Civil and Mechanical Engineering.

STEAM-BOILER WATERS AND INCRUSTATIONS.*

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All natural waters contain more or less mineral matter. This is acquired by contact with the earth's surface, and by percolation through its soil and rocks. It consists principally of carbonates of lime and magnesia, sulphate of lime, and chloride of sodium, in solution, and clay, sand, and vegetable matter, in suspension. The many other saline ingredients found in various waters exist in very small proportions, are generally very soluble, and therefore have no relation to the utility of waters in boilers. Of the above-mentioned salts, the carbonates of lime and magnesia are only soluble when the water contains free carbonic acid—consequently the waters of rivers, lakes, &c., contain them in less quantities than those of wells, springs, and creeks, owing to the precipitation caused by the spontaneous evolution of the solvent on exposure to air, heat, and light. Our American rivers contain from 2 to 6 grains of saline matter in the gallon, in solution, and a varying quantity in suspension, generally exceeding 10 grains. Well and spring waters hold but little in suspension but a quantity of the dissolved salts, varying from 10 to 650 grains in the gallon. When such water is boiled the carbonic acid is driven off, and the carbonates, deprived of their solvent, are rapidly precipitated in a finely crystallized form, tenaciously adherent to whatever they may first fall upon. Sulphate of lime requires 500 parts of water for its solution, and as the water evaporates supersaturation occurs, and the salt is precipitated in the same form and with the same adherent quality as the carbonates. Chloride of sodium and all the other more soluble salts are precipitated by the same process of supersaturation, but, owing to their greater solubility, much more evaporation is required. All suspended matter gradually tends to subside. This combined deposit, of which the carbonate of lime usually forms the greater part, remains adherent to the inner surface of the boiler, undisturbed by the force of the boiling currents. Gradually accumulating, it becomes harder and thicker, till it is as dense as porcelain,

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though tougher, and at length may obtain such a thickness as to prevent the proper heating of the water by any fire that can be placed in the furnace. The high heats sometimes necessary to heat water through thick scale, will sometimes convert the scale into absolute glass by combining the sand with the alkaline salts composing it. The evil effects of the scale are due to the fact that it is relatively a non-conductor of heat. Its conducting power compared with that of iron is as 1 to 37.5. Consequently more fuel is required to heat water in an incrustated boiler than in the same boiler if clean. A scale $\frac{1}{16}$ th inch thick will require the extra expenditure of 15 per cent. more fuel. This ratio increases as the scale is thicker. Thus when it is $\frac{1}{4}$ inch, 60 per cent. more fuel is needed; $\frac{1}{2}$ inch, 150 per cent., &c. Abstractly, then, to raise water in a boiler to any given heat, the fire-surface of that boiler must be heated to a temperature according with the thickness of the incrustation in an increasing ratio. To illustrate—to raise steam to a pressure of 90 lbs., the water must be heated to about 320° F. In a clean boiler of $\frac{1}{4}$ inch iron this may be done by heating the external surface of the shell to about 325°. If $\frac{1}{2}$ an inch of scale intervenes between the shell and the water, such is its non-conduction that it will be necessary to heat the fire-surface to about 700°, almost low red heat. Now the higher the temperature at which iron is kept, the more rapidly it oxidizes, and at any heat above 600° it very soon becomes granular and brittle, and is liable to bulge, crack, or otherwise give way to the internal pressure. This condition predisposes the boiler to explosions, and makes necessary expensive repairs. Again, it is readily seen that the presence of scale renders slower and more difficult the raising, maintaining and lowering of steam.

