Recent Developments in the Processing of Beet Sugar

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UNDER the impetus of relatively high sugar prices and high volume of production on the one hand and high unit costs of labor and supplies on the other, our industry is experiencing a surge of new ideas in the processing of beet sugar. No one person can follow in detail all the current promising developments so my remarks must necessarily be limited to those newer developments with which I have had some experience or on which I have had reports.

Before describing equipment and processes, it will make the picture clearer to discuss economic pressures which are dictating the trend of technological developments.

For this purpose, I have prepared tables giving data which are indicative of changes in the economic picture during the past 10 years.

The largest single item of cost in the production of beet sugar is the amount paid farmers for beets. Table 1 shows these amounts per ton paid during the past 10 years for beets of 16.0 percent sugar content.

Table 1

Year	Amount paid growers per ton of beets of 16.0 percent sugar content	Percentage
1938-39	$ 4.06	100.0
1939-40	3.94	97.0
1940-41	4.98	122.6
1941-42	6.16	151.7
1942-43	6.76	166.5
1943-44	6.84	168.5
1944-45	6.94	170.9
1945-46	6.42	158.1
1946-47	10.72	264.0
1947-48	11.72	288.7

These payments to farmers have been calculated by using the sliding scale in the beet purchase contracts and the actual net return from the sale of sugar by our Company in each respective year. You will note that cost of our raw material has risen 188.7 percent. The amount paid farmers for the raw material constitutes a very substantial part of the total cost of manufacture of sugar.

Table 2 shows the average hourly earnings of all factory employees during the campaign period for the respective campaigns. These earnings per hour are calculated by taking the total payroll and dividing by the total number of hours worked. Included in the group covered by this table are all employees from the classification of assistant superintendent to unskilled labor, inclusive.

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Table 2

Campaign	Average hourly earnings of factory employees	Percentage
Avg. 1935-36 to 1938-39	$ .4635	100.0
1939-40	.5030	108.5
1940-41	.5316	114.7
1941-42	.6341	136.8
1942-43	.7601	164.0
1943-44	.8146	175.7
1944-45	.8783	189.5
1945-46	.9553	206.1
1946-47	1.0656	229.9
1947-48	1.2220 (estimated)	263.6

The first figure ($ .4635) covers the years from 1935 to 1939 which are the years chosen by the Department of Labor as a base period for calculating the index of cost of living. Average hourly earnings of employees have increased 163.6 in the past 10 years. The current index of cost of living published by the Department of Labor is 166. Wages paid have outpaced rising cost of living by 100 points. These 100 points are available to employees for increased savings and improved standard of living.

Cost of fuel represents one of the largest items of factory operating expense. Table 3 shows the delivered cost of coal per ton at our Nyssa factory during the past 10 years.

Table 3

Year	Delivered cost of coal per ton	Percentage
1938-39	$5.13	100.0
1939-40	4.99	97.2
1940-41	5.11	99.6
1941-42	5.18	101.0
1942-43	5.40	105.3
1943-44	6.06	118.1
1944-45	5.70	111.1
1945-46	6.16	120.1
1946-47	6.23	121.4
1947-48	8.20 (estimated)	159.8

The increase in unit cost of coal delivered is 59.8 percent.

Sugar bags have contributed more than their share to rising costs and their use is not subject to managerial control. The use of low-cost types such as paper 100-pound units effects a substantial saving but the choice of container lies largely with the customer. To illustrate increased cost of containers a single type will be used as an example.

The price of a single container unit consisting of ten 10-pound cotton pockets with an 8-ounce burlap baler was $ .241 in 1938. Currently this same unit costs $1.005, an increase of 317.0 percent.

As a side light on current costs of containers, it may be said that our profits would disappear completely if the buyer elected to receive all sugar in the most expensive container now being used and if the current sugar sales differentials were continued.

Rising costs of the supply items shown in the preceding tables are typical of the trend of cost of all supplies.

While costs have risen, we have been enjoying an increase in the net return from the sale of sugar. Table 4 shows the net return per 100 pounds of sugar sold by Amalgamated in the past 10 years.

Table 4

Year	Net return per 100 pounds sugar sold	Percentage
1938-39	$3.19	100.0
1939-40	3.13	98.1
1940-41	3.59	112.5
1941-42	4.24	132.9
1942-43	4.46	139.8
1943-44	4.50	141.1
1944-45	4.58	143.6
1945-46	4.28	134.2
1946-47	7.06	221.3
1947-48	7.25 (estimated)	227.2

This increase in returns amounting to 127.2 percent may seem to offer an off-set to rising costs but the sliding scale beet purchase contract has compelled payment of a very substantial part of the higher income to farmers. Furthermore, there is evidence that the peak of sugar prices has been reached while there is no evidence of any end to the increase in costs.

