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PROGRESS REPORT V

PROCESSING OF SUGAR BEETS

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ABSTRACT

This report presents the results obtained using continuous equipment for disintegrating sugar beets. The principle of the proposed method of recovery of juice from sugar beets is briefly reviewed. The operation of the disintegrator is described together with details of the experimental technique.

A series of experiments have been performed to determine the degree of disintegration and sugar recovery as influenced by the design of the impingement baffle and by the chemical and heat pretreatment of cossettes. Three comprehensive experiments have been carried out in which the juice from the pulp, as well as the diffusion juice, were submitted to the standard purification process. The characteristics of raw and thin juices prepared by these two methods were then compared. In neither of these runs was the purity of the thin juice prepared by the new process lower than that of the thin juice obtained by the usual method. The actual processing capacity and steam consumption have been brought close to the corresponding design values given by Progress Report IV. A sugar recovery of 99 percent has been reached at a draft of approximately 130 percent by weight. At the end of the report suggestions are made concerning the further study and development of the proposed method for the recovery of juice from beet pulp.

PROGRESS REPORT NO. V

PROCESSING OF SUGAR BEETS

I. REVIEW OF THE PREVIOUS WORK

The main point of the proposed method for the recovery of juice from sugar beets is the preparation of a beet pulp sufficiently fine to enable a good recovery of juice by a direct method of separation such as centrifuging, filtration, etc. followed by washing. Therefore, the previous studies, as well as the work presented in this report, deal mainly with the method of disintegration of sugar beets.

The feasibility and economy of the preparation of beet pulp on a commercial scale depends mainly on the following factors:

1. The quality of the juice should not be decreased by the process.

2. The equipment should be low in cost and easy to maintain.

3. The time of retention should be short so as to reduce the size of the equipment and prevent or decrease the action of microorganisms.

4. The process should be continuous to facilitate the supervision of the equipment and to decrease the costs of labor.

5. The cell structure of the beet should be ruptured as completely as possible without, however, producing a great amount of fines. This last point is of importance for easy centrifuging or filtration.

6. The pulp should be sufficiently disintegrated to permit good recovery of the sugar from the beets.

6. The pulp produced should not undergo appreciable dilution during the process of disintegration. Such dilution would result in a higher draft and a decrease in the economy of the process.

7. The steam or mechanical energy consumption should be within reasonable limits and correspond to the conditions existing in an average sugar factory.

In previous experiments the cossettes were preheated to a temperature of 100°C and then brought in contact (for about 2 seconds) with saturated steam (50 psig) and the pressure suddenly released. The cossettes were accelerated by the expanding steam and were then allowed to strike against an impingement baffle. It was believed that the stress caused by the sudden evaporation of a part of the cell content together with the stress developed on impact was responsible for disintegration. However, in later experiments (described in Progress Report III) it was found that even with the use of compressed air, instead of steam, a reasonably good disintegration could be obtained. To minimize dilution and the possibility of a decrease in the quality of the juice, it was decided to utilize rupture by impact in preference to rupture by inflation and to design a continuous disintegrator in which the particles would be accelerated to high velocity and ruptured essentially by a sudden change of momentum. The constructional details of the disintegrator and accessory equipment were described in Progress Report IV.

The description of the disintegrator and its operation will be reviewed in the next pages of this report.

II. GENERAL OUTLINE OF THE PROPOSED METHOD OF RECOVERY OF JUICE FROM SUGAR BEETS

The flow sheet given in Fig. 1 presents the general idea of the proposed method of production of raw juice. Cossettes or beet particles of other shape are introduced into the hopper of the disintegrator from which they are carried away by the impeller of the air lock. A part of the expanded steam leaving the separator is recycled into the lower part of the air lock to fluidize the cossettes. The fluidized mixture of cossettes and exhaust steam enters the ejector chamber. In the ejector chamber the high pressure steam issuing from the nozzle transfers some of its momentum to the mixture of vapor and cossettes which enters the chamber as a result of the vacuum created by the high-velocity stream. The cossettes are accelerated to a high velocity and strike an impact surface arranged in the separator where they disintegrate. The resulting pulp is then removed from the separator either by keeping it at a pressure slightly higher then atmospheric or by a suitable revolving scraper. The expanded steam is partially recycled to the air lock and the rest is used for juice heaters, etc. The juice is

