# Operation of Juice Softeners in a Beet Sugar Factory

L. P. ORLEANS, W. A. HARRIS, L. W. NORMAN, H. W. KELLER[1]

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## Introduction

A continual degradation in quality of beets grown in the Imperial Valley of Southern California has caused a gradual increase in lime salts concentration of the sugar juices produced from these beets. This increase in lime salts concentration from .045% CaO on thin juice solids in 1956 to .084% in 1961, has made it increasingly difficult to concentrate these juices in the evaporators because of scale formed on the heating surfaces. The use of ion exchange resins to soften sugar containing juices has proven successful in European sugar mills and preliminary softening trials using juices produced at Holly's Carlton mill, indicated that this procedure should be economically feasible.

## Laboratory Tests

Laboratory tests were conducted in 1961 to determine the best operating conditions for softening of evaporator thin juice. These tests indicated that by using Illco—C-211W resin, a maximum loading of 1.89 lbs/cu ft as $CaCO_3$, or 1.06 lbs CaO could be expected by the time we reached a leakage of 42% of the hardness in the juice being treated. The average leakage for the complete cycle would be 13% at this point. Figure 1 gives the percent of total hardness which leaked through into the effluent from the softening trials. The flow rate established by these tests was 8 gpm per sq ft of bed cross section. (Used for water softening).

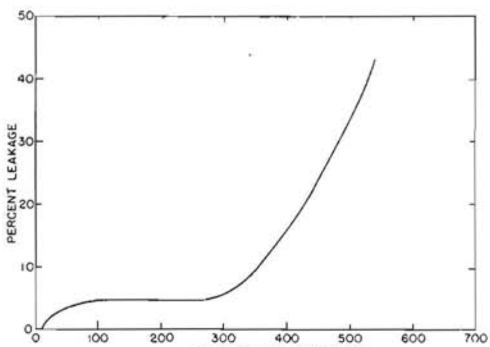


Figure 1.—Percent hardness leakage vs. throughput.

[1] Research Engineer, Research Chemist, General Chemist, Holly Sugar Corporation, Colorado Springs, Coloralo; Assistant Research Director, Illinois Water Treatment, Rockford, Illinois, respectively.

From these preliminary tests the following equipment sizes were established. The 1,200 gpm flow rate dictated a 150 sq ft bed cross section in order to hold the average flow to 8 gpm per sq ft. The column diameters were set at 10 feet with two columns operating in parallel. We need one additional column being regenerated while two are in service. The minimum bed depth is 4 ft, making a total volume for each column of 315 cu ft. The height of the column was set at 11 feet to allow enough free board for the addition of another 158 cu ft of resin if needed. Table 1 indicates the service cycle to be expected using a bed volumn of 315 cu ft.

Table 1.—Expected service cycles.

| % CaO on dry substance | Throughput to 42% Leakage gallons/cu. ft. | Service time hours |
|---|---|---|
| 0.02 | 3660 | 32.0 |
| 0.04 | 1810 | 15.8 |
| 0.06 | 1210 | 10.6 |
| 0.08 | 910 | 7.9 |
| 0.10 | 730 | 6.4 |
| 0.12 | 600 | 5.3 |
| 0.14 | 520 | 4.5 |

The preliminary tests indicated the desirability of reclaiming brine for reuse in the following regeneration cycle. The volume of brine to be reclaimed is 4.5 gallons per cu ft of resin with 8.5% brine concentration. A 10% fresh brine solution is used for regeneration, at the rate of 7.5 pounds per cu ft of resin.

## Equipment

The final arrangement of the equipment included three columns 120 inches in diameter by 132 inches high with the necessary headers and valve arrangements to facilitate automatic operation of the units by a timer controlled panel. The columns have top, center and bottom distributors. The bottom distributor is covered by a quartz bed which supports the resin bed. The center distributor is 12 inches above the top of the settled resin bed. The top distributor is approximately 3 feet below the top of the column and is used for the backwashing outlet. The softener installation also includes a brine reclaim pump and a horizontally mounted brine reclaim tank 78 inch diameter by 120 inches long. The softener columns and brine reclaim tank are protected with a baked epoxy lining. The control panel includes a flow meter for each unit with a totalizing integrator which sounds an alarm when a pre-set gallonage has passed through the unit. The panel also contains a series of timers to control the regeneration cycle and the necessary interlocks to prevent two columns from being put into the regeneration cycle at the same time. The complete regeneration cycle is listed in Table 2.

