used for clarifying the water can be dangerous and cause corrosion.

The next point raised by the same speaker was a statement at the beginning of our paper where we mentioned "there have to be taken into account the following features. . . . etc.," and the one mentioned was item 10, the varying load on the boilers. In putting that in, our reason was to make the statement very conclusive. There are cases in marine boilers where the boilers have to be forced and where troubles occur which would not occur with normal steady loads which obtains from day to day under ordinary conditions.

With regard to oil, if filters are used, as they often are, and properly attended to, oil inside a boiler should be non-existent. As regards marine boilers, these are very well looked after, but it is surprising in land practice how different things are. We know of cases where a tremendous quantity of condensate is literally thrown away.

The next speaker mentioned scaling tools and whether our remarks apply to copper tubes and tubes of any other metal. When boilers are badly scaled and resist all other forms of treatment and you simply have to cut the scale off, these tools are quite all right in their place, but the trouble is that they are so liable to damage the skin of the metal (I think this applies to any metal, copper or the like). There seems to be a skin which will resist corrosion more than the metal underneath. Once that skin is damaged, corrosion seems to take place much easier, and it is for that reason that we said that scaling tools should be avoided as far as possible. The correct treatment is to keep the metal free from scale and to resort to the tools finally. I would like to make it clear that the pneumatic tool is a fine thing in itself, but chipping hammers used by people having more brawn than brains may perhaps damage the plates.

On the question of evaporators, in those marine evaporators mentioned, working at 5-7 lbs. pressure, we agree that there is little risk of the hydrochloric acid being carried forward and liberated, but in the other cases there was a big risk of this occurring and the acid coming over into the condenser. A paper was read by us some time ago before the Institution of Engineers in Charge, when Vice-Admiral Sir George Goodwin gave some interesting examples of the water from evaporators passing along copper pipes and being used for drinking purposes. Several men became poisoned and it was traced to this acid in the evaporators. That was some years ago, and evaporators are now greatly improved.

The next point was in connection with condensers, closed circuit and open circuit, and our statement that "about 95 per cent. of the condensed steam is returned to the boilers by means of the condenser. Unfortunately this condensed water contains a large proportion of the dissolved gases coming from the boilers, and this applies whether an open or closed system is in use." By this we mean to say that when water is boiled in a boiler, the dissolved gases escape and a certain proportion of them are condensed in the condenser; no matter what the conditions are in the condenser, we claim that you can have anything from 1·5 to 2 % of dissolved oxygen in condensed steam. Of course, in marine condensers, the tendency is to eliminate it, and it is of course well known to you that a closed system is far better than an open system in that respect. The dissolved gases are still there at the present time and anything that can be done to reduce them is all to the good.

Lieut. Marsden asked whether colloids offer any resistance to the circulation of the water in the boiler? No; the particles are extremely small in size. In actual practice they are no larger than a pin's head, so that as the water circulates, a portion of them is carried round, but the remainder settle to the bottom of the boiler and are removed at intervals by the blow-off valve. They do not bake on because of their capacity for absorbing water.

The next question was as to whether the fine particles moving in the water help towards free steaming. That is true, and it also applies to these colloids, because about 50 per cent. are going round with the water and each day a portion of them is blown off. When once you have the scales and salts in the form of a very fine gel, it should be blown out of the water.

Mr. R. J. Gibbs asked how " Algor " is fed to the water and what becomes of it. I have just dealt with the last part of that question. "Algor" in a highly diluted form is fed into the hot well or into the water in any convenient manner according to whether you are at sea or at a port. A continuous feed of "Algor" is preferable.

Mr. Flint referred to water softening in connecting with lime and soda, and asked whether anything could be done to apply it as it takes three hours or more to complete the reaction. Apart from the action of heat, which hastens the reaction, at the present time nothing is known about this. Even where heat is applied there is always a hardness of the water, small, it is true. We have demonstrated that if you take water from a softening plant and pass an electric current through it, you get colloidal chalk instead of ordinary chalk, and that the water is apparently clear as tap water, showing that the reaction has not been complete. The only thing to do is to have suitable treatment that will effectively deal with the colloidal chalk when it tends to come out. In land boilers it tends to come out in the economisers, or in the boiler itself.

