cream contained with a single exception the largest proportion of soluble nitrogen compounds. This would indicate that in cheese rich in fat the insoluble casein is converted into soluble forms more rapidly than in case of skim-milk cheese; in other words, cheese rich in fat becomes digestible in ripening more rapidly than skim-milk cheese.

THE PURIFICATION OF WATER, WITH SPECIAL REFERENCE TO BOILER FEED WATERS AND SCALE PREVENTION.[1]

BY C. A. DOREMUS.

PROF. VIVIAN B. LEWES, of the British Royal Naval College, has epitomized in two papers read before the Institution of Naval Architects in 1889 and 1891 a series of the most highly interesting and instructive analyses and experiments on incrustations in marine boilers and their causes to be found in the literature relating to scale formation.[2] A careful study for some years of a great variety of boiler feed waters from all sections of the country has convinced me that many points brought forward by Professor Lewes are so generally applicable that they can not be overlooked by the chemist who attempts to rectify the serions troubles arising from these sources.

The following quotations are typical: "The presence of calcium sulphate exercises a very marked influence upon the condition and physical properties of the incrustation as under the conditions in which it is formed in a boiler it separates in a crystalline form and binds the deposit into a hard mass, an action which is also aided by the presence of magnesium hydrate." When calcium sulphate is deposited from sea water in a boiler it comes down in small crystals containing two molecules of calcium sulphate and one of water; whilst after deposition in the boiler and in contact with the heated plates and tubes, it undergoes a further change of crystalline form, and becomes "anhydrite, which is pure calcium sulphate free from

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[1] Read before the World's Congress of Chemists, August 25, 1893.

[2] *Chemical News*, 59, 222, and 63, 191.

water of crystallization, and it is this change in crystalline form which binds deposits containing it into such a hard mass."

In many carbonated waters the calcium carbonate also forms upon the heated surface as a crystalline coating, even though the quantity in solution is trivial. Thus in a Croton water which carries but a grain or two per gallon a scale forms on all heated surfaces, tubes as well as crown sheets, which is distinctly crystalline. The massive concretions often found in feed water heaters are crystalline in structure and firmly adherent to the hot tubes or surfaces. It is very easy to show this by a simple experiment. Place a carbonated lime water in a beaker. Raise it to boiling by steam delivered into it by a glass tube. The latter will become coated with an adherent crystalline layer of calcium carbonate. With gypsum water the incrustation does not form so readily since calcium sulphate is soluble to some extent in boiling water, and thorough precipitation not taking place before 140° to 150° C., a state of affairs reached in practice in boilers, where the calcium sulphate then separates in a crystalline form and attaches itself to the rough heated metal.

In a paper read at the Newport meeting I called attention to the use of sodium fluoride as an agent hitherto overlooked in water purification. Since then I have had opportunities to get the results of its use in several lines of work, but the present paper will be restricted to the service this substance renders in scale prevention. Starting with the idea that is so prevalent, that successful treatment of feed waters should be accomplished by such chemical or mechanical, or combined chemical and mechanical treatment, that the incrusting salts should be removed previous to the water entering the boiler, it was soon seen that this theoretical ideal was not practicable. There are many waters which yield an incrustation, whose proportion of lime and magnesium salts is so small that precipitation can not be effected either by the use of feed water heaters or of chemicals. Yet such waters yield a crystalline scale and often a scale containing magnesium hydrate. Surface condensers are frequently leaky, and many marine boilers starting with good water acquire scale from this cause. Manifestly such waters can only be treated by chemical means in the course of concentration in the boilers. From these almost soft waters we pass by upward grade to the excessively hard, which can be purified in some measure merely by heating or by chemicals. Since, however, calcium sulphate is not completely precipitated at 100° C., feed water heaters do not remove it thoroughly enough to prevent scale, and where waters have a permanent as well as temporary hardness due to magnesium salts these are not eliminated. When lime, soda ash, or caustic soda, or a combination of any of these is made use of, it is difficult to regulate the amount required to effect so complete a precipitation that no scale will form, and the trouble attendant on this style of purification is so great that in many cases it has been abandoned. Water softened by lime and soda ash or treated by soda ash or caustic, will generally possess an alkaline reaction, and is, for some purposes therefore unserviceable. The chemical treatment frequently causes the lime salts to separate in crystalline form, large masses of great thickness being formed.