Table 2.—Regeneration cycle.

| Sequence | Flow, gpm | Time, minutes | Total gallons |
|---|---|---|---|
| Juice blowdown | 600 | 1 | 600 |
| Sweeten off | 600 | 5 | 3000 |
| Sweeten off rinse | 600 | 5 | 3000 |
| Backwash | 450 | 20 | 9000 |
| Backwash blowdown | 600 | 6 | 3600 |
| Reclaim brine | 120 | 12 | 1440 |
| Fresh brine | 120 | 22 | 2640 |
| Slow rinse | 120 | 15 | 1800 |
| Fast rinse | 600 | 10 | 6000 |

The juice blowdown is accomplished by stopping the juice flow to the column and allowing air pressure to blow the juice from the column until the level has dropped to the surface of the bed. This decreases the dilution of juice with sweetening off water. Once the level of juice reaches the top of the resin bed, the rinse water is turned on and continues to force the juice from the column back to the sulphur tower for further processing. Sweetening off is continued until the sugar concentration drops to approximately 2%. The next step is the sweeten off rinse to finish removing all the sugar from the resin. (This step was omitted from the process the second year, to decrease the water requirements for regeneration, and the backwash followed immediately after the sweetening off.)

The backwash leaves the column through the top distributor so the column is completely full of water at the end of the backwash and this water is blown down through the bed and out the bottom distributor by introducing air into the column. This blowdown continues until the water level reaches the center distributor.

The reclaim brine is then introduced through the bottom distributor and flows upward through the bed and out the center distributor. The reclaim brine is followed immediately by the fresh brine, and this fresh brine is reclaimed for the next regeneration cycle. The fresh brine is followed by a slow rinse up-flow through the bed to force all the brine through the resin. Once the slow rinse has been completed, the flow is reversed and the fast rinse completely washes the remaining brine from the resin using a down-flow. The fast rinse completes the regeneration cycle and the column is ready to be sweetened on at the same time as the next column to be regenerated is sweetened off.

## Difficulties of Operation

Screens require clean water which was not available, and the screens were continually plugged from the inside. The pressure ruptured the screens. The resin loss was high, so the screens were removed from the center distributors and the control circuits changed to blow down the column, following the backwashing operation, through the bed and out the bottom distributor. This left only the brine and a slow rinse flowing out through the unscreened center distributors. Flow rates should be low enough so that the top of the bed would be well below the distributor level. The only resin loss should be caused by malfunction of the units, and to provide for this possibility, a resin trap was built in the flume carrying waste from the units.

Diaphragm valve operators caused considerable trouble. Diaphragm travel was too short to allow full opening of valves. Operator diaphragms were flat and pulled out of retaining flanges. The operators have been changed to allow full travel and molded diaphragms have replaced the flat ones originally installed.

Excessive pressure drop was encountered across the beds during the first campaign. A fairly heavy layer of calcium carbonate was being deposited on top of the bed while juice was flowing downward through the resin. It was impossible to remove this deposit by backwashing, and the units were treated with hydrochloric acid to remove the calcium carbonate. The source of this carbonate was not located until the end of campaign when maintenance workers discovered that a by-pass cock had a sheared pin which, unfortunately had sheared with the cock in a slightly open position, and allowed a small stream of second carb juice to by-pass the filters.

It was impossible to hold the juice at the proper level in the columns because of the great change in pressure drop across the bed from the beginning to the end of the cycle. It was necessary to manually adjust the level in the column before starting the regeneration cycle, in order to prevent excessive sweetening-off losses. A new level control system was installed which could compensate for a large change in pressure drop across the units during the juice cycle.

Control of parallel flows through the units was impossible by using a hand set valve, and control was accomplished by utilizing a level control on the feed tank cascading to flow controllers on each unit to balance the flows.

It is impossible to tell what rate of brine addition is being used during the regeneration step and brine consumption has been considerably above that recommended for this application.

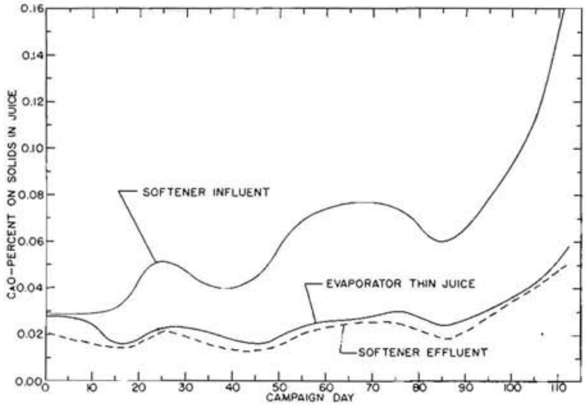


Figure 2.—Lime salts comparisons for treated and untreated juice.

Additional flow meters are being installed to correct this situation.

## Operating Results

Figure 2 shows the variation in lime salts from the beginning to the end of a campaign. The second carb juice contained .03% CaO on solids at the beginning of campaign, and made an erratic climb to more than .15% as the campaign drew to a close. The lime salts in the juice from the softeners was held between .015% and .03% until the last few days of campaign when it climbed as high as .055%. Figure 2 shows the lime salts in the effluent from the softeners as well as the lime salts in the thin juice to the evaporators. The difference in these two values is accounted for by a stream of juice which by-passes the softeners to control the minimum softness of the juice going to the evaporators. A completely softened juice is corrosive and during the early part of campaign, the juice softening was carried too far and considerable corrosion was experienced in the pipe lines to the evaporators and also in the first two effects of the evaporators. A greater percentage of juice should have by-passed the softeners during the first part of the campaign.