The next question was "Can accurate figures be given regarding the loss of heat due to scale?" We should like to express our thanks to Mr. Flint for his figures and explanation at the blackboard. The experimental side of this work is very difficult to carry out. We have data on this matter, though not available here. We shall be glad to let Mr. Flint have any information in our possession. The whole question bristles with difficulties. Scale undoubtedly causes loss of heat; calculated theoretically the plate should be nearly red hot, but with soft chalky scales this is not so in practice, otherwise it is difficult to understand why you get such good evaporation with scale, even in land boilers. Part of the trouble is due to the variation of feed waters. A chalky scale does not resist the passage of heat anything like a sulphate of lime scale, which is quite a good insulator of heat. Then a trace of oil in scale will cause great resistance to the passage of heat. A 1/1,000in. film of oil is equal to a $\frac{1}{4}$in. plate of iron or steel in this respect.

In connection with the suggestion that training is necessary for engineers in charge of land boilers, we certainly agree with the remarks made, because while there are any number of instances of engineers very fully qualified, there are a large number of boilers (especially in the case of those belonging to firms having only one or two boilers) where the men in charge of them have nothing like the training and experience which the Marine Engineer has. Of course, in large power stations the conditions are extremely good.

The next question referred to the "Algor," is it a liquid or what is it? "Algor" is not one liquid at all; it is a colloidal treatment and at the same time it is founded on scientific lines and it is not the same for different firms or different ships. In other words, it is made up to suit the conditions, and that I think you will agree is the only right and proper way to deal with the problem. The material must be made to suit the conditions. Not only should the various waters which are being used be borne in mind as regards suspended matter, etc., but the conditions of working the boilers, whether scale is the trouble or corrosion, and the engineering features should also be borne in mind. After that, any treatment should give the engineers in charge some idea of what is going on inside the boiler, and an indicator such as that shown to-night is very valuable. An analysis (by us) of water from salinometer cocks is also an indication of what is going on inside the boiler. Treatment on these lines helps to eliminate the human element. I think you will agree that the "Algor" treatment is a very different thing from anything else. Apart from the colloidal basis of the material, other ingredients are incorporated for the treatment of priming, corrosion, etc. It is also in different forms. It may be a powder and so on.

The final question by Mr. MacKillican was, could some remarks be made in connection with "Algor" in actual practice in connection with boilers. Mr. Carpenter, one of our consulting engineers, who has had good experience, has given some information on this point.

I have pleasure in further replying in detail, particularly to Mr. MacKillican.

This colloidal treatment is controlled by the Feed Water Specialists Co., Maxwell House, St. Paul's Square, Liverpool. The trade name is "Algor."

It is the outcome of over 46 years' experience in hydrological chemistry and boiler water problems in all parts of the world.

The treatment is formulated suitable to individual requirements, *i.e.*, based on water analyses and engineering features. No stock specific is kept and the treatment may be either powdered or liquid.

In marine practice the "Algor" is formulated suitable for dealing with sea water either in entirety or as a percentage of make-up. In dealing with the worst water therefore, the "Algor" is more easily able to deal with the best, hence our reason for prescribing on the worst contingency which could arise, *i.e.*, salt feed.

It can be either used as an adjunct to Zincs or in entirety. No additional apparatus is necessary for feeding. The treatment is diluted with water and introduced to the feed at a suitable point.

The outlay in marine practice is less than 1d. per 1,000 gallons of water evaporated.

An outside staff of engineering representatives is kept at the service of customers.

An after-sales service is given with the material which includes boiler inspections, special investigations, general advice on boiler plant efficiency, analyses of waters, the supplying of special indicators, etc., etc.

The treatment is installed in some of the largest industrial concerns in the country and is also extensively introduced in sea practice.

All investigations are conducted without cost or obligation.

It is guaranteed non-injurious, non-poisonous, non-explosive. Old scale is gradually softened and rotted away whilst further hard formation is prevented. Old corrosion is deadened and an extension prevented.