Measurements of Sugar Yields and Losses of Spreckels Sugar Company

W. A. McCann[1]

EVERY BEET SUGAR CHEMIST is vitally concerned with the accounting of sugar in beets purchased by his company and sugar entering the factory, as well as the various losses incurred during the processing period.

This paper is prepared to show various accounting methods used by the Spreckels Sugar Company in calculating the sugar losses occurring from the time beets are purchased until the processing to granulated sugar is completed.

It is believed that complete evaluation of losses must be made before effective control of losses can be accomplished. Considerable effort has, therefore, been made not only to improve the accuracy of determining the usual "known loss," but also to evaluate the various factors which make up the so called "unknown" loss.

The goal is to be able to say with assurance what has become of every pound of sugar received from the grower. This is admittedly an ambitious program and one that has not yet been fully realized. Nevertheless it is believed that considerable progress has been made.

We shall discuss some of the methods used in improving the accuracy of the customary measurements as well as in measuring some of the losses which are not usually reported.

The items designated as customary measurements are:

1. Beets purchased; 2. sugar entering factory; 3. battery losses; 4. lime flume losses; 5. steffen losses; 6. sugar loss in molasses; and 7. granulated sugar produced.

Beets and Sugar Purchased

It is obviously very important that these quantities be measured with utmost accuracy, and several precautions are found to be helpful in maintaining accurate work. The two measuring agencies are the beet receiving stations and the tare laboratories, which will be considered in order.

Printing scales are used in weighing the beet trucks at all receiving stations. Tel-autograph, electric communications systems or pneumatic conveyors are used wherever possible for the transmittal of the dirt weight figures from the dirt scale to the truck scale house where the tickets are compiled.

The method of taking the tare sample is extremely important. It was found that systematic errors in this procedure could easily develop unless

[1]Chief Chemist, Mantica Factory.

a rigidly standardized method was adhered to. Study of this problem led to the posting at each station of a large illustrated instruction card (figure 1) covering the right and wrong methods of sampling and reasons behind each prescribed step of the procedure. This is supplemented by personal instruction and inspection from a member of the Chemical Department.

The use of the instruction cards has improved the accuracy of sampling, particularly where new employees are concerned. In addition, it has almost completely eliminated grower complaints regarding the entire procedure.

INSTRUCTIONS TO SAMPLE MEN

A

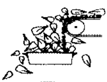
A sample of approximately 20 pounds must be taken for each truckload of beets dumped into the hopper. This is to be caught in the sample pan beyond the cleaning screen. The sample will be analyzed by the Tare Laboratory for dirt, trash, crown, and sugar content to determine the basis for payment to the Grower. It is, therefore, of the utmost importance that the following rules be observed, to keep the sampling on a just, impartial basis.

1. TAKE THE SAMPLE WHEN APPROXIMATELY ONE HALF OF THE LOAD HAS PASSED OVER THE CLEANING SCREEN. The middle of the load is the most representative portion; therefore it is the portion which should be sampled.

2. SWING THE SAMPLE PAN IN SO THAT AT LEAST PART OF IT PROJECTS UNDER THE CONVEYOR OR APRON FROM WHICH THE BEETS ARE FALLING. The dirt and trash tend to fall straight down while the beets tend to sail out from the conveyor or apron. Unless a portion of the pan passes under the conveyor or apron, the sample will not be representative of the amount of dirt and trash in the load.

RIGHT WRONG

3. SWING THE SAMPLE PAN OUT OF THE STREAM OF BEETS AS SOON AS IT FILLS. If the pan is left in the stream any longer than necessary to fill it, the beets will begin to pile up and roll off. Every beet which rolls off the pan, drops extra dirt into the pan, which again will make the sample unrepresentative. To take a proper sample, the pan must be swung completely in and out of the stream with a rapid motion and with very little hesitation in the stream.