Figure 3 shows the actual resin loading obtained throughout the campaign. The curve also indicates the maximum loading to be expected with this resin and during the earlier part of campaign we were considerably below this expected loading. The service cycles were much too short for the hardness of the juice and regenerations were being started much sooner than necessary. When it was realized that the juice was being oversoftened, the cycles were extended and better loadings were obtained.

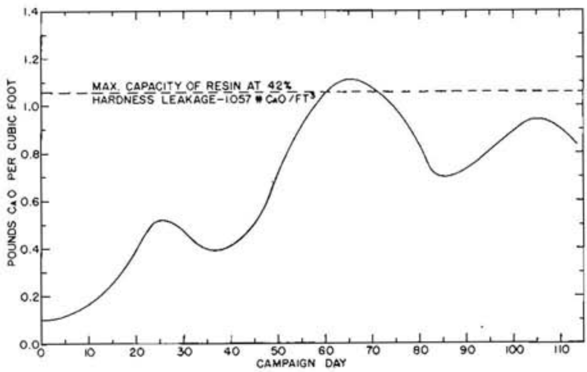


Figure 3.—Resin loading.

Tests conducted on the resin after the first year's operation showed that the capacity of the resin had decreased 4.3%. Analysis after the second year's use indicated capacity had decreased further to only 79.6% of the original capacity. This means that the maximum loading to be expected at the end of the second campaign would be 0.841 pounds of CaO per cu ft of resin instead of 1.057 as indicated on Figure 3.

The studies also indicated that the resin could be cleaned up and restored to 100% of the original capacity by treating with caustic soda and Sodium Hypochlorite. Screen analysis showed that very little if any change in particle size had taken place.

Figure 4 gives a typical curve for sweetening on and for sweetening off the columns. The sugar lost during sweetening on amounts to 25 pounds per cycle and the loss during sweetening off will be approximately 700 pounds per cycle. Total sugar losses in the juice softeners will vary from 0.06% of the sugar in the juice treated per cycle at the beginning of campaign to 0.32% at the end of campaign with the much shorter service cycles. With 488 regeneration cycles, the sugar loss averaged 0.14% for the campaign.

Dilution during sweetening off amounts to 1400 gallons and during sweetening on dilution is 600 gallons for a total of 2,000 gallons per cycle. This amount of water is not noticeable in the 861,000 gallons of juice per cycle at the beginning of campaign. There was no measurable difference in the campaign averages for brix of juice going to the softeners and juice going to the evaporators.

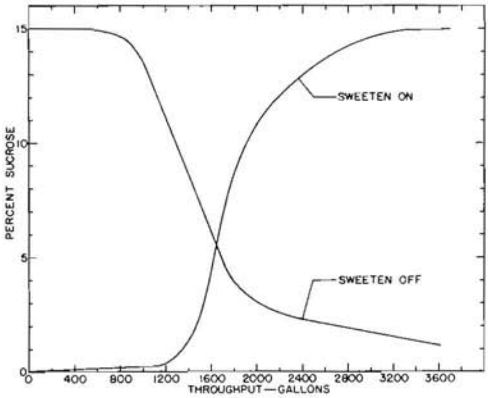


Figure 4.—Sweetening on and off curves.

During the 1961 campaign (before softeners were installed) evaporator bodies were boiled out 83 times while boilouts were only necessary on 41 bodies during the 1963 campaign. The total tons of beets sliced during the 1963 campaign was 17% higher than the 1961 campaign. Basing costs on 1963 prices and adjusting for differences in beets processed, the boilout chemicals cost $5,560 less for 1963 than for 1961.

The salt used for regeneration cost $15,100 for the 1963 campaign. There were 488 regenerations performed during the 1963 campaign using a total of 1,200 tons of salt. This salt consumption gives a regeneration level of 15.6 pounds per cubic foot of resin regenerated. The recommended level is 7.5 pounds per cubic foot, and steps have been taken to remedy this excessive usage of salt. Closer attention to length of cycles and increased loading of resin will further reduce salt consumption to less than half of the 1963 figure.

The average slicing rate increased from 5,404 tons per day for 1961 to 6,070 for 1963. This increase of 12% in slicing rate meant 14 less days in the 1963 campaign. Other changes in the mill operation undoubtedly contributed to this higher slice rate, but it is felt that a great portion of the increase can be attributed to the better performance of the evaporators operating on softened juice.

## Summary

The juice softeners installed at Holly Sugar Corporation's Carlton Mill reduced the lime salts in the thin juice from an average of .066 to .029% of total solids in the juice. Evaporator

boilout requirements were decreased 65%. The decrease in cost of boilout chemicals was only one-third of the cost of salt required for the softeners, but with better control of the brine flows in the future, these costs should very nearly balance each other. Slicing rate was increased 12% and, although all of this increase cannot be attributed to the softer evaporator thin juice, it is felt that enough savings were realized in the shorter campaign and less labor required for evaporator boilouts to justify the costs involved in the juice softener installation.