

# INSTITUTE OF MARINE ENGINEERS

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SESSION



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President : SIR ARCHIBALD DENNY, BART., LL.D.

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VOLUME XXVI.

## Demonstration of the Amalgaline Process of Metal Jointing.

By MR. T. HARDEN.

*Monday, September 21, 1914.*

CHAIRMAN : MR. JAS. ADAMSON (Hon. Secretary).

Before proceeding with the demonstrations Mr. Harden read the following paper.

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It is a source of much gratification to be invited to read a paper and to demonstrate "The Amalgaline System of Plumbing," as applied to marine work, before this Institute, an Association whose members are specially able to appreciate the advantages the system offers and who are qualified to criticise.

Some five years have passed since my Company were privileged to introduce to you what was then a practically new invention relative to the jointing of lead and the metals in use therewith.

Before proceeding to demonstrate the process, I would like to point out what is claimed for the system; the evidence of the demonstration will be sufficient to prove how far the claims are justified.

It is claimed that the system effects a true joint in every sense of the word between the two surfaces of the metal and, as will be shown to you, what is actually brought about is a complete fusion between the surfaces joined.

Secondly, it is claimed that the system lends itself more readily to conditions under which work has to be carried out, more expeditiously than by the older methods, and with far more satisfactory results.

Thirdly, it is claimed that the system proves more economical than any other approved method of plumbing; this, I am convinced, will be apparent to you when you have witnessed the demonstration we are giving.

The Amalgaline System combines the two most important factors of a successful modern enterprise, viz., economy and efficiency. This has enabled the system to obtain a firm footing in every branch of trade where lead is used.

In marine work the principal uses to which the system is applied is that of flanging pipes, the seaming of lead used in refrigerating chambers, and general sanitary work.

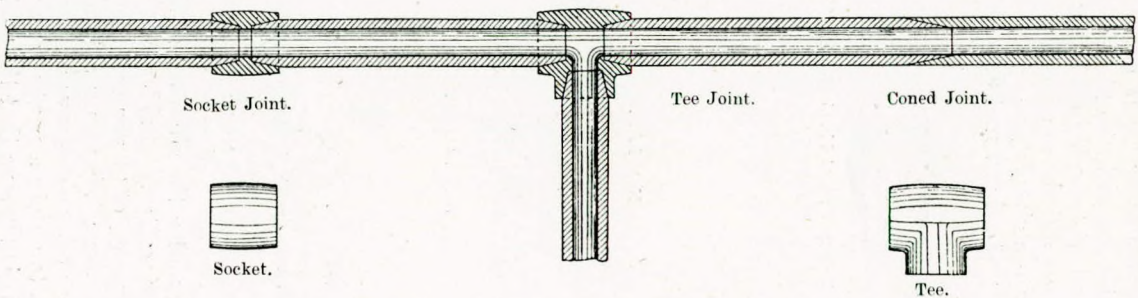
The system of flanging was first adopted by Messrs. Doxford, of Sunderland—a firm, doubtless well-known to members of this Institute—their experiences in the use of the system extends over the past seven years, a testimony sufficient in itself to prove the claims made for the system are not without justification. Since that time the system has gradually extended to the principal shipbuilding centres and has become in general use on the Clyde, Tyne, Tees, and Wear. The system has not been confined to the use of small pipes alone, but is used in an ordinary way on pipes varying in bore from 3in. to 9in. This we are aware of by the moulds the company are constantly supplying.

I now come to the details of the work. It is quite possible that the flanging of bilge pipes may be considered but a small item in marine construction, but those amongst you who have had occasion to deal with breakdowns in connection with lead flanges will appreciate the difficulty of repairs. Engineers are not adept plumbers—the result frequently is that of a temporary joint. Red lead and spun yarn is requisitioned and luck



trusted to until a proper repair can be effected. My point is to

THE AMALGAMINE METHOD OF JOINTING WATER PIPES.



*Note:—The Sockets and Tees are separate castings provided by the Company for this purpose.*

avoid such trouble arising. Unquestionably, lead is the most

suitable metal for bilge work on account of its pliability, giving and taking to all strains to which it is subjected; little or no trouble can be experienced with the pipe itself beyond mechanical injury. The cause of trouble invariably arises at the flange connection to pipe, and a little consideration will show that the reason for this is quite a simple one. The flange is connected to the pipe by means of a hard metal, in other words, solder,



Present form of Plumbed Joint.



New Joint.



Socket Cutter.



Spigot Cutter.

and in consequence, under the slightest strain, the hard metal tears away from the softer. Solder used for this work is usually an alloy composed of 60 per cent. lead and 40 per cent. tin, or similar proportion; this forms a hard and brittle alloy, and this composition at once destroys all flexibility of the connection. Therefore, to obtain a perfect connection between the flange and the pipe it is obvious that the material used must be as pliable as the pipe itself.

To bring about these conditions there remains, apart from Amalgaline, one other resource, namely, lead burning, but on account of cost and special skill required this is seldom resorted to; in fact, this method is principally confined to chemical work.

Amalgaline, like lead burning, is an autogenous or "burning to" process, but instead of using an intense local heat, the fusion is effected by the action of Amalgaline on the surfaces it is in contact with; the result—practically the same effect is produced—an amalgamation of the lead of the flange with the lead pipe. An entirely different result is obtained than by the crude method of connecting a flange by means of an alloy.

I have now to describe the scientific value of the invention. "Amalgaline" is a metallic ribbon .002" in thickness, practically a *pure* metal, which, when placed between two surfaces of lead and subjected to heat, fuses at a temperature of 160° lower than the actual fusing point of lead, and in fusing causes the lead surfaces to run together at a lower melting point, that of

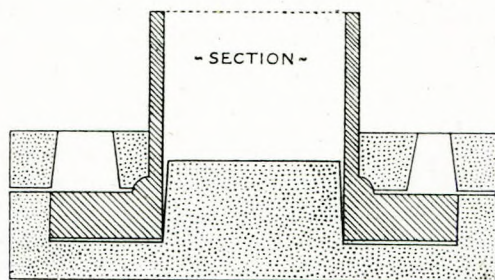


4-inch Lead Junction.

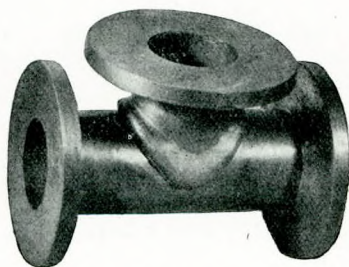
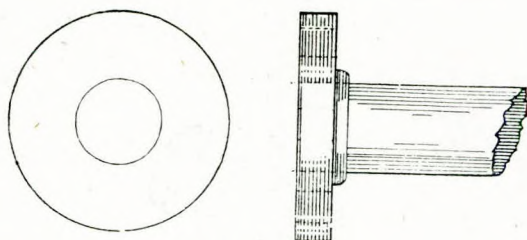
the body of the lead. This running together is an autogenous effect, and by intermolecular absorption the minute particles of Amalgaline are dissipated into the body of the lead and which, by reason of the absorption, becomes stronger at the junction than elsewhere. So perfect is the effect of this method of jointing lead that many uses have been discovered for it by chemical and electrical engineers. The fact that joints made by the process withstand the attacks of acid is being taken advantage of in the place of the system of lead burning by these industries,



and it is now used extensively for jointing plates in accumulators, acid tanks, and other purposes. The jointing of lead covered cables, junction and services, and for this purpose it is now in use all over the world by our leading telegraph com-



Mould for Casting Flanges on Lead Pipes.



The Tee Branch with Flange is Cast Direct on to Lead Pipe in One Operation by Means of Patent Combination Mould.

panies for connecting land lines in connection with submarine cables; also it is greatly in use for pipe lines in connection with the compressed air plants of the new creed instruments for rapid telegraph work.