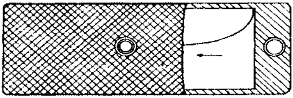


4. TRANSFER EVERYTHING CAUGHT IN THE PAN TO A RUBBER-LINED BAG. Just and accurate sampling is governed by the law of averages. A single sample, however carefully caught, may possibly contain slightly more or less tare or sugar than is representative of the load. But in a series of properly caught samples, such chance errors will cancel out, so that the results will be fair. However, if any hand treatment of the sample occurs, such as throwing or shaking off beets, or failing to completely dump the pan into the bag, the law of averages will cease to work and the results will become unjust.

Therefore, do not attempt to doctor the sample in any way. If you have followed steps 1, 2, and 3 correctly, put the entire sample in the bag. If you know that you have made a mistake in catching a sample, the only permissible action is to dump the entire sample out and catch a fresh one.

B

An analysis ticket is made up and placed in the envelope so that it FACES AND LINES UP WITH THE FRONT O, THE ENVELOPE. Enclose it in the fabric container according to the sketch below, and put it inside the sample bag.



1. Hold container with snaps facing you and cover flap at right.
2. Insert envelope with printed side away from you and flap at top.
3. Push envelope in as far as possible without crumpling, then close and snap container cover.
4. Place container with envelope in the bottom of sample bag before dumping in sample.

C

The sample bag is then tied with a double half-hitch and taken IMMEDIATELY to the sample house or bin. Under no circumstances is a sample to be left in the sun after being placed in the sample bag.

SPRECKELS SUGAR COMPANY

Let us now consider the Tare Laboratory. Warm weather is encountered during the California processing season. The polarization of the tare samples can change appreciably even though stored in rubber-lined bags. Therefore, effort is made to get the samples to the tare laboratories as rapidly as possible. During the 1947 campaign, all but 2 percent of the tare samples were analyzed the same day the beets were delivered.

Taring of the beets is conducted according to a procedure agreed upon by all California growers and processors. Illustrated instructions for procedures are posted at the laboratories. The accuracy of the tare scale work is controlled by saving and weighing all tare material. This weight is checked against the total tares of the individual samples. The weight ratio of crowns to total tare, and the polarization and purity of the crowns are also determined. These figures give a good indication of whether the correct quantity of crown tare has been taken. They also enable determination of the quantity of sugar received in crowns, so that complete accounting for this sugar can be made.

The sugar determination is checked by saving composites of both the pulped beet samples and the polariscope filtrates. These are read by both the main and tare laboratories, and are checked against the ticket averages.

The tare laboratories located in the hot interior valleys are air-conditioned. This minimizes the possibility of dehydration and instrument inaccuracies.

A possible source of error in the tare laboratory is false polarization due to raffinose, amino acids, and other polarizable non-sugars. This was checked during 1944 campaign. The filtrate composites for an entire campaign were analyzed by the double enzyme method of Paine and Balch. The false polarization was found to be a negligible factor in California.

Measurement of Sugar Entered and Battery Losses

These items are inseparable at two of the factories which have no beet scales. This condition requires that sugar entered be determined as sugar in raw juice plus sugar lost in the batteries.

The customary method of measuring battery losses was found to be inadequate for accurately determining sugar entered. There are two principal reasons for this, one being that the pulp water was assumed to be 100 percent on beets. This has been disproved in calorizator batteries by measurement. The other reason is that exhausted pulp in a single cell was found to vary in sugar content. Therefore, manual sampling of individual cells gave erroneous results, usually low.

The use of continuous pulp samplers on flume pulp was not the total answer to the problem. In order to obtain accurate sampling it was found that the pulp and water must be separated immediately after discharge from the sampler. Unless this is done, water from succeeding samples leaches the previous sample causing serious error. This becomes very important in flume pulp sampling where the weight of the pulp water is considerably greater than the weight of the pulp.

The separation of the pulp and water is accomplished by allowing the sampler to discharge onto an inclined screen. The pulp rolls off the screen into one container and the water passes through the screen into another container.