In one instance the feed pipe for a battery of boilers, though five inches in diameter, became so incrusted that a one-inch bar could not be thrust through it. The water had been treated with soda ash and afterwards filtered.

At an artificial ice factory using hard well water the sand of the filter became hard as stone from the calcium carbonate which crystallized upon it even after the water had been treated with soda ash and heated to soften it.

The cost of chemical treatment is often a bar to its employment quite aside from the expense of accessory apparatus, as settling tanks, filters, etc., since to be effective at least the theoretical quantity of precipitant must be used, with soda ash two or three times this quantity.

When sodium fluoride is added to water containing even a very moderate proportion of lime or magnesium salts a precipitate forms at once. When added in quantity sufficient to unite with all of the calcium and magnesium to form fluorides of these metals and the water is then boiled down the precipitate retains its amorphous character. Viewed through the microscope, it has always been found powdery and rounded. This circumstance together with other considerations has led to the employment of sodium fluoride in the direction of scale prevention, and it is pleasant to be able to record that to-day it is in successful operation in nearly every section of the country.

It is not an uncommon practice abroad[1] to employ sodium carbonate directly in the boiler, transforming the calcium sulphate to carbonate. The conversion not only of the sulphate of calcium but all magnesium salts to pulverulent fluorides therefore seemed possible and has proved practicable. Calcium fluoride has a molecular weight about twenty-five per cent. less than either calcium carbonate or sulphate or an equivalent quantity of phosphate and therefore the precipitate or sludge formed through its use is much more manageable and removable by blowing down the boilers.

At first it was deemed necessary to determine the total calcium and magnesium of the water often to make a sufficiently complete analysis to determine the salts held in solution and to calculate from these data the quantity of sodium fluoride necessary to transform the calcium and magnesium to fluorides.

Carefully made tests have shown, however, that in the greater number of instances a quantity of sodium fluoride one-quarter of this theoretical amount will, if fed continuously, prevent the formation of scale and leave the interior surface of the boiler so smooth that one chief cause of crystals attaching themselves is done away with.

The various types of water from New York to Albany and from there through the salt district to the lakes at Buffalo are now under this treatment with entirely satisfactory results. The employment of so small an amount of the chemical naturally reduces the cost of purification, while the ease of handling pleases the engineer.

More than once it has happened that the boilers were heavily incrusted when the use of the fluoride was begun. The old scale was found to loosen rapidly, falling off in some cases by the bucket full. In others it was rotted and softened so that on the first cleaning it was easily scraped off.

A specimen of highly silicated scale is presented to show how

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[1] L. Vignon, *Bull. Soc. Chim.*, III, 2. p. 596.

a chemical transformation with the formation of fluoride has resulted from the continued action of small quantities of sodium fluoride added to the feed water. When once thoroughly cleaned to the metal new scale does not form in such instances.

Live steam is so frequently used now in our large manufacturing establishments for cooking, boiling, etc., and so much condensed steam is used to furnish distilled water, especially in artificial ice manufacture, that a method of treating boiler water in such a way as to furnish pure untainted steam is exceedingly desirable. Since sodium fluoride completes its work without rendering the water alkaline the steam from water thus treated has proved most excellent for such purposes.

It is beyond the province of this article to enter more fully into these details.

IMPROVED APPARATUS FOR THE VOLUMETRIC DETERMINATION OF CARBON DIOXIDE AND OTHER GASES.

BY CHARLES A. CATLIN.

FOR the determination of small quantities of carbon dioxide in readily decomposed carbonates, the process and apparatus devised by Dr. Scheibler presents a most convenient and rapid method; but the inability to thus measure large quantities of gas has restricted its employment for the most part to determination of carbonate in bone-char. To extend the field of volumetric carbon dioxide determination I have devised the following described apparatus, retaining, as far as possible, the essential features of the Scheibler.

Referring to the cut: A, C, and D are essentially the same as in the Scheibler apparatus, A, being the decomposing bottle in which the portion of the sample to be operated upon, is placed, with its enclosed tube for the decomposing acid or other solution, with the further addition however, of a thermometer, inserted through the rubber stopper—a most important feature when the decomposition results in wide variations of temperature; C, the bottle containing the rubber gas balloon connected

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[1] Described at June, 1893, meeting of the Rhode Island Section of the American Chemical Society.