Returning to the question of flanging pipes. The method of carrying out this work is an extremely simple one, and requires but a short explanation. The end of the pipe is first cleaned, a strip of Amalgaline is wrapped round, the pipe is placed in the mould, molten lead is poured in. The work is completed with the exception of cutting off the runner and riser. What happens in the mould is practically what I have already described. The molten lead fuses the Amalgaline, which in turn fuses the surface of the pipe, and thus the flange automatically becomes part of the pipe itself; as a result, lead to lead throughout. Another branch of marine work is that of lining refrigerating chambers, a system, compared with the old method of seaming—a tedious and expensive one at the best—is simplicity itself, as we shall show in our demonstration. This system is now largely in use with the principal shipping lines, and has recently been adopted for use by the Admiralty for similar work. I will not trespass upon your time in dealing with its application to the jointing of pipes for sanitary purposes, the connection of lead and brass and the various applications to this class of work, but in all cases the argument applies, that it is a system that overcomes the use of alloys in connections and gives that pliability that is required wherever lead is used.

I now come to the latest application of Amalgaline in marine work; this is in connection with water-tight glands for bulk-heads, deck tubes, etc., as used for electrical cables on battle and other ships.

The Admiralty have experienced much difficulty in the use of the ordinary packed glands, due principally to the varying temperatures. It became a question of importance under present conditions in the Service that these glands through which the power, lighting and communication cables passed should be absolutely tight under all conditions. With this view I was called upon to design a gland that would fulfill all these requirements. The glands were submitted to the Admiralty who, after a series of severe tests applied at Portsmouth Dockyard, approved of same, and it may perhaps be of interest to hear that the flag-ship H.M.S. *Iron Duke* has been installed with these glands.

We have several of these glands here this evening for your inspection.

It is, of course, well-known that the cables which have to pass through the various compartments demand glands which, whilst preventing the passage of water, will not injure the in-



sulation of the conductors, and by examining the glands you will see how this has been effected.

The gland forming a cap; the cap is utilised as a mould; the cable passing through the gland is prepared by wrapping a strip of Amalgaline round, and molten lead is poured through a hole drilled in the back nut. The result is we build up a half ball upon the lead covering of the cable. Upon screwing up the back nut the pressure is exerted entirely upon the lead casting, forming a sound joint and at the same time relieving the insulation from any undue pressure that it would be subjected to as in the case of metallic packing.

Smaller glands are used for fittings, lamp holders, switches, distribution boxes, etc.; for these glands a separate mould is used, the type of gland you will notice is somewhat different.

In conclusion, gentlemen, I must thank you for your kind attention to the various uses of the invention which have been exploited. Like many other inventions it has been confronted by opposition and trade prejudices, but from the growing demands from all sources and the support received from the Navy, the Army, and practically all Government authorities, the leading shipbuilders and others, is conclusive that the system will be the leading one in the near future and prove an efficient substitute for the older methods of jointing lead and its alloys.

We will now proceed with the demonstrations, and I shall welcome questions on any point that may not be quite clear.

Demonstrations of the various uses of the process as described in the paper were then given, and the demonstrator replied to questions put by members of the audience.

A vote of thanks was accorded to Mr. Harden on the proposal of Mr. J. Clark (Member).



## BOILER EXPLOSIONS ACTS, 1882 AND 1890.

REPORT OF FORMAL INVESTIGATION. (No. 2255).

### Explosion from the Feed Check Valve Chest of the Boiler on Board a Steam Trawler.

THE explosion occurred on Friday, the 11th April, 1913, on board of a steam trawler, at about 2.40 p.m., whilst the vessel



was at sea trawling about 50 miles E.N.E. of Scarborough. The second engineer, was so severely scalded that he died within two days after the explosion occurred.

The fitting from which the explosion occurred consisted of a 1 9-16th inches diameter screw-down non-return feed-water check valve chest of the "Globe" pattern, which was fitted to the shell plating of the boiler (*vide* Plate 2) on the port side near the after end-plate. A loose-fitting valve-seating  $2\frac{1}{8}$  inches in diameter externally and 1 19-32nd inches in diameter internally, with flange 6 inches in diameter was fitted to the valve chest from the underneath side and held in position between the underneath flange of the valve chest and the feed-pipe flange (*vide* Plate 3) by five bolts and nuts each  $\frac{5}{8}$ ths inch in diameter. The valve, the seating, and the valve chest were made of gun-metal.

The trawler has one set of compound engines of 40 N.H.P.; steam being supplied by one single-ended steel boiler, 11feet long by 9 ft. 6in. in diameter, which is worked at a pressure of 90lbs. per square inch. The engines and boiler were fitted in the vessel in 1892, when she was built.

*Particulars and Dates of Repairs.*—Apart from minor and ordinary repairs to the vessel, made as were required, a sum of between £300 and £400 was expended in repairs at some time during last year, or the year before; but nothing has been done to the boilers excepting the ordinary surveys.

In December, 1911, the seating of the original valve chest was faced up, and the valve was ground in; in January, 1912, this repair was repeated; and again the same repair was made in April, 1912.

In the July following, the original valve was discarded and the valve orifice of the original valve chest was bored out afresh (*vide* Plate 3) and a bush was driven in from underneath as a loose-fitting; so that the top of the bush formed the new seating for the new check valve. The bush had a flange at the lower end of 6 inches in diameter which formed the middle flange between the superior flange of the valve chest and the inferior flange of the feed-pipe; and all three flanges were bolted together with five bolts and nuts.

After the explosion, which took place on the 11th April, 1913, the original valve chest and all its fittings were removed, and were replaced by an entirely new valve chest and valve similar in design to that which had originally been fixed.

*Nature of the Explosion.*—Whilst the joint between the flange of the feed-pipe and the flange of the bush was being remade the bush which formed the seating for the valve, together with the valve itself was forced downwards by the pressure of the

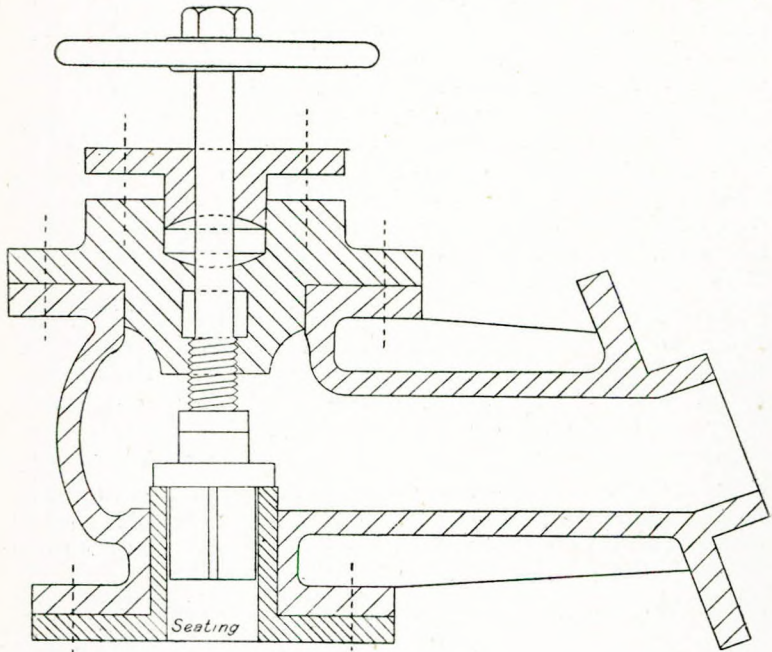


Plate I.

Sectional elevation of Valve Chest with fittings.

steam in the boiler, out of the valve orifice, after three out of the five bolts securing the joint had been removed, and whilst the fourth of the said five bolts was being knocked out. The bush was blown out into the stokehold and the valve was ultimately found lying in the bilge water.

