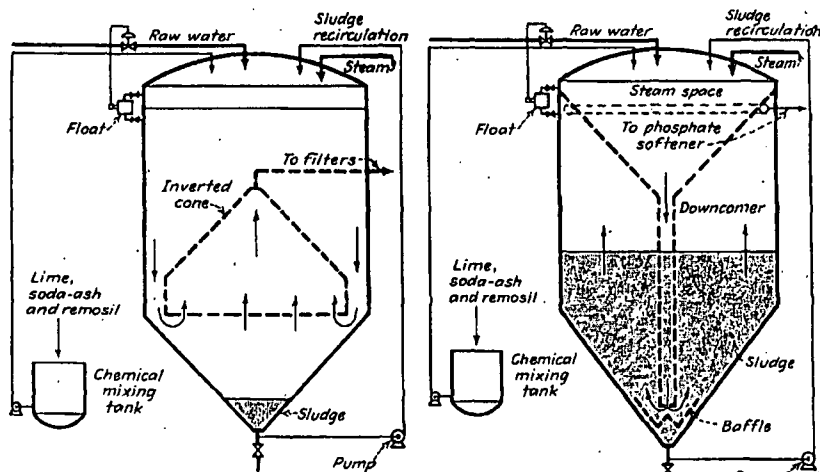




2 In conventional lime-soda softener, water flows downward depositing its sludge, then leaves through inverted cone 3 Water entering sludge-blanket softener settles to bottom, and then must flow upward through the sludge to get out

the pilot-plant stage, it showed possibilities of providing much more efficient silica removal than a new softener of the conventional type. A second-stage tank of conventional design was installed for phosphate treatment. Provision was made for lime and soda softening and silica reduction in this softener, so that it might be used as a lime-soda softener while the primary unit is out of service for inspection. Piping was arranged so phosphate could be added at the feedwater pump section during such operation.

In the new softener, raw water and chemicals are sprayed into a collecting cone at the top, Fig. 3. The mixture passes through a downcomer to the

bottom, where the water is deflected upward through a blanket of sludge. Clarified water is decanted to the phosphate softener.

SILICA-REMOVAL REACTION

Magnesium hydroxide, commonly used to remove silica from water, may be produced by precipitation of the magnesium salts in the water by calcium hydroxide. If there is insufficient magnesium in the raw water it may be added in the form of magnesium oxide or dolomitic lime. Activated magnesium oxide, especially prepared for this purpose, removes silica effectively. At this plant it was used in both types of softeners and was fed with high calcium

lime and soda ash to meet our needs. Removal of silica proceeds slowly, approaching a certain equilibrium point for each set of conditions. Several variables effect the speed and completeness of the reaction. The equilibrium point approached is determined by: (1) amount of silica in the raw water, (2) amount of magnesium oxide employed, (3) water pH, and (4) temperature in the softener. The speed of the silica-removal reaction varies with: (1) residual silica in the water, (2) concentration of magnesium hydroxide, (3) degree of unsaturation of the magnesium hydroxide, (4) water pH, and (5) temperature in the softener. As the silica is removed, con-

tinued removal slows to such an extent that attainment of reaction equilibrium in the softener is not feasible.

PRELIMINARY WORK

Research at the Permutt laboratories and pilot plant demonstrated the value of a concentrated sludge bed for silica removal. Data taken from this work were used in preparing curves, Fig. 4, which show the amount of silica remaining in solution plotted against magnesium-oxide feed, both with and without a sludge blanket. The curves show that silica removal is much greater when the reaction is carried out in a concentrated blanket of sludge. Furthermore, in the region of low-silica concentration, relatively large increases in magnesium-oxide feed are necessary to achieve further reduction in silica, with or without the sludge blanket.

SILICA-REMOVAL COMPARISON

Although reaction equilibrium is not reached in the new softener, it is much more closely approached than in the conventional type. The greater efficiency of the sludge-blanket unit is attributed primarily to greater concentration of magnesium hydroxide with which the water comes in contact. Some increase in efficiency is due to higher operating temperature.

Table I provides a comparison of the two types of softeners over comparable periods, and shows the new unit's greater efficiency, silica removal per unit of magnesium hydroxide being about double.

In comparing operating efficiencies, it should be pointed out that during the periods considered the new softener was operated at a temperature approximately 23 F above that of the old unit. Whereas extensive data regarding the effect of temperature on efficiency are not available, the results from operation for four days at lower temperatures indicate silica content of the effluent may increase by 1.5 ppm if the temperature in the new softener is dropped from 243 F to 220 F.

There was no significant difference in contact time of water with magnesium hydroxide in the two types of softeners. The contact time in the new unit could have been increased by raising the sludge level. This was unnecessary, however, because increasing the flow through the softener from 46 percent to 80 percent of rated capacity increased silica content of the effluent only one ppm.