Table 5 shows the percentage of the increase in returns which has been paid to farmers.

Table 5

Year	Percentage of increased value of sugar in a ton of beets paid to farmers
1938-39	0.0
1939-40	—70.5
1940-41	84.4
1941-42	73.2
1942-43	77.8
1943-44	77.7
1944-45	75.8
1945-46	79.5
1946-47	62.9
1947-48	68.9

An explanation of this table is desirable. The figures have been calculated by assuming a normal yield of sugar in a non-Steffen factory from beets of 16.0 percent sugar. Applying the actual net returns for sugar for the respective years to this amount of sugar gives the value of refined sugar extractable from a ton of beets. Payments to farmers have been calculated from the net return and an assumed sugar content of 16.0 percent. As the value of a ton of beets has increased by reason of the increased net return, the farmer has received about 70 percent of the added value. In table 5 the value of sugar in the beets each subsequent year has been compared to the value in 1938-39 to arrive at the figures shown.

This leaves 30 percent of the added return for the processor and from this 30 percent he must meet his rising costs.

The question has been asked as to why we pay farmers 70 percent of the added value of a ton of beets as sugar prices increase. The farmer is not a beet raiser only, he can turn to other crops and if our volume is to be maintained he must receive a net profit on beets that is comparable to profit on other crops or he will discontinue growing beets. He will continue to grow beets so long as his returns are high or if his costs are lowered. Lowered farmer costs are the primary interest in most of the papers offered at these meetings.

To summarize: We are in a situation where we are enjoying added returns from the sale of our sugar but of the increase 70 percent is being paid to growers for beets. We are faced with rapidly rising hourly wage rates and increasing unit costs of all supplies. If current trends continue, our share of increasing returns will not meet rising costs and we will be squeezed between the two opposing factors. High volume of production which lowers fixed costs per bag and further economies in use of labor and materials may enable us to continue profitable operations.

Reduction in factory labor costs per bag of sugar can be made by reducing the number of men employed and by increasing factory daily capacity. Economies in use of supplies can be realized by closer supervision of the process and by new developments in equipment and processes.

The balance of this discussion will deal with some of these newer developments.

Our process has changed little since the industry was established in this country. The basic steps remain and improvement has been largely in perfection of the details of processing and in improved equipment to carry out the old process.

Present trends are toward continuously operated, automatically controlled stations. Continuous operation provides more uniform results and automatic controls eliminate labor and improve processing results.

With equipment already in use, it appears practical to centralize controls on a single panel and to control the diffuser, first carbonation, second carbonation, sulphur station and evaporators with one man. If the Ellernan kiln proves successful it may be controlled from the same center.

Silver Continuous Diffuser.—A description of this equipment is not necessary since most of you are familiar with its design. It was invented, designed and built by the Silver Engineering Works of Denver, Colorado. Amalgamated has three of these in operation currently, the one at Nyssa having been installed in 1946. Table 6 below summarizes the essential operating data on current operation of these diffusers.

Table 6

Comparison of Standard Battery and Continuous Diffuser Operations

	Twin Falls	Nampa	Nyssa
Highest previous campaign average daily capacity in tons of beets—standard battery	1,945	2,111	2,350
Average tons beets sliced daily to date 1/1/48 with continuous diffuser[1]	2,354	2,816	3,209
Percent increase in capacity, diffuser over battery	21.0	33.3	36.6
Draft by sugar—battery	148	153	160
Draft by sugar—diffuser	129	123	126
Total sugar loss battery	.29	.32	.24
Total sugar loss[2]—diffuser	.21	.16	.20
Number of men employed—battery	24	21	21
Number of men employed—diffuser	3	3	3

[1]The data shown for diffuser operation for 1947-48 are to date averages for the following number of days of operation: Twin Falls, 93; Nampa, 106; Nyssa, 107.
[2]Sugar loss reported for the diffuser is the polarization of pulp.

On January 8, 1948, just 6 days ago, Nyssa established a new record slice of 3,447 tons of beets.

It is obvious that this equipment has made a valuable contribution toward reduction of man-hours of labor, toward reducing fuel consumption, reducing sugar loss and increasing factory capacity. In addition to the above measured savings are indirect savings arising from uniform high factory capacity.

The installed cost of a 21-cell diffuser, handling 3,200 tons of beets per day, has been of the order of $275,000.00.