It is also necessary to determine the quantities of the pulp and water which are represented by the continuous sample. The ratio of pulp to beets was obtained from marc determinations of the cossettes and of the pulp from the sampler. This ratio was found to be 100 percent for all practical purposes. The pulp being set at 100 percent on beets, a material balance shows that the weight of flume water is equal to the total quantity of water supplied to the battery and pit, less the weight of the diffusion juice.

Therefore, meters have been installed at all plants to measure accurately all waters to the batteries. Then if the analyses of pulp and water are applied to the known weights, an accurate picture of the loss is obtained.

Two factories without beet scales have accurate means of obtaining the weight of raw juice Beets sliced at these factories are calculated by the following formula:

Let A=weight of raw juice
B=weight of total water to battery and pit
C=percent sugar in pulp water
D=tons of sugar in pulp water or $\frac{C(B-A)}{100}$
E=tons of sugar in raw juice
F=percent sugar in cossettes
G=percent sugar in pulp
H=tons of cossettes or $\frac{100\,(E+D)}{F-G}$

The latter is merely a re-arrangement of the usual formula for obtaining draft by sugar content.

Tons of sugar in pulp$=\frac{HG}{100}$, since the weight of pulp is equal to the weight of cossettes.

The third factory has a beet scale for determination of sugar entered. This factory, however, also uses the above system for determining battery losses, since it has been found much more accurate than any method previously used.

Steffen Losses

Steffen losses are calculated by applying the percentage of sugar in final waste to the weight of final waste as determined by actual measurements. Both Steffen factories are equipped with continuous recordings weir meters.

Prior to the weir meter installations, the quantity of final waste was calculated by the usual method used where meters are not available. This method depends on the polarization of the various products in the Steffens. Since all saccharates have a definite solubility, excessive dilution of Steffens products, where solid phase is present, can cause an increase in losses without changing these polarizations.

The calculation method, therefore, allows losses due to dilution from excessive wash water, wet steam, foam sprays or other accidents to continue without recognition.

The weir meter installations have not only improved the accuracy of evaluating Steffen losses but have had an appreciable controlling effect in Steffen house operation as a whole. The meters have repaid their cost many times over by quickly detecting excessive dilution in the Steffens.

The laboratory analytical method has been improved by the use of double instead of quadruple dilution, thus doubling the precision of a single determination.

Sugar In Molasses

Sugar in molasses is determined by direct polarization, since there is little raffinose or other polarizable invert substances in California beets. This was checked for the entire campaign 1944-5 by the double enzyme method. The average difference between the true and apparent sugar was found to be two tenths of one percent.

Lime Flume Losses and Sugar Produced

These quantities are determined and checked by the usual methods.

Unusual Known Losses

Having concluded with the usual known losses, we will turn our attention to items making up the so-called undetermined losses. These losses are known to occur and it is believed their magnitude should be evaluated.

Items in this category include:

1. False polarization; 2. sugar losses in transit and storage of beets; 3. diffusion losses in beet flumes and washers; 4. beet tailings and pieces from trash separators; 5. inversion of sugar in process; 6. factory sewer losses; and 7. entrainment losses.

False Polarization

Losses from false polarization were found to be negligible, as previously discussed.

Transit Losses

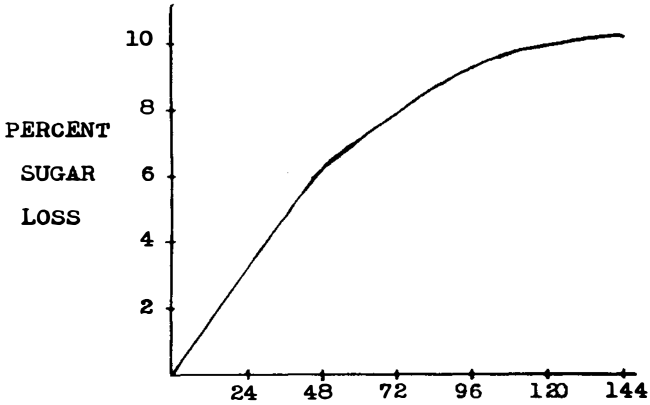
The processing of a large percentage of beets hauled by rail at the prevailing high temperatures during the processing period presented the problem of sugar losses occuring in transit from the dumps to the factory.