*Cause of the Explosion.*—When, after repeatedly facing up the seating of the original valve-box it was found that a sufficiently tight valve could not be obtained on account of the porous, sandy, or faulty condition of the metal surrounding and contiguous to the valve orifice, the superintending engineer to the owners decided to have some of this faulty metal bored out, thus increasing the size of the valve orifice from 1 9-16th inches



as originally made to  $2\frac{1}{8}$  inches (*vide* Plate 3); and to bush the aperture so as to restore the valve-box to its original dimensions or thereabout. This new bush was made, as above stated, with a flange at the lower end so as to admit of the bush being inserted into position through the bottom flange opening into the chest (*vide* Plate 1), with the apparent intention of facilitating the future withdrawal of the new bush whenever it might be desirable to again "skim up" the valve seating. The effect of applying the bush in this unusual manner, instead of the customary and proper method of fitting it with a collar on the valve seating end, was to leave the bush and valve quite unattached and unsecured in the valve-box except by such friction as existed owing to the tightness, or otherwise, of the bush when pushed into place (*vide* Plate 1), and until the valve-box was jointed to the feed pipe.

On the day of the accident, whilst such joint was being re-made, and after the valve spindle had been screwed down (*vide* Plate 1) with the object of closing the valve—though in fact

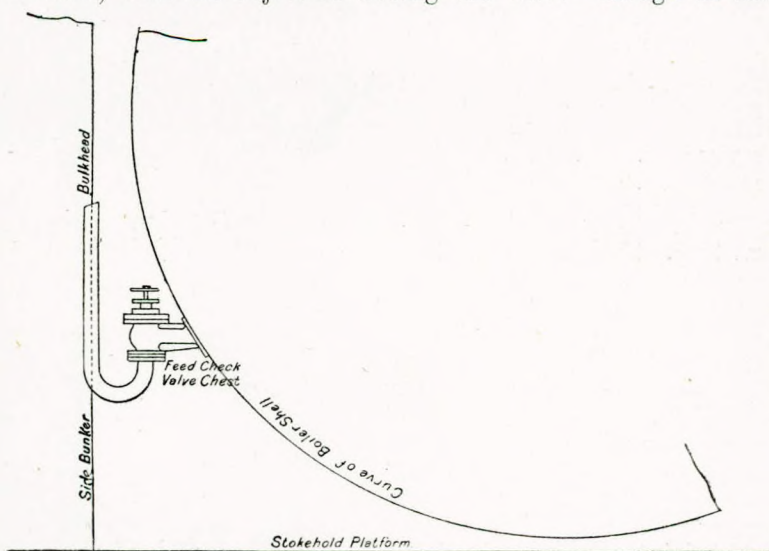


Plate II.

such screwing down had only tended to displace the bush—the pressure of steam inside the chest forced the valve and the bush down through the  $2\frac{1}{8}$  inches orifice, and so out of the valve chest altogether.

*Remarks.*—At the conclusion of the evidence called in behalf of the Board of Trade, Mr. Saxelbye submitted to us certain questions for our consideration; and after hearing the evidence, we stated as follows:—

We will now deal generally with the evidence which has been forthcoming during this investigation; and in so doing we will answer the questions which have been submitted to us by Mr. Saxelbye on behalf of the Board of Trade. The questions are as follows:—

Question 1. Was the feed check valve originally fitted to the boiler on board the steam trawler of good design and safe for the purpose intended?

Question 2. What was the alteration made in the design of the valve in July, 1912? Who was responsible for such alteration being made? Was the feed check valve as fitted on the boiler after alteration a safe and proper mounting for the purpose intended?

Question 3. What was the cause of the feed check valve seating blowing out on the afternoon of the 11th of April last?

Question 4. Is the superintending engineer to the owners of the steamship to blame for the explosion? Should he pay any, and, if so, what part of the costs of this formal investigation?

On the afternoon of the 11th of April, whilst the vessel was trawling, it was found that the feed-pipe flange joint connecting it to the valve-box was leaking, and in order to remedy this defect the chief engineer determined, so soon as the main engines were stopped for hauling and shooting the trawl, to separate this joint and remake it with new jointing material. He screwed down the feed valve hard on to the seating (*vide* Plate 1), thus shutting off effectually, as he supposed, all communication with the inside of the boiler. He then lowered the steam pressure from 90lbs. to 20lbs., as a precautionary measure to avoid excessive leakage should the feed valve be not quite tight; and he proceeded to separate the flanges of this leaky joint, with the result that when the fourth of the five bolts was knocked out, and the nut was off the last remaining bolt, the valve and bush, being left entirely unsupported, as already described, were blown into the stokehold, displacing the feed pipe on its way and allowing the contents of the boiler to escape.



When the superintending engineer effected the alteration to the valve-box by the introduction of a movable and renewable valve-seating, it is obvious that his desire was to prolong the useful life of the valve-box which he had reason to believe was gradually being worn away by constant leakage between the

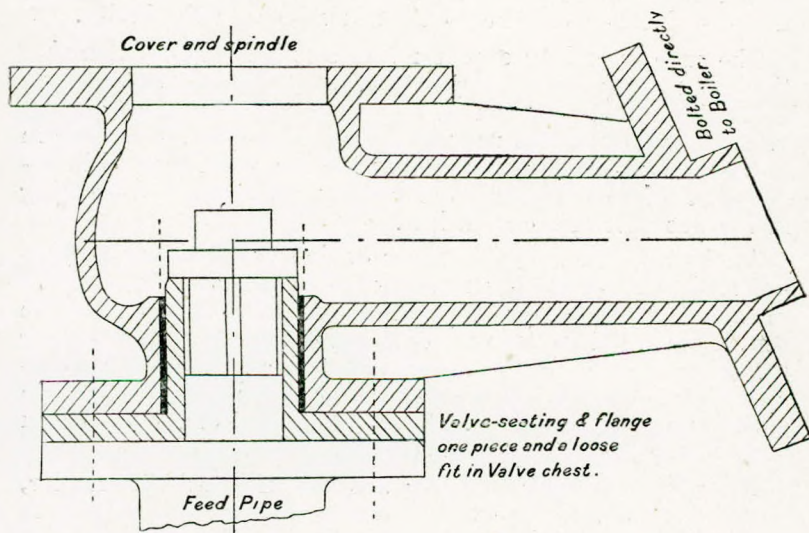


Plate III.

valve and the seating; and by the repeated facing up of the seating for the prevention of such leakage. Had this new separate seating been so secured in its place in the valve chest as to have become an integral part of the chest, it would have fulfilled the superintending engineer's intention; and would have left the box a self-contained valve chest.

With the valve tight on its seating, no communication between the boiler side of the valve-box and the feed-pipe side could have come about by the breaking of any joint below the valve. But with the new fitting as devised, and with the valve screwed down on its seating, there was, when any pressure existed in the boiler, quite free communication between the steam-side of the valve chest and the other side; and when the support of the feed-pipe flange was removed the functions of the valve no longer existed. The superintending engineer is generally recognised in this district, as well as by his em-

ployers, as a good and capable engineer, and had this view of the matter presented itself to his mind, we are satisfied that, with the knowledge of the possible danger which might and did result, he would have either secured the loose-seating in the chest independent of the feed-pipe flange; or, he would have resorted to the other common practice of interposing a stop or master-valve between the feed check valve and the boiler.

The superintending engineer seems to hold the opinion that the presence of two flanges jointed to the valve-box should have been sufficient indication to any engineer sent to work this vessel that the box was not now a solid box with the seating in in one with it, although outwardly the box was identical in appearance with what it was originally when the valve-seating inside was part of the solid box.