A number of problems have developed in connection with diffuser operation. It is customary in our control of the diffuser to determine pH on raw juice and on juice from the 13th cell each hour. In addition, tests are made at less frequent intervals on the juice in all cells. Low pH values were found and were accompanied by high invert sugar and serious corrosion of equipment. Observation has lead to the belief that low pH is the result of growth of micro-organisms and control of such growth leads to improvement in pH.

During the first 12 hours of operation at Nyssa this year, juice from the 13th cell averaged 7.2 pH and diffusion juice 6.6. By the fourth day pH of cell 13 dropped to 5.0 and diffusion juice remained at 6.4. One test on cell 13 on the 5th day showed a low of 4.9 pH.

About 2 gallons of formaldehyde were added per hour to cell 13 by a continuous feed from a constant level syphon. The pH rose to 5.9 and 6.0. Subsequently this dosage of formaldehyde became ineffective. Tests were taken on juice from all cells and at the point of lowest pH massive doses of formaldehyde were administered in one shot. These doses at times exceeded 3 gallons. This corrected pH for a time but became ineffective and massive doses were added at the point of minimum pH followed by the same dosage to a series of cells on either side of the point of minimum pH. It became evident that formaldehyde alone was not a sufficient corrective.

The Great Western Sugar Company reported that control of pH had been effected by admitting steam to the domes of cells 8 to 13. This was tried with considerable improvement in pH conditions.

After some experimenting with chlorination of battery supply water and neutralizing of the diffuser juices with lime or soda, we are now adding formaldehyde at the rate of 2 gallons per hour to cell 13 and maintaining a temperature of battery supply at 68° C. or higher. This is not to be considered a final solution of the problem but at the moment is maintaining pH at 6.0 or higher throughout the diffuser.

Corrosion of diffuser parts has been serious. After 250 days of diffuser operation at Nyssa it has been necessary to replace 25 perforated trays. It may be necessary to replace all original trays before the next campaign. Test plates of steel hung in the juice channels lost 20 percent of their weight in less than 100 days.

When pH values are maintained above 6.0, a dark scale forms on all surfaces which appears to afford considerable protection.

Presence of dissolved oxygen in the juices as well as low pH should not be overlooked as a possible cause of corrosion. To reduce oxygen content we keep all ports on the diffuser closed. Oxygen content drops rapidly after closing ports.

Since the gases remaining in the cell domes may be combustible, all flames and arcs should be kept away from cell openings.

From experience with the diffuser during the past campaign, I believe it will eventually replace the standard battery in many factories.

Ion Exchange.—Since several papers are being offered on this subject, it will not be discussed here except to say that it offers the most promising development and most radical departure from the standard process made available to the industry for many years. I believe it will eventually replace all standard process operations from the diffuser to the evaporators. In addition to higher recovery of sugar at lower cost it will stimulate a whole new field of by-product recovery.

Fuel Economy.—Consumption of fuel is subject to a greater degree of control than any other major item of supply cost. Since it is also one of the largest costs and unit fuel costs are rising so rapidly it offers a promising subject for investigation. The subject logically divides itself into steam economy and boiler house efficiency.

Steam Economy.—Without remodeling equipment already installed, substantial savings in steam consumption can be made by careful attention to station operation; low battery draft; reduction of wash water on carbonation presses; avoidance of excessive use of steam through open nozzles in open juice boilers and Steffen waste heaters.

With vacuum drum filters after first carbonation, water dilution may be as low as 5 percent on beets, a little carelessness and it increases to 10 percent. For each 2.5 to 3.0 percent of dilution 1.0 percent of steam on beets is required for evaporation.

Higher yields from pans, use of higher density syrups and other sound practices can yield high returns in steam economy. These are all recognized standard practices.

With standard non-Steffen equipment processing normal beets of around 16.0 percent sugar, we can expect steam consumption in the range of 80.0 to 90.0 percent on beets.

The new diffuser will reduce steam consumption 10 to 15 percent on beets, depending on the conditions of the steam balance.

Steam economy has probably advanced farther in Europe than in the United States. Only relatively few factories in this country have found the European methods justified by savings in fuel costs. Now the unit cost of fuel demands a review of our practices.

Starting with high-pressure boilers (300 psi or over) the steam can be put through a turbo-generator leaving the exhaust at 35 psi. At this pressure it seems advisable to employ long tube vertical evaporators in which retention time is of the order of 5 minutes in each body. If all classes of pans, including white, are boiled on vapor sufficient steam will enter the first effect to accomplish concentration of thin juice to normal thick juice in three effects. Because there must be fluctuations in pan demand for vapor resulting at times in lowered input of steam to the first effect a fourth effect would be required for these intervals.