Early tests of sugar loss in transit were made by having certain cars of beets marked at the dumps for special handling. These cars were to contain no split loads. On arrival at the plants, the cars were weighed before and after dumping, then sampled for percentage sugar and tare. Calculations were made for loss of sugar in transit. It was found impossible to sample the cars accurately, particularly for tare, at the average factory unloading station, so this method was abandoned.

Another method is now used, which appears to give entirely reasonable results. The rate-of-sugar loss in average beets stored at known temperatures is determined by an adaptation of the method of Fort and Stout (3).[2] The data so obtained is then applied to the known conditions of actual transit.

SUGAR LOSS VERSUS TRANSIT TIME

AVERAGE MEAN TEMP. - 80° F



A truck load of beets from a single field is dumped and the beets are segregated according to size. Test samples are then made up so that each contains equal numbers of beets of each size. Samples made up in this manner are found to be very uniform in sugar content. Thus, an accurate measure of weight and sugar loss can be obtained by analyzing some of the samples immediately and storing others in mesh bags under desired test

[2]The numbers in parentheses refer to literature cited.

conditions. If desired, the test samples can be actually shipped in cars, to be recovered, weighed and analyzed on arrival at the factories. It was found that loss rates so determined at one temperature could be applied to other temperatures by means of factors derived from the respiration data of Barr, Mervine and Bice (1) (figure 2).

Having established the average curve for loss versus time at a given temperature, it was possible to apply the test data to the transit times and weather conditions experienced during regular shipments, thus evaluating the actual sugar loss.

Storage Losses

It is believed that storage losses in the factory bins can likewise be established by placing the test samples at representative locations in the bins. To date, this has not been done, but from experience in determining transit losses by the foregoing method, accurate results are anticipated.

Storage and rehandling losses in piled beets have been established by setting up separate test piles of approximately three thousand (3000) tons. When these test piles were torn down, the beets were loaded into trucks, re-weighed, and re-sampled for sugar content.

Fluming Losses

All low sugar bearing materials such as main sewer, beet washer, flume washers etc., where inaccuracies may occur due to the very low polariscope readings obtained, are composited with measured amounts of Clerget acid. This serves the dual purpose of preserving the composites and of hydrolyzing the sugar for subsequent determination as invert. Samples handled in this manner may be held for 24 hours before analyzing. The analysis is then consummated by a modified Lane and Eynon method.

The quantity of flume water is determined by the best available method. For example, at Manteca, the flume makeup water is obtained from the overflow from beet washer, oliver condenser and spray lines from the picking table. All these sources of water are equipped with measuring devices or constant flows have been calibrated. The flume water entering the factory and the discharge from the beet washer are sampled every hour.

Direct determination of sugar in the flume water is impossible at one factory because a portion of the pulp water is used for fluming beets. In this case, an indirect determination of fluming losses is made. The average immersion time is determined by placing painted beets in the flume. A weighed sample of representative beets is then placed in a known weight of water at fluming temperature, which is agitated for the proper time. The rate of sugar loss is obtained from the increase in polarization of the water.

Beet Tailings

The beet tailings and accumulated trash from the trash catchers are sold by weight at one factory. Regular samples are taken of this material, prepared in the same manner as cossettes and polarized. It only remains to calculate the sugar loss by weight. Sampling of this material is somewhat of a problem, but by diligent quartering of a large sample, good results are obtained.

The beet tailings and trash are disposed of by disintegration at the other factories. This poses a problem in quantity determination. The solution was found in measuring the flow of fresh water which was used to flush the trash through the disintegrator. Since the trash was reasonably well drained before mixing with the water, the free liquid in the disintegrator effluent could be considered equal in quantity to the fresh water applied. The disintegrator effluent is therefore sampled regularly, and it's free liquid content is determined by passing the sample through a 20-mesh screen. The quantity of the effluent is then taken as the quantity of fresh water added, times 100, divided by the percentage free liquid in the effluent.