At the time the superintending engineer sent this loose seating to be applied we do not think it ever occurred to him that in the event of having to separate the feed-pipe flange from the box, it could not be done under steam without the loose seating being blown out; and had it occurred to his mind we believe he would have safeguarded the men in the engine room by specific instructions to the effect that the lower joint of the valve box should never be tampered with under steam.

The superintending engineer was not on board the trawler, he was at Hull, and the vessel was lying at Scarborough. It was an oversight on his part that he did not inform himself of the fact that there was no master-valve between the boiler and the feed-check valve; it was an error of judgment that, in the circumstances, he should have ordered the loose-fitting seating. Yet, we give him credit for every intention of acting in the best interests of the owners in getting the vessel again under weigh as soon as possible.

That the presence of the two flanges bolted to the bottom of the valve-box did not convey such knowledge as the superintending engineer supposed would be conveyed, to either of the two men, who started to remake this joint on the day of the accident is manifest. The chief engineer had the recollection of what he had known when he served in the ship two years previously, *i.e.*, that the valve-chest was a solid box with the seating in one with the box; and on the day of the accident he screwed down the valve hard on its seating; and he believed it was then properly shut—since the leaking momentarily stopped. He then proceeded with confidence to knock out the bolts of the feed-pipe flange.



As to the second engine-driver, who unfortunately lost his life owing to this explosion, although he did in fact assist in fitting the loose-seating, yet he did not appreciate the changed conditions of the valve-box; and, as to all appearances, the valve, when screwed down, was performing its functions as a valve, it did not suggest itself to his mind that such loose seating was liable to be blown out on removing the bolts of the feed-pipe flange. He had remade that joint with the original valve in use; he had acted under orders when he assisted in fitting the new loose seating; and he was at the time of the accident acting under orders in remaking the joint; and he did not appreciate the fact that there ought to have been a master-valve; he had been accustomed to rely on a valve as being at all times operative as a valve.

Shortly, in answer to the questions above set out:—

1. The feed check valve originally fitted was of good design and safe for the purpose intended.

2. The alteration in the design of the valve has been described as above. The superintending engineer was responsible. The alteration was in itself, without a master-valve, not an efficient mounting for the purpose intended.

3. The cause of the feed check valve seat blowing out has already been fully stated.

4. We have carefully dealt with all the circumstances of this explosion; and we exonerate the superintending engineer of blame; we think that we should be doing him an injustice were we to order him to pay any part of the costs of this investigation.

*Recommendation.*—Whereas more than one of the witnesses called before us have spoken in terms somewhat favourable of the bush seating devised by the superintending engineer as an inexpensive and in some ways a convenient method of renewing the valve seating; and whereas the device appears to us to possess certain intrinsic merits, provided always that a master-valve be interposed between the check-valve and the boiler; we therefore make the Recommendation following: that is to say, that all owners of steam trawlers should be warned of the danger attending the use of such loose-fitting seating unless at the same time such loose-fitting be under the control of a master-valve.

Dated this 18th day of June, 1914.

GEORGE WARNER }  
J. MELROSE } *Commissioners.*

To the Assistant Secretary,  
Marine Department, Board of Trade.

## PRIZE ESSAY.

(*Competition for Associate Members, 1914.*)

### Superheated Steam.

BY SURCHAUFFE (MR. W. SMITH, Associate Member).

THE marine engineer is essentially an economist, and as such, is always ready to adopt and develop anything which promises to increase the efficiency of the plant for which he is responsible. It is, therefore, not surprising to find him putting superheaters on shipboard as far back as 1859, and when we consider the many difficulties which were encountered, such as burnt-out superheater tubes due to the use of salt feedwater, scored cylinders and valve faces due to unsuitable lubricants of low flash point, we must credit them with an amount of enterprise and energy beyond the ordinary.

The development of the superheater continued with more or less success up to about 1870, when the introduction of the compound engine, together with higher boiler pressures, caused marine engineers to abandon the superheater and develop the multi-expansion engine which offered fewer mechanical difficulties and promised higher economies than were to be obtained with the superheater of that period.

The conditions which obtain to-day are, however, much more favourable to the use of superheated steam than was the case 50 years ago; superheater construction is better, salt in the feedwater is no longer tolerated, oils suitable for high temperatures are easily obtainable, and efficient filters for the removal of oil from the feedwater are on the market.

The foregoing remarks, together with the fact that practical limit of efficiency with saturated steam has almost been reached, amply justifies the policy of many engineers who are now reverting to superheating.

Having thus briefly defined the position of the superheater at the present moment, we may proceed to discuss the advantages which accrue from its use. These may be enumerated as follows:—

1. Considerable increase in efficiency.
2. Less pressure drop and no condensation between boiler and engine. (Incidentally, less risk of water hammer).



3. Addition of superheater, a convenient means of increasing power of existing boiler plant.

Of these the first need only be considered, it being by far the most important, the steam economy effected ranging from 5 per cent. to as much as 25 per cent., depending upon the particular conditions under which the plant operates. For instance, slow running engines show a larger gain than fast running engines, small engines more than large, simple more than compound.

If we take the trouble to analyse this statement, we shall find a striking similarity between the comparisons, it being in each case clearly a question of cylinder condensation. It is well known that condensation is proportionately greater in slow engines than in fast, in fact it may be assumed to be inversely proportional to the square root of the revolutions. Again, the factor  $\frac{\text{cylinder surface}}{\text{volume}}$  is greater in small engines than in large, and lastly, the condensation in simple engines is naturally greater than in multi-expansion engines, owing to the reduced temperature range in each cylinder of the latter. Upon this question of cylinder condensation, the whole gain due to superheating depends, and it has been shown that for each 1 per cent. wetness at cut-off  $6^{\circ}\text{F}$  of superheat must be added to maintain the steam dry at cut-off. Using this as a basis, we may investigate the saving which would be expected to accrue in a simple engine using saturated steam 20 per cent. wet at cut-off.

The amount of superheat required =  $20 \times 6 = 120^{\circ}\text{F}$ ., and taking the specific heat at  $\cdot 48$  this equals 58 B.T.U.'s per lb. of steam. Assuming that the thermal efficiency of the above engine is 10 per cent., we have approximately 100 B.T.U.'s converted into work per lb. of saturated steam. But only 80 per cent. of the steam supplied to the engine does useful work. The addition of 58 B.T.U.'s, however, ensures dry steam at cut-off, thereby increasing this figure to 100 per cent., representing a gain of 25 per cent.

This shows a thermal efficiency of 11.8 per cent. with superheat against 10 per cent. without, which gives a clear efficiency for that portion used for superheat of 28 per cent. Besides ensuring that the steam in the cylinder shall remain dry, due to its surcharge of heat above saturation, it has also the salutary

effect of reducing the rate of heat exchange between the cylinder walls and the steam. This effect may be shown by extending our previous example thus:—

Heat units lost per lb. of saturated steam at 120lbs. per square inch = 1 per cent. of the latent heat = 8.74 B.T.U.'s. Heat units lost per lb. of superheated steam =  $6 \times 0.48 = 2.88$  B.T.U.'s since  $6^{\circ}$  of superheat are required to eliminate 1 per cent. of initial condensation. Therefore approximately three times as much heat is lost in the first case as in the second.

Coming now to the consideration of the multi-expansion engine, which is, of course, synonymous with the marine engine, it is not practicable to so superheat the steam that any superheat passes into the second cylinder.

