WATER SOFTENING AND FILTRATION PROCESSES.

Fundamental Principles. That a supply of water free from impurities is greatly to be desired, is shown by the money annually expended to secure such a supply. Plants have been erected by municipalities for filtration purposes; Edinburgh, Scotland, and Southampton, England, have in addition installed water softening plants. A plentiful supply of water free from contamination and impurities is a valuable asset for any manufacturing concern, but the value to the textile industry can hardly be over-estimated. Of course some chemical impurities in water are an aid to certain textile processes, but such a condition rarely exists.

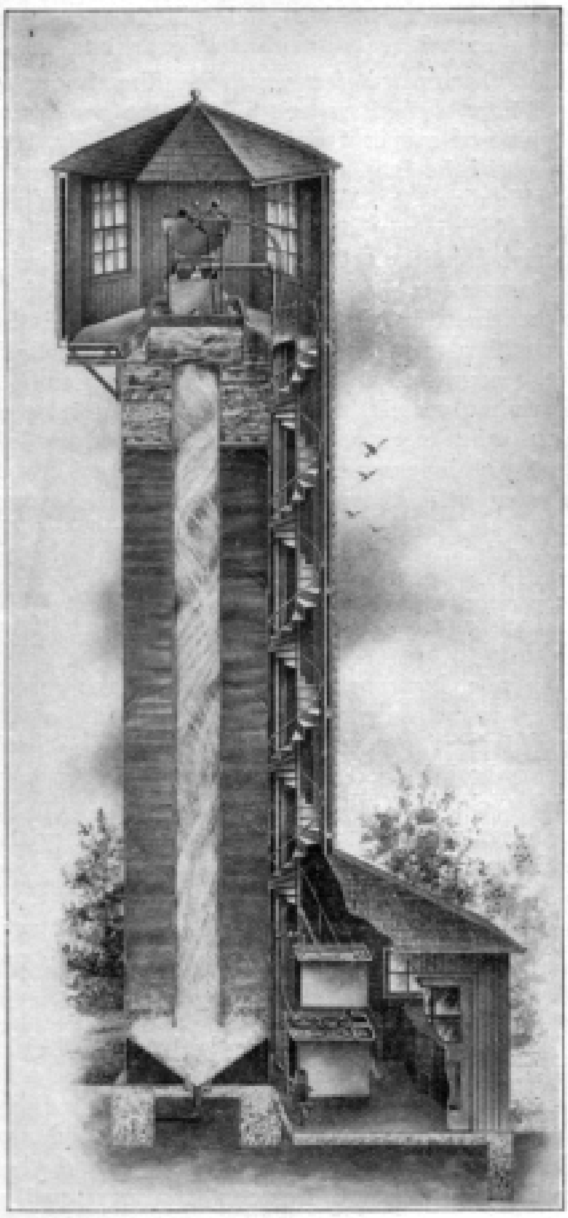


FIG. 1.

To a great extent, the content of a water depends upon its source; of course the original source of all water supplies is the rain which falls upon the earth, but as little or no rain-water is used as such, we will consider only the direct sources of supply,—surface waters (rivers and lakes) and ground waters (springs and wells).

Surface water is frequently contaminated by refuse, waste and sewage from towns; such water is difficult to deal with and the methods to be used will be set forth under filtration processes.

Ground waters are seldom contaminated, unless from a cess-pool. But both surface and ground water are apt to contain chemical impurities in solution. Water is an excellent solvent, and, as such, takes many salts into solution. The salts most often taken into solution are calcium and magnesium compounds; free acids, basic impurities and occasionally a ferric compound may be present.

At present the effect of the salts of magnesium and calcium will be considered. Water, containing these salts is usually spoken of as *hard water*. The calcium and magnesium are present usually as carbonates and sulphates, but occasionally as chlorides and nitrates. The carbonates cause temporary hardness, while the sulphates, chlorides and nitrates cause permanent hardness. Temporary hardness is removed by boiling, a friable deposit is produced which is readily removed. Permanent hardness is not removed by boiling and the scale which is formed by water which is permanently hard is difficult of removal.