Percentage sugar in the effluent is determined by digesting a portion of the sample at 80 degrees Centigrade for 30 minutes. This establishes the equilibrium between the solid and liquid phases, and is followed by cooling, dry lead clarification, and polarization.

Factory Inversion

It is considered that all invert found in the molasses has come from sugar decomposed in the process. This is believed practically true on the grounds that the small amount of invert passing the carbonation is subsequently destroyed. Tests are now being made on the accuracy of this assumption.

Inversion prior to carbonation may be determined by comparing the invert analysis of the cossettes and the raw juice. This has not yet been undertaken.

A modified Lane and Eynon method is used for all invert determinations.

The possibility of applying the method of Davies, Yearwood, et al (2), was also tested. This method appeared to offer good possibilities for determining losses of sugar by decomposition in the factory. It consisted of determining the ratio of sugar to chloride in the various processing phases. A simple titration method for chloride was presented, which could readily be adapted to routine work.

Unfortunately it was found that the beet factory juices contained appreciable amounts of un-ionized organic chlorine. The ratio between ionized and un-ionized chlorine was found to change as the juice progressed through the factory. Thus the simple titration was unusable. The A.O.A.C. carbonated ash method and the Carius method for chlorine were found too tedious to run the large numbers of samples required. Therefore the project was abandoned.

A method has been developed, however, for determining the sugar decomposition in any given phase of the process with great accuracy. The time temperature conditions of the process in question are reproduced on the laboratory bench by means of a series of jacketed coils and closed vessels. Representative samples of juice are forced through this system under pressure at the correct flow rate. The juice flows through a heat exchanger, cooling it to room temperature, before it emerges from the system. The system being hermetically sealed, there is no weight change of the flowing juice.

The simple analysis of the juice, before and after passage through the apparatus, therefore, gives directly the loss of sugar.

Factory Main Sewer Losses

The method of determining the sugar concentration in sewer samples has already been discussed.

Methods have been found at each factory for measuring the flow of all waters to the main sewer by the use of a system of manometers, weirs and pitot tubes. Flume and Beet Wash effulents are also measured. One factory has a removable weir which is lowered into the sewer flume at frequent intervals.

Another factory meters the cold water entering, and deducts from this the known quantities of water discarded at points other than the sewer. This procedure is facilitated by the concentration of all Steffens waste and the recirculation of the condenser leg waters over a cooling tower. The quantity of pulp flume water is determined as previously described, and the amount of lime flume water is readily obtained from the CaO balance.

Entrainment Losses

These losses generally are of a minor nature. Continuous samplers on all condenser leg lines are used for control at all plants, and any continuity of sugar loss is thoroughly investigated. Sugar entrainment to evaporator condensates used in boiler feed are controlled by patented sugar detectors.

Reporting of Losses

The venturesome step has been taken of reporting on the extraction statements not only the usual known losses, but also the other losses which can reasonably be determined by the above methods. It is believed that several important results have been achieved:

1. The unaccountable losses have been reduced to a very low figure.

2. It is becoming much easier to place a value on such formerly nebulous items as improved rail service, rapid handling of beets through the bins, shortening of flumes, reduction of juice retention time in process, etc.

3. Actual reporting of these losses has been a great stimulus to developing, simplifying and improving the accuracy of the methods used.

4. Isolation and presentation of all possible sugar losses has created a co-operative spirit among the operating personnel regarding undetermined losses that might otherwise be undetected.

Literature Cited

(1) BARR, MERVINE AND BICE.
1940. Proc. Amer. Soc. Sugar Beet Tech., pp. 52-65.

(2) DAVIES, YEARWOOD, ET AL.
1942. Sugar, 37, No. 12, pp. 29-33.

(3) FORT AND STOUT.
U.S.D.A., Agricultural Chemical Research Division, Contribution No. 177.