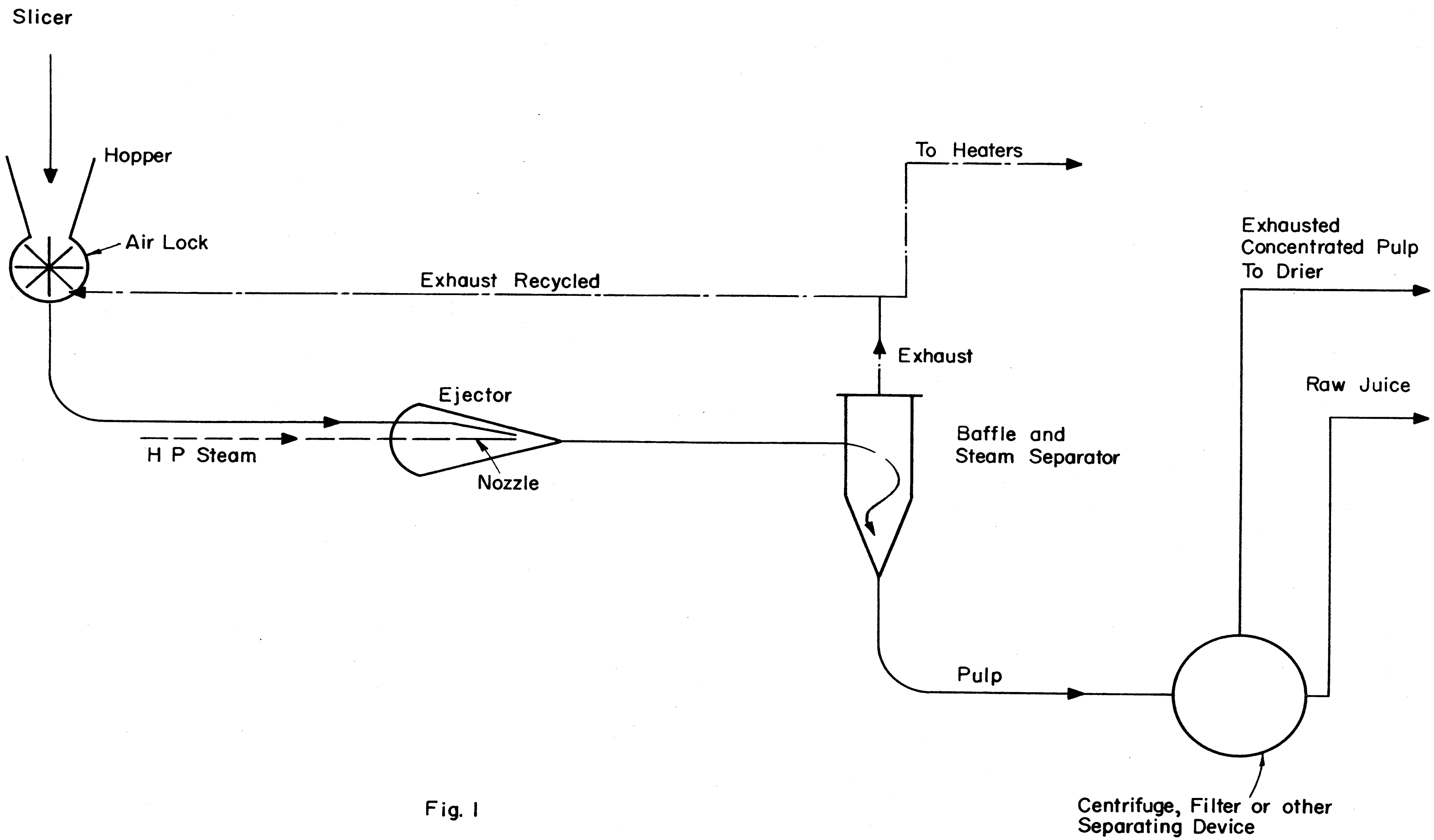

Fig. I

General Flow Sheet of the Proposed Method removed from the pulp in a centrifuge, filter, or other separating equipment with the aid of a wash and the exhausted concentrated pulp sent to a drier. In the experiments presented in this report the amount of cake (dehydrated pulp) varied from 30 to 21 percent beet, depending on the centrifugal force used. This pulp needs little or no pressing before it is sent to the drier. The cost of the juice separator therefore would be partially offset by the cost saved through the elimination of pulp presses.