It has been remarked in regard to the simple engine that for maximum practical efficiency, the steam should be dry at cut-off although theoretical efficiency demands the steam dry at release. This is attributed to the very high superheat required to ensure the latter condition, in fact it is found in practice that even with considerable degrees of superheat ( $600^{\circ}$ ) it is unusual to find the steam dry at release. Again, in attempting to attain the maximum theoretical efficiency, there is the danger of overdoing it and passing some of the steam to exhaust which would, of course, represent a dead loss. This condition, however, would not occur in the multi-expansion engine, and this point, together with the fact that the later cut-off and the consequent smaller ratio of expansion renders dry steam at release more easily obtainable, suggests to engineers the desirability of aiming at the maximum theoretical efficiency, subject, of course, to the particular conditions involved. To maintain the steam dry on its admission to the next cylinder, multi-tubular reheaters using superheated steam may be fitted between the cylinders. These reheaters would materially increase the efficiency of the following cylinders, and this method is much superior to direct mixing.

The steam turbine does not show such a good return with superheat as the reciprocating engine. This is only to be expected as the condensation in the turbine is reduced to a minimum, owing to the constant temperature of the internal surfaces. The economy obtained is about 1 per cent. reduction in steam consumption for every  $10^{\circ}$ F. superheat, and is attributed to the rotor revolving in a less dense medium. The degree of



superheat adopted does not exceed  $50^{\circ}\text{F}$ ., owing to the increased possibility of blade stripping due to the higher temperature. With slightly increased clearances, superheat up to  $150^{\circ}\text{F}$  may be safely employed. The foregoing remarks relate more particularly to turbines of the reaction type as the larger clearances and earlier temperature-drop in the impulse type render it more suitable for superheat.

The introduction of turbines having their high pressure ends arranged for impulse working and the low pressure end reaction, marks an important development in steam economy, for, apart from the gain obtained from the combination of the high pressure velocity compounded stage and the low pressure reaction, this machine should be suitable for superheats of  $200^{\circ}\text{F}$  or more.

We must now turn our attention to the most salient features of the superheater itself. Firstly, in regard to its position, this should be the hottest place available consistent with safety and reliability, for by this means the size is kept within reasonable limits owing to the greater rate of heat transmission per sq. ft. The most usual position is the lower end of the uptake. The construction of the superheater should permit of the free expansion of all parts and special attention should be paid to all joints to see that they are not unduly strained.

There are practically only three types of superheaters of interest to marine engineers, *i.e.*, the Babcock and Wilcox, the McPhail Simpson, and the "Schmidt." Of these the first is used solely in conjunction with water tube boilers. It consists of a number of "U" tubes, one end of which connects to the saturated steam header and the other end discharges into the superheater steam header. This nest of tubes is arranged along the width of the boiler between the water tubes and the drum, and is therefore screened from the direct action of the fire. Arrangements can be made for flooding the superheater with water to prevent overheating of the tubes during steam raising. The superheater then forms part of the boiler heating surface.

The McPhail Simpson superheater is shown in Fig. 1. The arrangement is neat and the design embodies all the essential features of the successful superheater suited to the ordinary marine boiler. For instance its position above the smoke tubes leaves them quite clear for cleaning or repairing. This is an important fact and should be emphasised, as the tubes of some superheaters intrude into the smoke tubes, rendering these operations difficult. Further, it does not interfere with the

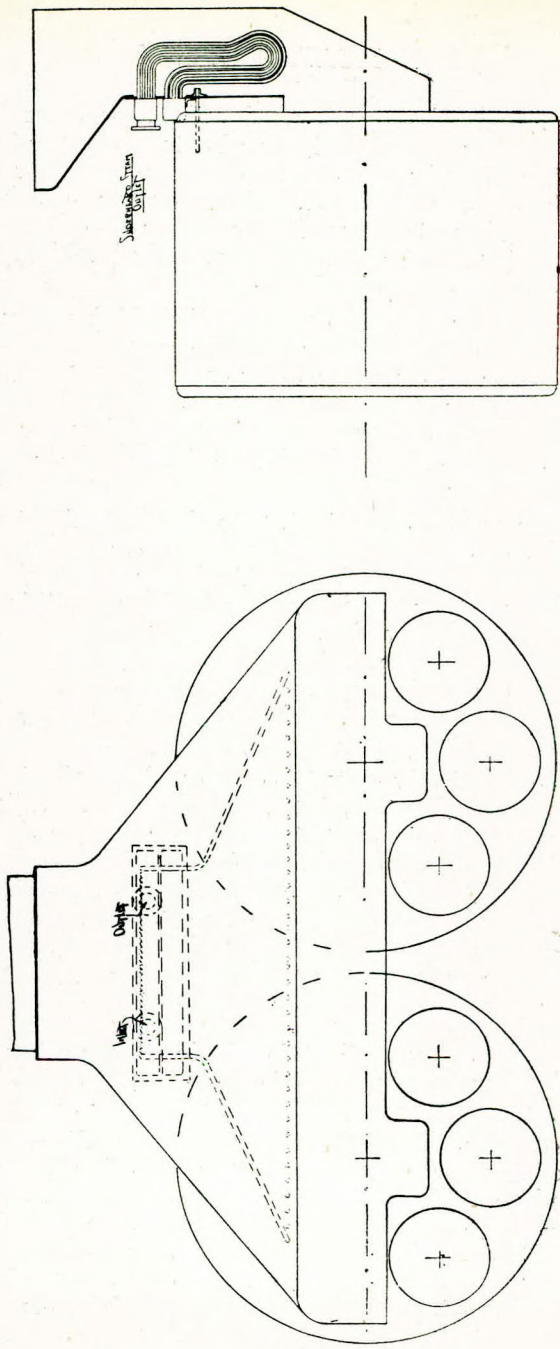


Fig. 1.  
Arrangement of McPhail & Simpson's Superheater.



working or construction of the boiler itself, requiring but little alteration to the usual form of smoke box. It is designed for only a moderate degree of superheat and therefore calls for no special valves or fittings. Easy access to the tubes is provided for examinations or repair.

In the "Schmidt" superheater the tubes are of the usual "U" shape and several are connected in series, the ends then connecting to the headers in the usual way. Each "U" tube is arranged centrally in a smoke tube as shown in Fig. 2. This

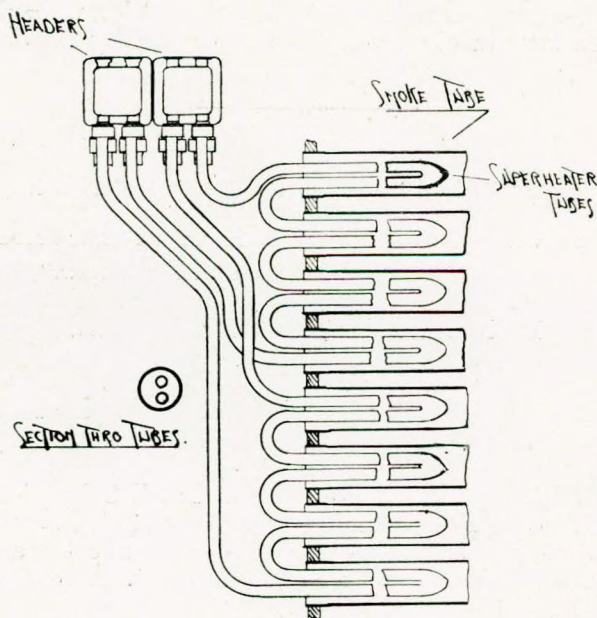


Fig. 2.

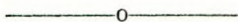
Arrangement of the Schmidt Superheater.

appears to reduce the area through the smoke tubes and consequently the draught, but it is claimed that the effect is just the reverse.

The area occupied by the superheater tubes is small compared with the smoke tube area, and as the coal consumption is greatly reduced owing to the fitting of the superheaters, the ratio of smoke tube area to fuel burnt is not materially altered.

There is yet another class of superheater, namely, the "separately fired" type which, although adopted to some extent on land, has seen but little service at sea, and then only in certain foreign naval vessels. There appears, however, to be but little desirability to adopt this form of superheater as the "integral" type satisfies all the demands of present day marine practice, besides being cheaper, more efficient and requiring less attention.