All sludge was blown down from the old softeners once each eight hours, whereas only part of the sludge was

blown down from the new unit once every two days. The average retention time of the magnesium hydroxide in the old softeners was 4.7 hours, compared to 100 hours in the new unit. Concentration of sludge in contact with the water in the old softeners averaged 1500 ppm; the added magnesium hydroxide was 23 percent of the sludge. Concentration of sludge in the new softener was 60,000 ppm of which 17 percent was added magnesium hydroxide.

Added magnesium hydroxide in the sludge layer was thirty times as concentrated as in the conventional softeners, although only 66 percent as much magnesium hydroxide was fed. As the speed of the silica-removal reaction is proportional to the concentration of magnesium hydroxide, and the contact time of the sludge with the water is the same in either case, it would be expected that more complete silica removal would occur in the new unit.

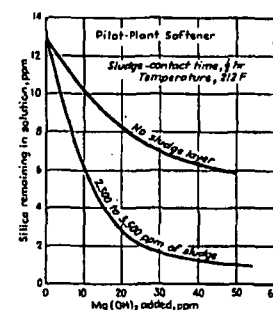
In the new softener, part of the unspent magnesium hydroxide settles out below the baffles at the bottom of the downcomer, requiring that sludge be recirculated from this area to obtain maximum efficiency. Rate of recirculation is not important; it may be stopped several hours without adversely affecting silica removal.

Recirculation of sludge in the old softeners caused the magnesium hydroxide to be re-used, and also increased the concentration of sludge in contact with the water from 480 ppm to 1500 ppm. The average retention time of the sludge was increased from 1.5 hours to 4.7 hours. Twice as much magnesium oxide was required when sludge was not recirculated; failure of sludge recirculation equipment consequently reduced silica removal.

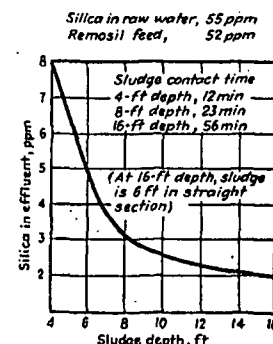
The amount of silica removed in the new softener increases with the depth of the sludge layer through which the water passes. During the operating period on which the figures in Table I are based, the sludge level was about 7 feet above the conical section. Raising the level above this point improves silica removal only slightly at normal load, Fig. 5.

EFFLUENT HARDNESS

Chemical feed to the new softener may be discontinued several hours without causing a dangerous increase in silica. This is due to the stabilizing effect of 4000 pounds of added magnesium hydroxide in the sludge layer. Failure of chemical feed to the old softeners, on the other hand, always



4 Residual silica in the effluent with and without sludge-blanket action



5 Raising sludge level above 7 ft improves the silica removal only slightly

caused a rapid and immediate increase in silica content.

As shown in Table II, the raw-water hardness averaged 100 ppm. Hardness of the effluent from the new softener averaged 15 ppm as compared to 21 ppm from the old softeners. The lower hardness was due in part to the stabilizing effect of the undissolved calcium hydroxide in the sludge blanket, and in part to the lower solubility of calcium hydroxide at the higher operating temperature. Following stoppage of the chemical feed for two or three hours, treated-water hardness increased to only 25 to 30 ppm. This resulted in part from the 10 ppm excess sodium alkalinity of the raw water.

Although the percentage undissolved calcium hydroxide in the sludge of the old softeners was higher than in the sludge-blanket unit, the total

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TABLE I—Data Obtained from Softener Operation

Characteristics	Conventional design*	Sludge-blanket design**
Silica in raw water, as SiO ₂ , ppm	53	53
Silica in effluent, as SiO ₂ , ppm	11	2.0
MgO feed, ppm	79	30
Parts SiO ₂ removed per part MgO	0.6	1.1
Avg retention time of Mg(OH) ₂ , hr	4.7	100
Contact time of water with Mg(OH) ₂ , min	91	87
Hardness of effluent, as CaCO ₃ , ppm	21	15
Average load on softener, % rated capacity	65	46
Temperature in softener	220 F	243 F

*Results based on operation during June-Oct. 1945.
**Results based on operation during July-Sept. 1947.

Table II—Typical Analysis of Raw Water

Total hardness as CaCO ₃	100 ppm
Calcium hardness as CaCO ₃	60 ppm
Magnesium hardness as CaCO ₃	40 ppm
Methyl-orange alkalinity as CaCO ₃	110 ppm
Phenolphthalein alkalinity as CaCO ₃	9 ppm
Silica as SiO ₂	53 ppm
Chlorides as Cl ₂	6 ppm
Sulfate as SO ₄	13 ppm
pH	7.9
Temperature	74 F