To use vapor for white pan boiling requires a calandria type pan. The ribbon coil pan seems to have some advantages over standard design. Latest developments tend toward mechanical circulation.

At this point, it may be well to total the steam savings that are possible in a modern efficiently operated plant over the plant that has not taken advantage of new equipment and methods.

The continuous diffuser can save at least 10 percent steam on beets. High pressure evaporators with the necessary remodeling of pans can save another 10 percent. Efficient beet and sugar end management can each save another 5 percent. The total saving will then be some 30 percent on beets.

With present knowledge the practical lower limit for steam consumption is from 55 to 60 percent on beets.

Boiler House Efficiency.—(Since none of the factories of our Company can use gas or fuel oil, my remarks will be limited to coal fired equipment.)

The trend in modern boiler construction is toward higher pressures, the use of pulverized coal in place of firing coal on a grate, and the use of air preheaters.

For the present, there seems to be little justification for going above 300 psi working pressure. With modern turbine design acceptable water rates are realized at these pressures and as there is need for about 50 percent process steam on beets we must add 10 to 15 percent low pressure make-up to the exhaust line even for turbine back pressures of 35 psi.

Below 400 psi it is difficult or impossible to exceed a boiler efficiency of 80 without an air preheater. With an air preheater efficiencies of over 85 are reached.

Current coal prices justify air preheater and induced and forced draft fans.

The trend is toward fewer boilers. Former practice provided from 5 to 12 or even more units. The limit in reduction has been reached at our Twin Falls factory where one boiler serves the factory. With one or two units it is a relatively simple matter to employ automatic, registering controls. We have found Bailey controls reliable and they require little maintenance.

Probably a substantial number of the factories in this country operate with steam consumption at a level of 90 percent on beets and a boiler house efficiency of 70 percent.

A factory cutting 2,400 tons of beets per day and having 100 days of campaign will spend $215,000 for coal under the above conditions. Compare this with a factory designed to consume 60 percent steam on beets and with a boiler house efficiency of 85 percent. This plant would spend $118,500 in a similar campaign. The saving is $97,000 per campaign or $970.00 per day. As fuel costs go higher these differences will increase.

Evaporator Control.—Evaporator controls developed by the Taylor Instrument Company have now been in use long enough to be evaluated. They are successful in eliminating the evaporator operator and in giving more efficient operation than manual control. Brix of thick juice is more uniform. More nearly constant pressures are maintained on vapors used for heating and pan boiling. Electric eye foam controls have been installed on each body at our plants to avoid the need of continuous supervision. Elimination of the evaporator operator on three shifts results in a saving of $3,456 in a campaign of 120 days at current wage rates. Indirect savings are difficult to estimate. The equipment was installed complete with foam control for about $11,000 per factory.

First Carbonation Control.—Work on this control has not progressed to a point where the operator can be eliminated. However, some encouraging results have been obtained.

Second Carbonation Control.—For the past two campaigns we have used fully automatic control on second carbonation and have obtained better results than with manual control. The Second Carb station control consists of a Beckman No. 9000 Model R pH Meter connected to a Bristol pH Recording Pyromaster Reset Recorder Controller Model K R 531 which in turn is connected to an air operated Diaphragm Valve on the gas line. Installation of these instruments was made in such a manner that the sample to the Beckman is taken from a point a very short distance above and somewhat to one side of the gas manifold in order to get a sample free of gas and with a minimum of lag.

The Beckman Model R pH Meter sells for about $524.50 complete with the necessary electrode assembly. The Bristol Controller with 12-inch chart sells at approximately $470. A good diaphragm operated valve for a 4-inch gas inlet sells for approximately $167.

Sulphur Station.—For the past two campaigns we have used automatic controls on the sulphur station with satisfactory results. I realize this has been long established in factories where liquid SO_2 is available at reasonable cost. The controls referred to here apply to sulphur stations equipped to burn elemental sulphur in Glen Falls type stove. The stoves are manually fired and all other operations are fully automatic.

The sulphur station is operated in the same manner as the second carbonation except that for opening and closing a gas valve the Bristol Controller operates a Bristol No. 12 Syncro-Lever Motor which is connected to the damper on the sulphur stove. Care must be exercised in determining the point of sample connection to the sulphur tower in order to get as quick a sample as possible to the Beckman. Cost of the sulphur station equipment is the same as second carbonation equipment except for the Syncro-Lever Motor, which sells for $95 as against the gas valve used on carbonation at $170.