In conclusion, we can only predict a rosy future for the practice of superheating. It must follow as a natural sequence the many other one-time refinements, now necessities, which have in turn been introduced, developed, and eventually standardised.



## Feedwater and its Treatment.

[READ BEFORE THE SCOTTISH FEDERATED INSTITUTE OF MINING STUDENTS AND  
PRINTED IN "THE IRON AND COAL TRADES REVIEW."]

BY MR. WILLIAM BARROWMAN.

(REPRINTED BY KIND PERMISSION OF THE AUTHOR, THE COUNCIL OF THE SCOTTISH FEDERATED INSTITUTE OF MINING STUDENTS, AND THE PROPRIETORS OF "THE IRON AND COAL TRADES REVIEW").

THERE is a tendency to increased cost in all industries. The modern craze for legislation has contributed to this, and makes it imperative that advantage should be taken of every available method for keeping costs at the lowest point. The subject of this paper is one of these factors.

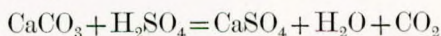
The ideal feedwater for a boiler is pure water, but this is so rare that it may be regarded as a scientific curiosity. The purest natural water is rainwater, but during its passage through the air, even this becomes charged with impurities to a greater or less extent. The gases, oxygen, nitrogen, carbon dioxide, sulphur dioxide, and sulphuretted hydrogen all exist in the atmosphere, and they along with soot and dust are all found in rainwater, more especially in manufacturing districts. When this water, in turn, percolates through the earth, it exerts a solvent effect on the minerals with which it comes into contact, and the gases in solution add, in some cases consider-



ably, to its solvent powers. Carbon dioxide in solution is a weak acid, which, however, enables the water to dissolve large quantities of sodium, calcium, magnesium, and iron salts which it encounters, forming the corresponding bi-carbonates, as represented by the equation:—

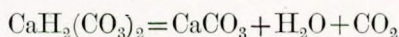


Similarly the sulphur dioxide is readily oxidised in solution to sulphuric acid, and this attacks many minerals, forming sulphates; for example:—

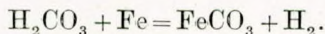


Chlorine is found in most minerals in the earth's crust and is taken up from them in the water as the chlorides of calcium, magnesium, sodium, and other elements. It may exist in mere traces, but the quantity increases rapidly as the seaboard is approached. Small quantities of nitrogen also, under the influence of electrical discharges and otherwise, combine with oxygen to form nitric acid, and this also adds to the tale of substances in solution as nitrates of the alkaline earths.

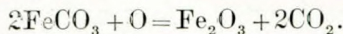
While some of these substances are practically innocuous in small quantities in a steam boiler, there are others which give rise to serious trouble from corrosion, or the formation of incrustations, the removal or prevention of which causes endless expense. When water which, in its passage through the earth, has become impregnated with carbonate of calcium or magnesium percolates through into some open space; for example, a cave to which the air has access, the carbon dioxide in solution is absorbed by the air and the carbonate in solution is deposited in a more or less crystalline condition upon the roof or floor as stalactite or stalagmite. The same reaction takes place in a steam boiler, but much more rapidly, the calcium carbonate being set free as a fine crystalline mud, while the carbon dioxide finds its way to the surface of the water and passes away with the steam. The equation shows this reaction:—



If present in large quantities this carbon dioxide may give trouble in the upper part of the shell of the boiler or in the steam piping, by dissolving in condensed water, and attacking the metal, forming in the first place carbonate of iron, thus:—

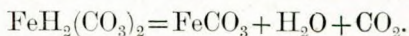
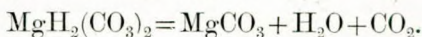


But this bicarbonate, under the influence of oxygen contained in the water and the high temperature, again breaks up forming iron oxide and setting free carbon dioxide.



The carbonate of calcium precipitated floats about in the water, the lighter particles coming to the surface, and forming a scum, while the heavier particles gradually sink and ultimately settle upon the tubes or bottom of the boiler as a soft sludge. When a solution of any salt in water is evaporated there comes a point at which the water is saturated with that substance and any further concentration of the water results in the separation of solid particles of the substance. If solid particles should be already present in the solution, they serve as nuclei round which the substance tends to crystallise, and this occurs the more readily if these nuclei already possess a crystalline form. This is exactly what occurs in a steam boiler. The particles of mud already formed gradually grow larger as fresh quantities of the salts crystallise out of the water and sink, while those which have already settled become bound together into a solid mass which continues to grow in thickness so long as scale-forming salts are present in the boiler.

Magnesium and iron carbonates are precipitated in a similar manner to calcium carbonate, thus:—



The solubilities of the various salts vary to a large extent at different temperatures. The solubility of calcium carbonate in pure water increases from 2 parts per 100,000 of water at 20° C to 9 parts at 100° C, while its solubility in carbonic-acid water decreases from 123 parts at 20° C to 9 parts at 100° C.

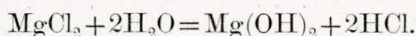
The solubility of calcium sulphate in pure water varies very little, 225 parts at 20° C and 220 parts at 100°, and it does not become insoluble until a temperature of 320° C is reached.

In sea water, however, calcium sulphate becomes insoluble when a temperature of 135° C is reached. Magnesium carbonate decreases from 182 parts in pure water at 20° C to 10.4 parts at 100° C, while in carbonic-acid water, 2,570 parts dissolve at 20° C, decreasing also to 10.4 at 100° C. Magnesium



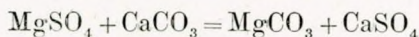
hydrate decreases from 17 to 10 in the same range. This variation in the solubility has a profound influence on the nature of the scale deposited. When the solubility decreases quickly, the scale as a rule is only moderately hard, and easily removed, while scales consisting chiefly of calcium sulphate or magnesium hydrate are usually found to be very hard, necessitating the vigorous use of the chipping hammer. This is apparently owing to the fact that the calcium-sulphate crystals grow more slowly and to a larger size, enveloping the other compounds and binding them into a very hard, compact mass, since calcium sulphate is never entirely insoluble at the temperature of the water at any ordinary boiler pressure.

Sodium chloride is practically innocuous unless present in large proportions, when it may have the effect of causing frothing and priming. The case is different, however, when chloride of magnesium is present. Wagner found that this salt attacks iron at the temperature of boiling water even when air is absent, and it has been found that when waters containing it are used in steam boilers there is often serious corrosion produced. This is due to the fact that at high temperatures and under high pressures this salt is decomposed as shown by the equation:—



The magnesium hydrate produced is precipitated and the hydrochloric acid dissolves in the water and may attack and corrode the boiler plate.

If magnesium nitrate is present it may decompose in a similar manner, forming nitric acid, which is also very corrosive. Although calcium chloride and nitrate may possibly set free acids in a similar manner, the main objection to them is that they can decompose sulphates of other metals, forming the chlorides of these and depositing calcium sulphate. Sulphate of magnesia itself seldom forms scale; but when present along with calcium carbonate they may at high temperatures react together to form calcium sulphate and magnesium carbonate, thus:—



and give rise to a very troublesome scale.

In some districts, and very frequently in mining localities, bicarbonate of soda is found in the water. This salt does not

form a scale, but when concentrated in the boiler it is apt to cause priming, and the water has in consequence to be treated for its removal.

Before considering how water may be treated for the prevention of incrustation or corrosion, we may consider the effects of scale formation. Professor Rankine estimated that the conducting power of carbonate of calcium for heat was  $\frac{1}{17}$  that of iron and that of calcium sulphate only  $\frac{1}{48}$ , and using these figures as a basis he calculated that a deposit of scale  $\frac{1}{8}$  in. thick would raise the fuel bill 16 per cent.;  $\frac{1}{4}$  in. thick would raise it 50 per cent.; and  $\frac{1}{2}$  in. thick would raise it no less than 150 per cent.