As has already been mentioned, the study of this new process was concerned mainly with the production of pulp, with the qualities of the obtained juices, and with the sugar recovery from pulp in a centrifuge. The following points of the general flow sheet have not yet been studied.

A. The Steam-Pulp Separator

A separator which would also act as an impingement baffle was designed and constructed (see Progress Report IV, page 16 and Fig. 2 of this report).

However, the short duration of each experiment (30 to 60 seconds) did not allow the adjustment of the separator during a run. As the construction of the separator depends to a great extent on the type of baffle used, it was decided to postpone the study of this problem until more data are available on the optimum design of the baffle.

B. The Juice Separator

In all the experiments a centrifuge was used for separating the juice from the pulp. The results obtained were very encouraging. The juice separated easily and good recoveries were obtained at reasonable drafts. It is, however, possible that a rotary filter may prove more advantageous.

C. The Exhausted Pulp

The drying properties of the concentrated exhausted pulp have not yet been studied. It has been noticed, however, that the pulp cake when left in the open air dries fast and even after partial dehydration the particles stick firmly together giving a layer of cake with considerable mechanical strength. Therefore, it may be advantageous to pass the pulp through a pair of rollers to produce flakes before introduction to the drier.

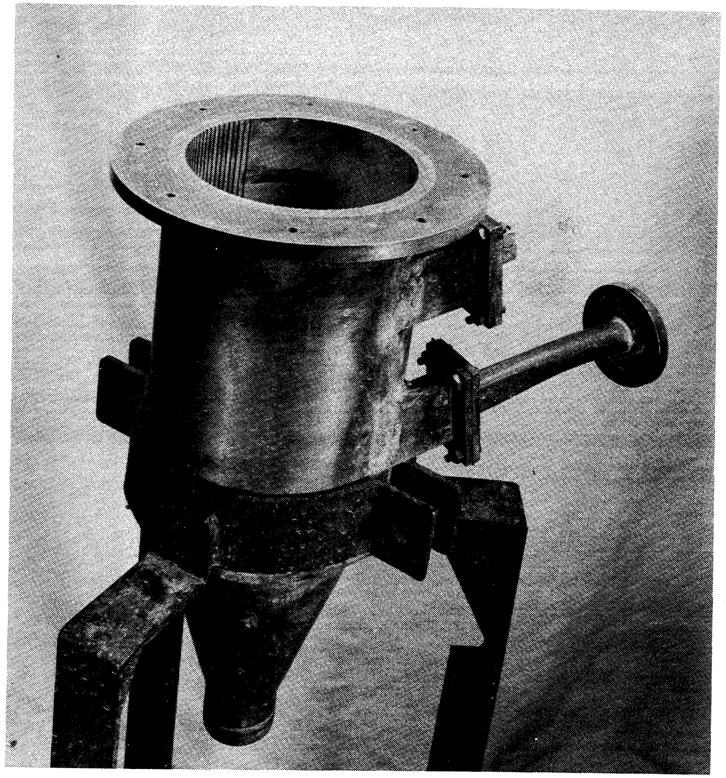

Fig. 2. The Cylindrical Baffle

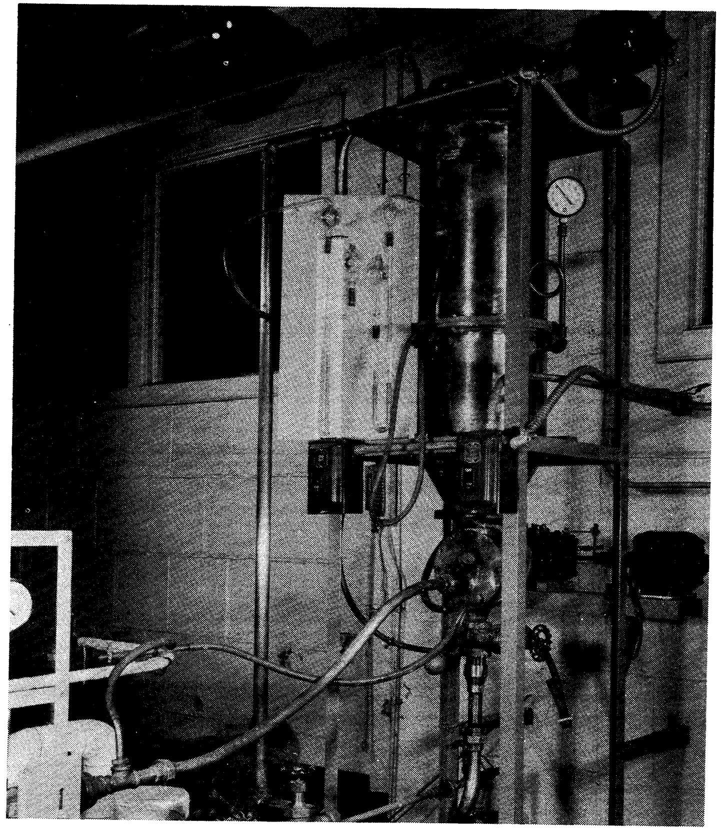

Fig. 4. The Feeder

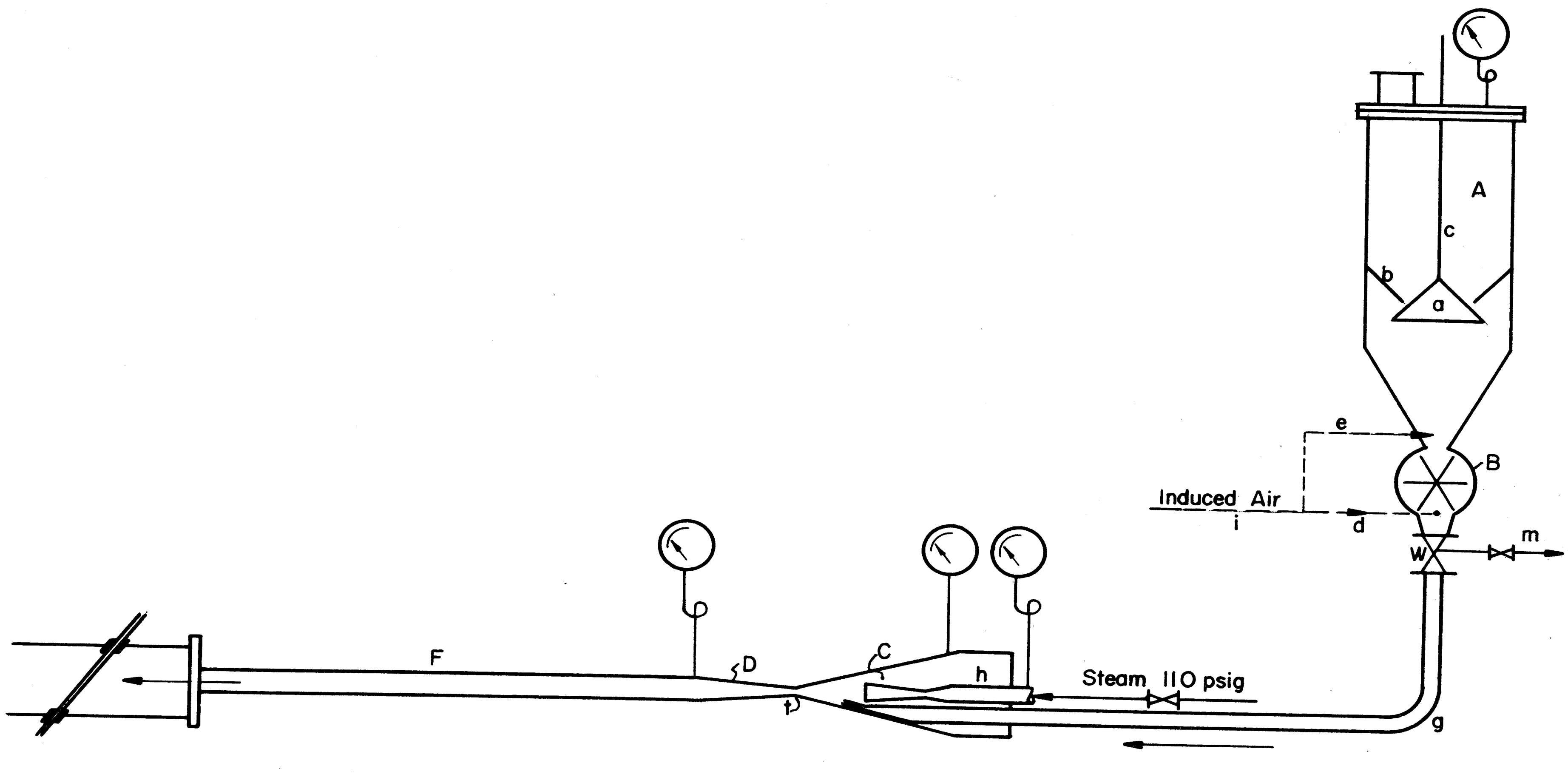