Factory Bulk Sugar Storage.—This is not a recent development but is not yet in general use largely because of high initial investment. It has many advantages. Sugar need be sacked on only the day shift thus avoiding the necessity of trained supervision and skilled stackers on two shifts. It is not necessary to anticipate buyers' requirements for sugar packages of different sizes and types. Within a reasonable range of grain sizes, sugar can be screened at time of sale into a number of grades from the regular run in bulk storage. Loss in broken containers is greatly reduced. Initial cost of bulk storage currently runs from $ .50 to $ .55 per 100 pounds of sugar. Our bins have been installed by J. T. McDowell and Sons, Denver, Colorado.

Quality of Sugar.—In recent years the three boiling system has been adopted almost universally in American beet sugar factories. This has resulted in higher purity white pans. The use of high speed, automatically controlled centrifugals together with fillmass of higher purity has brought about improvements in the quality of sugar. For analyses of representative sugars from our industry the annual report of the Bureau of Agricultural and Industrial Chemistry of the United States Department of Agriculture may be consulted.

Bottlers and canners have established minimum standards governing contamination of sugar by the following groups of organisms: flat sours, thermophiles, positive anaerobes not producing H_2S, bacteria developing at 37° C., molds and yeasts

Exceptional care is required to meet these standards.

A preliminary survey of the process by our bacteriologist indicated that initial contamination of juices was greatly reduced by high alkalinity and temperatures in first carbonation. Subsequent contamination occurred where juice was exposed to the atmosphere. Many organisms were killed in the white pan but from there on contamination might recur.

It is now our practice to spray standard liquor presses and the whole area around high melter, white mixers, white machines and all equipment from these machines to the sacking station, with roccal or hyamine solution.

Condensate on the sides of wet sugar scrolls and elevator and in pan storage tanks are potent sources of contamination. These surfaces where exposed are subjected to rays from sterilamps. Chutes and scrolls under the white machines are completely enclosed and air is forced through a radiator and then through a bank of sterilamps and through this area to dry the condensate and reduce the growth of organisms. The whole environment of the final sugar must be kept as sterile as practical conditions permit.

In one of our plants all air going to the granulator is passed through a series of screens, then through glass wool filters and then through a Westinghouse precipitron. The precipitron removes suspended particles as small as those in cigarette smoke. After this treatment the air passes through the standard radiator to the granulator.

If all precautions against contamination are faithfully followed, the sugar may approach sterility.

Thick Juice Filtration.—Plate and frame presses seem to me to be an exceedingly crude method for filtering, involving as they do high labor costs and high consumption of filter cloth. Favorable reports have been received on Niagra filters but I have no direct observations to report.

Lime Kiln.—We feel that we are approaching practical limits on lime kiln capacity. In some cases passage of the rock through the kiln occurs in less than 30 hours requiring a rock so small that quarry costs are increased beyond the normal cost increase. We are investigating the Ellernan kiln which seems to have advantages over the standard shaft type where small-size spalls are available. We expect to make one installation for the 1948 campaign.

Cutters.—It has been assumed by some operators that the new continuous diffuser does not require uniform clean-cut cossettes. In my opinion the same care should be exercised on knives and cutters where the diffuser is used as for the standard battery. The Ogden Iron Works cutter with chrome plated wearing surfaces has many refinements that are of practical value. Chrome plating of wearing surfaces prolongs the life of parts and reduces distortion of equipment resulting from wear in long campaigns.

Pumps.—Continued high capacity operations during campaign are particularly dependent on pumps. We have found the recently designed Bingham pumps manufactured by the Bingham Pump Company of Portland, Oregon, highly satisfactory. Each pump is designed for its individual service. The foam-liquid juice pump separates foam, entrained air or gases from the liquid entering the pump suction and transports the juice without pulsation. The Bingham beet pump elevates beets and water from the flume replacing beet wheels and elevators ahead of the washer. The Bingham pulp hog has eliminated many of the troubles found with most pulp pumps. We have found these pumps long lasting and relatively trouble free.

Minor Improvements.—A whole new field of minor improvements is available to the processor. To mention only a few, we have improved metallic alloys and plastics which may be used in special service to reduce abrasive wear and corrosion. New welding equipment and techniques are available. We are trying new plastic filter cloths which appear far superior to the old textiles.

In this discussion specific pieces of equipment have been mentioned. I would like to emphasize that the list is not exclusive. Those mentioned are some of the newer developments that have proved useful. There is a whole field of standard equipment produced by well-established firms that cannot be listed here.