To obviate the evils arising from incrustation, many methods have been devised to prevent and remove it. For this purpose picking, scraping, cleaning, &c., are very generally resorted to. Such is its toughness and tenacity, however, that this only partially succeeds, and is moreover expensive in time and money, since it is generally necessary to lose a working day in the operation. Various mechanical contrivances have been introduced, intended to intercept the precipitated saline matter from the supply water on its passage through the heating apparatus. They consist essentially of a series of obstructions to the flow of the water. After it has been heated almost to boiling by the exhaust steam, the carbonates are precipitated, and subside upon the shelves, straw, and other obstructions, over which the

water flows. This plan, however, only partially fulfils the purpose, since it only intercepts a portion of the carbonates and suspended matter. The soluble salts all pass on into the boiler, and a great portion of the dissolved carbonates also, which cannot be precipitated during the short passage through the heater. The scales form more slowly, but as surely. It is impossible to make such contrivances completely efficacious. No mechanical arrangement will suffice. To chemistry alone must we look for the desired means. For a long time simple chemical means have been used in an empirical way with some success. The *modus operandi* of some of these I will notice. Starchy matters—such as Indian corn, potatoes, oil-cake, &c.—prevent scale only by enveloping the precipitates with gelatinous matter, thus lessening their weight, causing them to float, and obviating their agglutination into solid masses. This application, however, tends to cause foaming or frothing of the water, making it impossible to determine the quantity in the boiler, and hence is objectionable.

Molasses, fruits, cider, slops, vinegar, cane-juice, and a variety of other things, containing more or less acetic acid, placed in the boiler, convert the carbonates into soluble acetates. The sulphate of lime remains unaltered, however, and the iron being as much open to the attacks of the acid as the saline matter, the boiler is slowly but surely damaged.

Oak, hemlock, and other barks and woods operate by means of the tannic acid therein. Various extracts, such as catechu, logwood, &c., very rich in tannin, are also used. Tannic acid decomposes the carbonates, but, unlike the acetates, the resulting tannates are insoluble. Their specific gravity, however, is low; they float in the currents of ebullition, and, having no tendency to adhere, do not agglutinate into a mass, and cannot form a scale. The sulphates and chlorides are not acted upon at all by the tannic acid, and will incrustate notwithstanding its presence. Tannin, as offered in the above-named agents, is left free to act upon the iron, and will, after a time, exhibit its damaging effects on the boiler.

The fixed alkalies are much used for this purpose, in the various forms of lye, ashes, carbonate of soda, caustic soda, potash, &c. These agents decompose the sulphate of lime, sulphate of soda or potash and carbonate of lime being the results. The first is held in solution, the latter is precipitated, but in larger crystals, which do not form so refractory a scale as ordinarily. The carbonates of lime and magnesia are also precipitated by these agents, the free carbonic acid being

taken to form carbonates or bicarbonates of soda or potash; the chlorides are not affected. This method simply modifies the form of the precipitate, and consequently the quality of the scale, without affording any means for its prevention, and therefore deserves but little attention. Ammonia and its carbonate have a precisely similar action, and the same objection stands against them. These alkalies have no chemical action upon the boiler, but rather tend to preserve it, inasmuch as they prevent the free carbonic acid from combining with the insoluble crust of oxide of iron (formed by contact with the water) to form a soluble carbonate of iron, which, being dissolved away from the iron, would leave a surface constantly exposed to fresh action. Chloride of ammonium is another means employed. This has its action only on the carbonates of lime and magnesia. The reaction produces carbonate of ammonia, which, being volatile, passes off with the steam, and chlorides of calcium and magnesium, both very soluble. This is an efficient way of removing old scale. Its only objection is the ammoniacal odor of the escaped steam.

The foregoing are methods in which a single agent is used. They are frequently combined with a view of obviating the mentioned objections. Starch, tannin and soda constitute the basis of most of these combinations. Crude petroleum is also used with reported partial success. The *rationale* of its action is not well understood, owing to the complexity of its chemical constitution. There are many proprietary compounds at present in use composed essentially of these elements, generally, however, with the addition of other things, introduced for the purpose of disguising their composition. Besides these, many other preparations are before the public which have been patented, all having a general resemblance, inasmuch as tannin, starch, and soda, are the principal ingredients, in some form. Gum catechu is most generally the tannin-bearing body; sal soda, the alkali; and flax-seed, oil-seed cake, bran, or coarse flour the starchy element. In most of those which I have examined these very useful agents have been simply mixed empirically, without regard to chemical laws, and they generally contain more or less free tannic acid, and a considerable amount of inert, insoluble vegetable matter, which tends to produce foaming, besides being useless. Besides these methods, in which the chemical agents are introduced directly into the boiler, others have been devised, in which the waters are depurated, by chemical means, before entrance into the boiler. Clark's process consists in the precipitation of the carbonates with milk of lime, the free carbonic