There is another effect, however, that may follow the deposition of scale in a boiler. It has been found that in a boiler working at a pressure of 25lbs. per sq. in. the temperature of a clean plate was 350° Fah., while the temperature of the same plate with half an inch of scale on it was 750° Fah. It can be easily imagined that at the higher temperatures which accompany higher steam pressures the boiler plate could easily be red hot when covered with a thick scale, and the risk of dangerous pressures should the scale peel off the boiler shell and allow the water to reach the red-hot plate can readily be understood. Not only so, but when it is remembered that the strength of a steel plate at a red heat is only a small fraction of its strength when cold, it is not difficult to guess the probable consequences.

In this connection it will not be out of place to deal with the effect of oil on a boiler. The saving on the fuel bill that can be effected by returning the condensed steam to the boiler is very considerable. In modern engines the amount of feedwater required to produce the necessary steam is approximately 2 gallons per horse-power per hour. A 100-h.p. engine would thus require 200 gallons per hour. Taking six days of 24 hours each, every grain per gallon of hardness in the water represents 4-lbs. of scale deposited, or 82lbs. per week from a 20-grain per gallon water, a degree of impurity which is quite common among boiler waters.

It has been estimated that every 10° Fah. rise in temperature of feedwater by the use of exhaust steam is equivalent to a saving of 1 per cent. of fuel. This water, however, carries with it all the oil which has been fed into the cylinder of the engine. On allowing the water to settle, part of the oil floats to the surface and can be skimmed off, but the greater part remains in



suspension in the water as a very fine emulsion which will not separate even after standing for hours. Even where a baffle-plate oil separator is introduced to separate the oil from the exhaust steam a quantity escapes recovery.

In a series of experiments made at the Massachusetts Institute of Technology it was found that 25 per cent. of the oil in the steam could not be separated, but passed on to the condensers. When water of this nature is introduced into a boiler the oil is gradually deposited along with the mud, forming a spongy scale which is very difficult to deal with, and is a very poor conductor of heat. If there should be no scale-forming matter in the water, however, the danger is still present. The small quantities of oil added are always accumulating, and they may attach themselves to the sides and stick there as a greasy deposit and ultimately give rise to overheating and distortion. This may very readily happen, *e.g.*, when the boiler is being blown down for cleaning, the oil sticking on the sides left uncovered as the water is blown off. Sir A. J. Durston, K.C.B., a British naval engineer, in the course of some experiments on the effect of grease in boilers, found that the temperature of the plates in a small boiler was  $430^{\circ}$  Fah. when that of the water was  $344.5^{\circ}$  Fah. (110lbs. steam pressure), a difference of  $85^{\circ}$  Fah. When a  $\frac{1}{16}$  in. layer of grease was spread upon the bottom of the boiler, he found a difference of  $151^{\circ}$  Fah. (at 140lbs. steam pressure); water,  $359^{\circ}$ ; plate,  $510^{\circ}$ . When the coating of grease was continued up the sides of the boiler to the water line, he found that when the water had attained a temperature of  $80^{\circ}$  the plate had reached  $617^{\circ}$  Fah., or a difference of  $537^{\circ}$  Fah. Prof. Lewes proved by heating a vessel coated with a mixture of scale and oil  $\frac{1}{10}$  in. thick, that a temperature of  $2,500^{\circ}$  Fah. could be reached in the iron before the water had reached  $212^{\circ}$  Fah.

When water is dropped into a red-hot vessel it does not boil, but assumes a spheroidal state and moves rapidly over the bottom of the vessel while its bulk diminishes very slowly. The cause of this phenomenon is that immediately on striking the red-hot vessel sufficient steam is generated to envelop the globule and prevent it coming into contact with the red-hot vessel. When the vessel is allowed to cool, however, a point is reached at which the steam is not generated sufficiently fast to support the globules. When this occurs the water comes in contact with the vessel, which still holds sufficient heat to vaporise the water, and almost immediately evaporates as steam. We have

here an analogous case to that of the steam boiler using water containing oil or grease.

It is a curious fact that the scale attached to boilers which have been overheated and damaged owing to the presence of greasy scale very seldom contains any oil, it having been driven off at the high temperature which the damaged portion had attained before distortion occurred. Oily water is also very prone to cause foaming and priming.

A trouble of a different kind, fortunately not so common now, owing to the more general use of mineral oil lubricants, is associated with the use of tallow and other animal or vegetable oils. When tallow is introduced into a steam boiler under the influence of the steam and the high temperature, it becomes hydrolysed or broken up into its component parts, glycerine and stearic acid. The glycerine dissolves in the water, where it is practically harmless, but the fatty acid attaches itself to the nearest plate and corrodes it, combining with the iron to form iron stearate. Boilers where tallow was regularly used, and which were partly fed with condensed exhaust steam, very often showed this corrosion to a marked extent immediately above the water line.

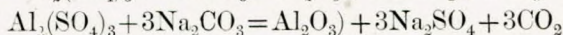
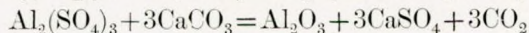
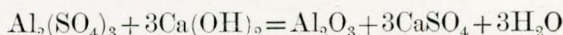
Having thus discussed the nature and effect of the various impurities commonly met with in feed waters, let us consider the best means for their eradication.

### OIL, FINELY DIVIDED SUSPENDED MATTER AND ORGANIC MATTER.

If a small proportion of alum or sulphate of alumina be added to water containing a hydrate or carbonate, a flocculent precipitate is formed which has the power of entangling any other suspended matters present in the water. Take the case of a vessel containing a very dirty water, which, on being passed through a filter, is still coloured and muddy in appearance. No perceptible difference is seen after adding a small quantity of lime water, but immediately alum is added a precipitate is formed which settles fairly readily, and by entangling the particles of mud and organic matter present allows the liquid to be easily filtered and purified. If these salts are added to water containing an emulsion of oil, the oil is entangled in the same way and is easily removed by filtration.



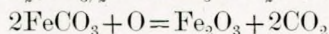
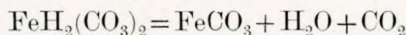
As will be seen from the equations:—



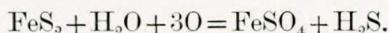
alumina and sulphate of calcium are precipitated where lime salts are used, and after filtration leave the water free from added solid matter, and a very small quantity of the alumina salts are necessary.

Use is made of this reaction in most of the modern water-softening plants, the reagents being added to the water, mixed, and allowed to settle somewhat before being passed through a filter which removes the last trace of oil or other suspended matter. It is also combined with other reactions to render precipitates more easily filterable.

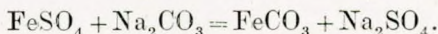
When a solution of carbonate of lime, magnesia or iron in saturated carbonic acid water is exposed to the air, or has air blown through it, part of the carbonic acid is driven off and some of the carbonate present is deposited. This reaction is utilised in the treatment of waters containing bicarbonate of iron, the form in which this element most commonly occurs in water. The simplest treatment of such waters consists in exposing them to the air as freely as possible by allowing them to percolate over coke or other porous material. The carbon dioxide escapes into the air leaving behind carbonate of iron, which in turn becomes oxidised by the oxygen of the air to oxide of iron and this is then removed by settlement and filtration. Thus:—



Iron is often met with in mining districts as sulphate, resulting from the decomposition of iron pyrites or brasses in the coal by the combined agency of air and moisture, thus:—

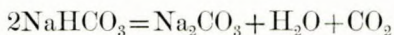


It is usually removed as hydrate or carbonate of iron by treatment with lime water or sodium carbonate:—



The solubility of calcium carbonate in pure water is 3 parts per 100,000 at 20° C, while in carbon dioxide saturated water it is 123 parts. Hence, if the carbon dioxide can be removed from the water it should be possible to precipitate 120 parts of calcium carbonate. At atmospheric temperature carbon dioxide is soluble to the extent of 130 per cent. by volume, but its solubility rapidly decreases as the temperature rises, being 77 per cent. at 35° and 7 at 80°, while at 100° C it is practically insoluble.