The softening of water is accomplished by the simple process of precipitation by the use of chemicals. To remove the carbonates, lime is used as the precipitant. The carbonates are held in solution by reason of the carbonic acid dissolved in the water. Upon adding lime, the acid unites with it, forming carbonate of lime. Since the acid is no longer present, the almost insoluble carbonate is precipitated. This reaction may be represented as follows:

$$CaCO_3 + CO_2 + Ca(OH)_2 = 2\ CaCO_3 + H_2O$$

or with the magnesium salt

$$MgCO_3 + CO_2 + Ca(OH)_2 = MgCO_3 + CaCO_3 + H_2O$$

but in this case the magnesium carbonate is quite soluble in water so that an added quantity of lime is necessary, as,

$$MgCO_3 + Ca(OH)_2 = Mg(OH)_2 + CaCO_3$$

The magnesium hydroxide then precipitates out. To remove the sulphates, sodium carbonate is used, and in the case of magnesium, lime is also added:

$$CaSO_4+Na_2CO_3=CaCO_3+Na_2SO_4$$

and

$$MgSO_4+Ca(OH)_2+Na_2CO_3=Mg(OH)_2+CaCO_3+Na_2SO_4$$

The sodium sulphate, Glauber's salt, is very soluble, but in the small amount present after this operation, its presence is unobjectionable. The chlorides and nitrates are removed in the same way, by the use of sodium carbonate.

Iron is occasionally present in water; when so occurring, it is usually in the form of the carbonate, or as the sulphate. The sulphate, present as ferrous sulphate, is easily oxidized and dissociates, ferric oxide being precipitated. Therefore, a cure for iron impurities is to thoroughly aerate the water. This process can be represented as follows:

$$FeSO_4+2O+H_2O=Fe_2O_3+H_2SO_4$$

Free sulphuric acid remains in the solution, but this can be precipitated as sodium sulphate, by the addition of sodium hydroxide.

Sulphuric acid is the only mineral acid which is commonly present in water; but frequently certain organic acids may be met with. These acids are good solvents for iron, and are therefore objectionable.

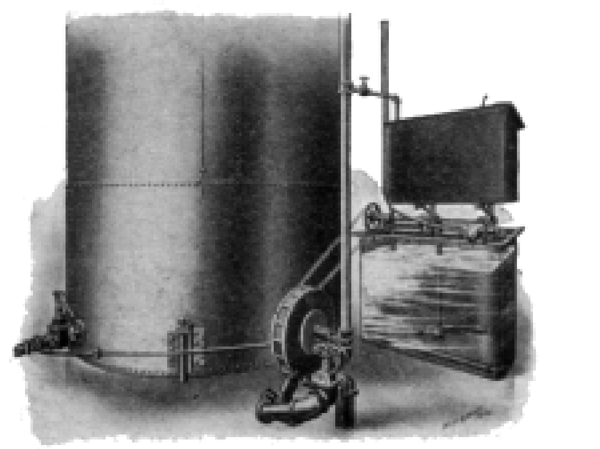
Sodium carbonate is the only alkaline impurity likely to be present. This readily precipitates on the addition of sulphuric acid. Lead and copper impurities occasionally occur, and their presence requires especial attention.

Commercial Processes for Water Softening. In the Clark Process, called also, the lime process, lime-water is added, and the precipitate removed by subsidence in large tanks. The Porter-Clark process, one of the most commonly used, has the same underlying principle, but after the application of the lime, the water slowly rises through an iron cylinder containing broad shelves. The precipitate settles on these shelves and is removed either by means of sludge cocks or the shelves are scraped. Ordinary mechanical filters have also been used.