acid being taken up; the sulphate of lime remains in solution. Another method, proposed by myself, consists in converting the earthy carbonates into soluble chlorides by hydrochloric acid, and neutralizing the excess of acid by filtration through carbonate of baryta (with-erite) in coarse powder. The soluble chloride of barium thus formed decomposes the sulphate of lime, chloride of calcium being kept in solution, and the sulphate of baryta being deposited insoluble. This method recommends itself for railway water stations, on account of its cheapness and simplicity.

Oxalic acid may be used very efficiently for the complete precipitation of all the lime salts as insoluble oxalates, but the expense might be a bar to its use. Tannic and acetic acids, the excess being properly neutralized by carbonate of soda, may also be used for tank depuration.

These tank methods, however, cannot influence to any great extent the scale already formed; and as the removal of this is as needful as its prevention, it is palpable that that method is best for general application which attains the complete removal, as well as prevention, by chemical means operating inside the boiler.

Having this end in view, the writer has proposed two processes: one consists simply in the introduction into the boiler of a sufficient quantity of the oxalate of soda to cause the immediate decomposition of the scale-forming salts as they enter the boiler, converting them into insoluble oxalates, which are precipitated as a mushy sediment, which has no tendency to form scale, and which may be blown out from the mud-receiver, or otherwise voided. In the other process tannate of soda is the agent, kept constantly present in the boiler in solution; it decomposes the carbonate of lime and magnesia as they enter, tannates being precipitated in a light, flocculent, amorphous form, so that they do not subside at all in the boiler, but are retained in suspension by the boiling currents until they find their way into the same receiver, when they settle into a loose, mushy mass, which may be easily blown out from time to time. The carbonate of soda formed in the reaction is retained in solution, becoming a bicarbonate by appropriation of the free carbonic acid in the water. This decomposes the sulphate of lime, the resulting sulphate of soda being retained in solution, and the carbonate of lime being acted upon by fresh portions of the tannate of soda as above. The constant presence of the alkali protects the iron from all action, either of the carbonic or tannic acids. The same reactions take place between the

tannate of soda and the already existing scale with like results, but more slowly, some weeks being generally required, in practice, in removing the deposit, if it exists in any considerable quantity.

Portions of scale are detached, from time to time, which may be removed at the usual cleanings, which should be made at short intervals, when possible, until the boiler is entirely clear of all incrustation, after which this will not be necessary. Extensive practical trial of this process for two years has demonstrated its utility for all varieties of boilers. It is economical, easy of application, and generally adaptable. It may be used in marine boilers as well as those using fresh water, since the marine scale is almost identical with that formed in boilers using ordinary waters, consisting almost entirely of the carbonates of lime and magnesia and sulphate of lime. The chloride of sodium, forms a mushy deposit, but is only incorporated in the scale to a slight extent.

HINTS ON MECHANICAL DRAUGHTING FOR APPRENTICES.

BY J. RICHARDS, M. E.

It has been claimed that draughting bears the same relation to mechanics that penmanship does to literature; a proposition that is entirely wrong. Geometrical drawing is not an artistic art; it is nearer to being a constructive, mechanical one. An artist may delineate an object without understanding its nature, but a mechanical draughtsman cannot make drawings of a machine unless he understands its functions and operation; at least he cannot make drawings that are reliable, or have any great value. Artistic drawing is addressed to the eye, geometrical drawing to the understanding. The art of making geometrical drawings must, however, include artistic skill; not in the sense of ornamentation, but to meet the standard of neatness and effect that has by common custom been assumed, and which conveys an idea of competent construction in the drawings, as it does in the machinery to which they relate.

The artistic part of the business is an easy thing to learn, and is rather to be guarded against than encouraged in the beginning. It is quite a secondary matter when compared with the knowledge of mechanics, that is indispensable to the draughtsman.

It is easy to learn *how* to draw, but it is difficult to learn *what* to draw. This the apprentice must keep in his mind, and his first efforts be directed to *how* to draw, of which we now come to speak.