Fig. 3
Disintegrator and Feeder

III. DESCRIPTION OF THE EQUIPMENT USED

The design of the disintegrator and feeder is shown in Figs. 3, 4, 5, and 6 of this report and Figs. 7 to 29 of Progress Report IV.

A. The Feeding Device

The purpose of the feeder (Figs. 3 and 4) is to obtain a constant and uniform flow rate of the particles so that the ejector can be uniformly and continuously charged without appreciable pulsation in the flow. This point is of special importance because of the small cross sections of the conduits in the experimental plant and the consequent danger of choking. Increasing the dimensions of the disintegrator pipe and diffuser throat was impracticable as that would require a processing capacity too great for laboratory conditions. This problem, although of lesser importance in a large-scale installation, is of great importance in a small-scale plant. Feeder A (Fig. 3) consists of three parts made of bronze. The upper cylindrical part, 12 inches in diameter, can easily accomodate about 25 lb of cossettes. The bottom of the upper part consists of a system of two cones. The outside cone, b, is made of stainless-steel screen to allow the passage of condensate in the case of steam pretreatment. The closing cone, a, is fixed on the stirrer rod, c, which makes a reciprocating motion up and down. The length of the stroke, the number of strokes per minute, as well as the position of the cone, a, on the stirrer rod can be adjusted. The reciprocating motion of the cone loosens the mass of cossettes and allows the particles to flow through the central cylindrical section of the feeder down to the conical bottom. From there the cossettes are transferred by the rotating blades to the