There are many different devices used to operate water-softening plants. The same simple principle governs all, but the machines devised to accomplish the action are some more complicated than others. After a comprehensive study, the following process, as used by the American Water Softener Co., has been selected for description. The devices used are simple, the process is thorough, and the cost of operation very small. In addition the system has been in extensive use and has always been up to requirements.

Fig. 1 shows a sectional view of a typical plant. The water, direct from the source of supply, enters the motor, revolves it, passes out through the pipe on the opposite side and rises to the top of the tower. The motor which is shown to better advantage in Fig. 2, is a motor of the direct and positive type, and with an effective water pressure of three pounds this motor will supply enough power to operate the entire apparatus.

The mechanism for mixing and handling the softening solution is shown in Fig. 2. This apparatus is situated at the ground level. In the upper tank, sufficient lime (CaO) is slaked to operate the plant for twelve hours. After the lime is thoroughly slaked ($Ca(OH)_2$), the valve is opened and the milk of lime flows into the lower tank through a screen that removes any foreign matter that may be present. Soda-ash (crude sodium carbonate) is then added in



sufficient quantity and the whole solution thoroughly stirred and kept in constant motion by the agitator. (Both lime and soda are added, so that temporary and permanent hardness may both be removed. Before this apparatus is installed, the water to be operated on is analyzed and the proper amounts of reagents to secure absolutely soft water are determined.) The shafting which operates the agitator also operates the pump, which, drawing the solution through a fine strainer, raises it to the chemical tank at the top of the tower. Any surplus is returned to the lower tank by the overflow pipe.

The upper mechanism is shown in Fig. 3. The water flows through a large pipe into a chamber of the oscillating receiver. As the chamber is filled, the centre of gravity moves until the equilibrium of the "tipper" is destroyed, and the contents poured into the tank; at the same time the other chamber of the receiver is brought beneath the orifice of the supply pipe. Above the receiver is the semi-cylindrical reservoir containing the softening solution. In the bottom of this tank is a valve through which the solution falls into the oscillating receiver. This valve is operated by the mechanism shown in the illustration. It is readily to be seen that by the system of levers, this valve is made to open each time the receiver oscillates. There is a constant head of the solution over the orifice of this valve so that a constant quantity of the solution is delivered at each operation of the valve. The lift of this valve can be regulated for any definite amount of softening solution. The oscillator, of course, is always operated by the same weight of water and the valve must feed exactly the required amount of solution whether there is one or ten oscillations to the minute. Therefore, if the pressure head on the pipes which deliver the water supply be not constant, the apparatus is as efficient as if the head were constant. Fixed to the underside of the oscillating receiver is a paddle, which acts not only to prevent too violent movement of the "tipper," but also more thoroughly mixes the water and the softening solution, which have already become well mixed through the motion of the oscillator. The solution in the chemical tank is constantly agitated, and the reagents kept

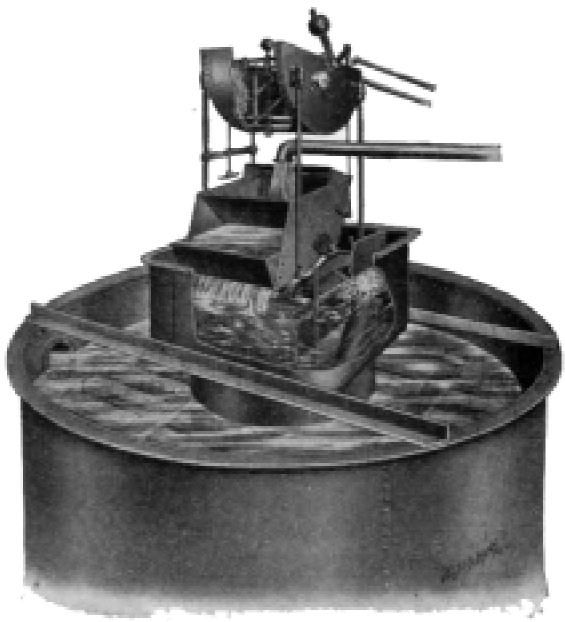


Fig. 3.

mixed, by means of the rod and rocker arm connected with the "tipper."