When a solution of bicarbonate of soda is heated there is strong effervescence in consequence of the breaking up of the bicarbonate by heat into carbonate of soda and free carbon dioxide, thus:—



It is as bicarbonate that the lime exists in solution, and if the solution is heated a similar reaction takes place:—



In exhaust steam softening plants the water flows downwards over plates or cups in a chamber up which the exhaust steam is flowing. The carbon dioxide is driven off and the carbonate of lime deposited in the cups, while the condensed and purified water flows onwards to the boilers, the temperature of the feed-water having been meanwhile raised to 200° Fah. or more.

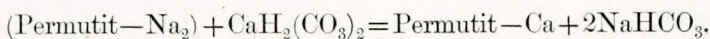
Another method for the removal of carbonate is to add some reagent to the water which will combine with the carbon dioxide, and for this purpose the cheapest is ordinary lime, which is added as lime water or as milk of lime:—



As will be observed from the above equation, the lime unites with the carbon dioxide, forming carbonate of lime, which is insoluble; no solid matter is therefore left in solution. This process was first introduced by the late Dr. Clark, of Aberdeen, who patented its use in 1840. If caustic soda is used, the calcium is all precipitated as carbonate, and an equivalent quantity of carbonate of soda left in solution. This substance in small quantities is quite harmless, but when concentrated, especially in locomotive boilers, it is very apt to cause priming.



In this connection it may be of interest to refer to the "Permutit" process of water-softening. As already mentioned, some natural waters are found to contain bicarbonate of soda in solution, although this salt does not occur native in the district. It has been found that some silicates of alumina and soda called zeolites have the property of combining with the calcium and magnesium contained in water which comes into contact with them, and at the same time setting free an equivalent quantity of sodium. The converse of this reaction also takes place when to the exhausted zeolite is added a solution of a sodium salt. Advantage has been taken of these reactions in the "Permutit" water-softening process, in which water is passed through a bed of artificially-prepared silicate of alumina and soda crushed to fine grains, which substance is found to be very much more active than the natural zeolite. The reaction may be expressed as follows:—



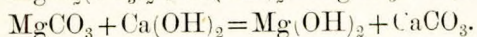
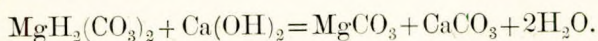
When the material becomes sluggish in its action, a solution of common salt is passed through it, which replaces the sodium, the calcium being redissolved and carried away to the drain.

When waters containing bicarbonate of sodium have to be treated, probably the most convenient method is to treat with a mixture of calcium chloride and lime water, either cold or in the presence of exhaust steam. The reactions which take place are as follows:—

- (1).  $2\text{NaHCO}_3 + \text{CaCl}_2 = \text{CaCO}_3 + 2\text{NaCl} + \text{H}_2\text{CO}_3.$
- (2).  $\text{H}_2\text{CO}_3 + \text{Ca}(\text{OH})_2 = \text{CaCO}_3 + 2\text{H}_2\text{O}.$

The reactions which occur when waters containing magnesium carbonate are treated with lime or soda are similar to those for calcium carbonate, but there is a very important difference. Magnesium carbonate is soluble to a considerable extent in pure water, even at the temperature of boiling water, so that it may, even after softening, leave a bad scale-forming water. Magnesium hydrate, however, is much less soluble, and therefore the treatment of a magnesia water has to be carried on much further than in the case of calcium carbonate. In this case it is necessary to add double the amount of reagent, so that the second reaction may be complete. This reaction also takes place much more slowly than the other; so that when this element is present, longer time must be allowed between the

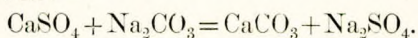
addition of the reagents and the filtration of the water. The following equations show the reactions which take place:—



Magnesia waters are for this reason very difficult to deal with properly, and even when partly softened they may cause endless trouble and expense.

The concentration of solutions has not a little effect on the rapidity and completeness with which reactions take place. It has been found, for instance, that using milk of lime reduces the time necessary for the completion of a reaction to from an eighth to a tenth of that necessary when using lime water. This materially helps in reducing the size of apparatus necessary for treatment.

Calcium sulphate is responsible for a large proportion of the manual labour in boiler cleaning. Scales consisting chiefly of it are very hard and tough, more especially in the parts of the boiler nearest the furnace. This gives every inducement to the boiler cleaner to leave it in places, with the ultimate result of a bulged plate, or worse. Fortunately, the treatment of water for the prevention of this scale is easy and can be accomplished without great expense. Soda ash, which is a very strong variety of carbonate of soda, acts on calcium sulphate, forming carbonate of calcium and sodium sulphate, which latter salt dissolves in the water and, unless in very large quantities, will do no harm. The carbonate is precipitated as mud, which can easily be removed:—



The use of boiler fluids added to the boiler itself is one which cannot be recommended. In the first place the boiler is for raising steam and not for softening feedwater, and in the second, it is very difficult to say whether the necessary reactions have taken place partially or completely, or if excess has been employed. If it should be necessary, from want of room or otherwise, to use a fluid, one which has been found by analysis of the water to be suitable for its treatment should be used, and in the proper doses. The boiler should be blown down several inches in the glass, at stated intervals, to get rid of the precipitated sludge, and valves and fittings examined regularly to make sure no damage is being sustained from the initial excess



of reagent. The compounds which have been recommended for this purpose are legion; some have stood the test of time, soda and soda carbonate for example, while many have been introduced only to be given up again. Prof. Doremus, of New York, recommended the use of sodium fluoride, which has the advantage that the precipitate which it forms will not adhere but remains as nuclei for the deposit of the remainder.

His formula is  $\frac{1.5 \text{ CaO} + 2\text{MgO}}{4}$  in water = sodium

fluoride necessary for complete precipitation; 2ozs. per 1,000 gallons is a usual quantity. Davis proposed tribasic phosphate of soda:— $\text{Na}_3\text{PO}_4$ . It is sold as Tripsa, and  $2\frac{1}{2}$  grains per gallon per degree (Clark) is recommended. The precipitation of magnesia by this reagent, however, is very slow. Barium chloride has been used in some cases, leaving calcium chloride in solution. Barium hydrate would in the writer's opinion make a good substitute if it could be cheaply obtained. Doremus also patented the use of sodium fluoride phosphate,  $\text{Na}_2\text{PO}_4\text{NaF} \cdot 12\text{H}_2\text{O}$ , which has the advantage of crystallising in large octohedra, and is not deliquescent like phosphate of soda. Some years ago a book was published containing a list of 180 substances used for feedwater treatment, and the number is always being added to:—Paraffin oil, tallow, potato skins, tannin extracts, sugar, sal ammoniac, seaweed, peat, mica, French chalk, are only a few; most of them comparatively useless, and some positively harmful.

Of water-softening plants also there is a great variety. Most of them have some point of interest about them, but the absolutely perfect apparatus, suitable under all conditions, has yet to be invented. The important points about a softener are: (1) It should take up little room in proportion to the quantity treated. (2) It should be so simple that any ordinary labourer can use it. (3) It should be entirely automatic in its action, for the same reason. (4) It should have nothing in its construction which can be corroded away by the solutions in use. (5) All measuring should be done with pure water. (6) All solutions should be thoroughly mixed automatically to ensure uniformity in composition and action.

