

brown to black. The color of the precipitate gives a good indication of the progress of the action.

While there is dissolved oxygen present there is iron in solution, depending upon the amount of active carbonic acid. Soon after the oxygen disappeared it was but rarely that more than 0.5 to 1.0 p.p.m. iron was in solution. It is obvious that the amount of dissolved iron is greater with increase in the active carbonic acid.

The amount of oxygen within wide limits does not seem to affect the rate of corrosion materially, but the total amount of iron removed from the pipes in complete reaction, other factors remaining the same, is directly proportional to the dissolved oxygen in the water.

When iron pipe is exposed to the continuous action of water, as in service, a protective coating forms according to the nature of the water. Its action is to delay corrosion rather than to stop it, and to reduce the amount of iron appearing in the water. The corrosion goes on slowly, but the oxides cling to the iron, increasing the amount of scale. In cold action the greatest protection was acquired experimentally in ten days, and then remained constant. Flatbush and Brooklyn waters caused a better protective coating than Croton water. The iron produced in 24 hours dropped from 114 and 84 p.p.m. respectively for the two former to 21 p.p.m., Fe, for the Croton, and its modifications from 56-102 to 29-35 p.p.m., Fe. Croton was tried in four modifications—untreated; with free carbonic acid neutralized by sodium carbonic acid; neutralized by lime hydrate to bicarbonate, and treated with one grain of alum per gallon.

In hot action the protective coating formed in two days. Flatbush water reached the lowest level of 3 p.p.m. iron with an average of 8. Brooklyn water reached 4 p.p.m. iron with an average of 9. Untreated Croton fluctuated high and low with an average of 41 p.p.m. iron. The alum-treated Croton averaged 26. The soda-neutralized Croton averaged 23 p.p.m., Fe. All the averages, cold and hot, include results from the tenth to the twenty-first day.

The pipes which had acquired a protective coating from these different waters were subjected for 24 hours to the action of untreated Croton water and to Croton water containing 20-27 p.p.m. free carbonic acid. The water with increased carbonic acid produced an average of 38 p.p.m. iron from the pipes with scale formed in cold action, against 24 p.p.m. produced by untreated Croton (5 p.p.m. CO_2). On the pipes with scale produced in hot action about the same relative quantities were produced, 34 against 22 p.p.m., Fe, showing that water containing the greater amount of carbonic acid causes more corrosion upon pipes protected by scale.

The scale produced by Flatbush, Brooklyn and soda-neutralized Croton water proved the more protective.

General Summary.—Extensive corrosion takes place rapidly in new pipe while the iron is fairly clean from incrustation. This explains the abundance of complaints of iron rust in new service installation.

Concerning the kind of pipe, there is little doubt that steel pipe is most readily attached, wrought iron next, and galvanized iron the least. The latter is far preferable for use. Lead pipe should never be used any more than absolutely necessary because of the danger of accumulative poisoning with minute amounts of lead (less than 0.5 p.p.m.).

The chief agent in dissolving the iron is carbonic acid, as it is also the chief agent in holding iron in solution.

The chief agent in carrying the rusting to the greatest extent is oxygen.

Through the catalytic action of active carbonic acid about 70 per cent. of the oxygen in the iron rust comes from the water by chemical decomposition, hydrogen gas being set free. The remainder only, about 30 per cent., is furnished by the dissolved oxygen in the water.

Soft Water Containing Much Free Carbonic Acid Causes the Most Trouble.—Waters which give the most trouble are very soft and contain considerable free carbonic acid.

Hard waters rarely cause complaint, as they form an excellent protective coating on the pipes.

The action in distribution services probably never reaches completion on account of protecting scale of oxide, etc., which retards corrosive action. The scale varies with different waters in protective properties. Tap samples in New York City have shown no appreciable diminution in dissolved oxygen or in free carbonic acid, so that only slight corrosion can have taken place in proportion to volume of water and possible reaction. Even hot services have shown the usual amount of carbonic acid and more oxygen than would saturate the water at the temperature when drawn.

Since in distribution services there is no exhaustion of oxygen, any increase in free carbonic acid may mean a possible increase of soluble iron in the water, which would be precipitated in the hot water supply.

Neutralization of free and half-bound carbonic acid is impracticable as it tends to hasten corrosion if there be the slightest excess of hydrate, removes zinc when hot from galvanized pipe, interferes with alum precipitation and color removal, and produces considerable precipitation of calcium carbonate in the water, which would deposit in the pipe system, meters, etc., unless previously removed by filtration or sedimentation.

Neutralization of only free carbonic acid is feasible, since it retards corrosion and reduces the amount of soluble iron.

Either soda-ash or lime oxide may be used. Both reduce the corrosive action, cold or hot. Only sufficient lime should be used to form bicarbonate. This reagent increases the hardness 1.1 p.p.m. for every 1 p.p.m. free carbonic acid neutralized to bicarbonate. About 5.3 lbs. CaO per 1,000,000 gals. of water are required for each 1 p.p.m. carbonic acid. It is best handled dry. It costs about 2 cents per 1,000,000 gals. per 1 p.p.m. carbonic acid.

Soda-ash is more soluble, can be handled in concentrated solution and consequently in small-sized tanks, and probably with better regulation of dosage would not increase the hardness, but, on the contrary, would decrease the lime sulphate in the water, changing it to sodium sulphate, thus improving the water for boiler use and for other industrial purposes. It also apparently helps to form a better protective coating on the pipe. About 20.2 lbs. soda-ash per 1,000,000 gals. of water are required for each 1 p.p.m. carbonic acid. This would cost about 20 cents per 1,000,000 gals. for each 1 p.p.m. carbonic acid. Soda-ash has been used successfully on a small scale to obviate red water trouble. The great difference in cost is due to the greater molecular weight, less combining power and greater cost per pound. The cost must be considered in connection with the degree and advantage of the change of sulphates to carbonates, etc.

Aeration of water by splashing followed by neutralization of residual free carbonic acid (about 5 p.p.m.) is probably the best practice.