The water with the precipitate that results upon the addition of the softening solution passes to the bottom of the small tank. From here it goes under the division plate and enters the pipe which is inclined at an angle of 45°, so that the water entering the cylindrical downtake, shown in Fig. 1, is given a decided whirling motion. This whirling motion causes the precipitated matters to coagulate rapidly so that almost all the suspended matter is deposited before the water rises in the stand-pipe. The precipitated matter which collects in the bottom of the stand-pipe can be readily remove by opening a waste valve, provided for the purpose, and allowing the pressure head of the water in the tank to blow out the slimy material, which is not of a very heavy consistency.

If two or more sources of water be tapped in order to secure a sufficient supply, it is possible to provide a final output of water of the same degree of hardness. This is accomplished by using separate softening solutions for each source of supply, and introducing the reagents by means of separate oscillators. The apparatus can be so mounted that only one stand-pipe is necessary.

By the use of this method, plants using as much as 15,000 gallons of water, per hour, have been supplied with water of a uniform character, free from any trace of chemical impurities. For plants, which in comparison require a very small supply, it is advisable to dispense with the motor previously described, and periodically to run the softening solution directly into the upper tank; but of course, the head on the discharge valve would then vary. To overcome this difficulty the solution reservoir is divided into two parts by a division plate which rises only part up in the tank. The paddles which agitate the solution in this tank are made scoop shape. At each oscillation of the "tipper," these scoops raise a certain quantity of the softening solution over the division plate into the valve compartment. The amount raised is in excess of the amount discharged, the surplus flowing back into the solution compartment. By this means a constant head is kept on the orifice of the valve and the same amount of softening solution is delivered at each movement of the "tipper."

For some purposes it is better to install a rectangular type of softener. The process both as to mixing and introducing the reagents is fundamentally the same as for the type illustrated; but instead of using the high cylindrical downtake and stand-pipe for settling, the water flows under a partition from the compartment, into which it is discharged by the "tipper," to a chamber, in which the water rises to flow through a downtake pipe into a settling chamber. Then the water flows through a filter to a storage compartment. The flow of water from the filter is regulated by a balanced valve attached to a float in the storage compartment.

The cost of operating an "American Water Softener" is slight. The chemicals used are mainly lime which costs about ¼ cent per pound and soda-ash costing 1 cent per pound. The quantities used makes the total cost range from ½ to 3 cents per 1,000 gallons of water treated, depending on quality of water. There is no hoisting of material, no climbing to top of tank, except at rare intervals, everything is automatic except that about 15 to 30 minutes a day has to be devoted by some laborer to mixing the chemicals —this costing say 15 cents a day. The plant automatically starts or stops, according to the amount of treated water required.

The saving that will immediately follow the installation of a water-softening plant cannot be exaggerated. One degree of hardness (this means one part, of the foreign matter present, to seventy thousand parts of water) due to salts of calcium or magnesium will kill one and one-half pounds of good soap per one thousand gallons. One reason for dull colors, spots and blemishes is hard water. In dyeing, scouring, fulling and finishing as well, pure, soft water gives better and more economical results. In printing and bleaching works the same arguments apply. Then the saving in fuel and boilers is no inconsiderable item. Hard water causes boiler scale and one sixteenth of an inch of boiler scale requires thirteen per cent more coal. The boiler itself becomes pitted and is constantly in need of repairs. The scale makes frequent overhauling of the boilers necessary, tubes have to be taken out and replaced and the varying expansion of scale and iron causes a great amount of breakage.

In this day of germs, perhaps a few words as to the bacterial efficiency of the various softening processes is timely. Experiments by Frankland, and results obtained by practice show a considerable degree of bacterial purification, in some instances results were secured quite as good as those obtained by special purification processes.

(*To be continued*)