in the following manner: As soon as ebullition begins, the contained free gases are driven off, since they are not soluble in hot water, and, as the presence of carbonic acid is necessary to the solution of the carbonates of lime, magnesia, iron, these salts, which are found in all waters, are precipitated in a finely crystalline form, tenaciously adherent to whatever they fall upon. Sulphate of lime, which is commonly present, is soluble in 400 parts of cold water, but scarcely at all in boiling water; therefore as the evaporation proceeds supersaturation occurs, and this salts is thrown down in the same form and possessing the same adherence as the carbonates. The other contained elements, which are more soluble, are precipitated in the same way by super-saturation. As the quantity of water is lessened the suspended matter gradually subsides and agglutinates with the other deposits. In a steam boiler the deposits from the evaporated water tend to take place in the same manner, but the constant supply of fresh portions and the occasional emptying out of the saturated water prevents the precipitation of the more soluble salts; these are retained in solution. Practically, it is found that the deposits from all kinds of boiler waters consist almost entirely of carbonates of lime, magnesia and iron, and the sulphate of lime. Scarcely more than 5 per cent. of other salts are found.

It is important both for the safety and efficiency of a boiler that the tubes and sheets are kept free from scale. The evil effects of scale are due to the fact that it is relatively a non-conductor of heat. Its conducting power, compared with that of iron (according to Desprety), is as 1 to 37.5 or thereabout; accordingly more fuel is required to heat water through the shell and flues of an incrusted boiler than would be required if the boiler were clear of scale. It is readily demonstrated that a scale one-sixteenth of an inch thick will demand the extra expenditure of about 15 per cent. more fuel. This ratio increases as the scale grows thicker. If a boiler be perfectly clean, the contained water may be raised to any given temperature by heating the external fire surface to a temperature a few degrees higher, but if any scale be present it will be necessary to heat it still higher, according to the thickness of the scale, in an increasing ratio. To illustrate: To raise steam to a pressure of 90 lbs., the water must be heated to 320° Fahrenheit. If the boiler be clean, this may be done by heating the fire surface to about 325°; but if one-half inch of scale intervene between the shell and the water, such is its non-conduction that it will be necessary to raise the fire surface to a temperature of about 700°—almost low red heat. Now, the higher the temperature at which iron is kept, the more rapidly it oxidizes or carbonizes, and undergoes molecular change. At any temperature above 600°, it soon loses the fibrous nature of the wrought iron, and becomes granular like cast iron (which it has really become) by carbonization. In this condition it is brittle, thin, and, under high heats, liable to bulge or even give way to the great pressure upon it. Weakness of boilers thus produced predisposes them to explosion, and causes necessarily expensive repairs.

To obviate these evils, namely, danger from explosion, expense of repairs, loss of time and waste of fuel, very many methods have been devised, having in view the prevention and removal of scale. For this purpose, picking, scraping, chaining, etc., are generally resorted to periodically. Such is its toughness and tenacity, however, that mechanical force only succeeds in removing a portion of it, and is generally unsatisfactory, since in addition it is necessary to empty the boiler and to allow it to get cool enough to enter, which, with the operation itself, generally requires a whole working day.

Various mechanical contrivances have been and are now used to intercept the precipitated saline matter from the supply water on its passage through the heating apparatus. They consist essentially of obstructions to the flow of the water. This latter being heated to boiling by being intermingled with the exhaust steam in the heater, the carbonic acid is driven off, and a precipitation of the carbonate takes place, the deposits accumulating on the shelves, straw, or other obstructions, over or through which the water slowly flows. In this way large accumulations of the matter in suspension, and of the precipitated carbonates, are prevented from going into the boiler, and being retained in the heater, may be removed very conveniently when opportunity is afforded. This plan, however, only partially remedies the difficulty, since it is only the precipitated carbonates and the matter in suspension that are retained by this apparatus. The soluble salts all pass on to the boiler and also a great portion of the earthy carbonates which cannot be precipitated during the short passage through the heater, therefore the scale in the boiler forms more slowly.

Another variety of mechanical device for preventing scale is the sediment pan. This, of which there are many forms, consists essentially of a shallow vessel which is placed in the bottom of the boiler, with the view of catching the precipitate and preventing its deposition on the inner portion of the shell. This plan succeeds in gathering much of the sediment, but much necessarily fastens itself to the boiler, and the scale, as before, continues to form.

For a long time, simple chemical agents have been used in an empirical way, or applied without science, with a certain success. Some of these are molasses, fruits, slops, vinegar, cane-juice, and a variety of vegetable substances containing more or less acetic acid, which when placed in a boiler, at regular intervals, will remove and prevent the incrustation to certain extent. The acetic acid decomposes carbonates, forming acetates, which are kept in solution and hence cannot become increments of scale. The sulphate of lime and other salts are not affected by it, and from this the scale will gradually be formed. Moreover, the iron of the boiler being open to the attacks of the free acid, will be gradually corroded, and after a time rendered useless, if not dangerous.

This fact alone ought to forbid the use of these agents.

Starchy matters, in various shapes, such as potatoes, corn, oil cake, etc., have been much used. These prevent scale only by enveloping the precipitates with gelatinous matter, which lessens their weight and prevents their agglutination into a solid mass. Starch, as well as nearly all other organic matters, has a tendency to produce foaming or frothing of the water in the boiler. In this case the exact quantity present cannot be determined by the gauge cocks. This is a source of great danger, and ought to prevent the use of such agents.

Oak, hemlock and other barks and woods are operative in the prevention of incrustations, on account of the tannic acid which they contain.

Various extracts, such as catechu, logwood, etc., rich in tannin, are also used. Tannic acid