lower part of the rotary feeder, B, where they meet the stream of the induced fluid introduced through the front plate of the casing (see Fig. 4). As a result of the vacuum existing in the ejector chamber, C, the cossettes, together with the induced fluid (steam or air), are carried away into the ejector chamber.

In the experiments presented in this report air was used as induced fluid instead of steam. There were several reasons for introducing this change. First, it was noticed that especially at higher capacities there was a tendency on the part of cossettes to choke the entrance to the rotary feeder. This was caused by the small size of the equipment as well as by the surface characteristics of cossettes. To prevent this harmful effect air was introduced tangentially at the lowest part of the cone, e, to keep the cossettes in a swirling motion, and thus, allow an easy charging of the rotary feeder. If steam were used in the rotary feeder and the pressure fell below stmospheric, the air used for stirring would bleed past the clearances of the rotary feeder and become mixed with the steam. The determination of the amount of the induced fluid would then become difficult and unreliable. Also, if the pressure in the feeder increased above atmospheric, a leakage of steam would occur in the direction upwards to the cossettes resulting in some steam condensation on the cossettes. As there was no time for improving the air-locking property of the rotary feeder the following procedure was adopted: a known amount of air* from a critical flow nozzle was introduced into pipe, i, (Fig. 3) from which a part was used for stirring of cossettes at the bottom of the cone and the rest was passed directly to the lower part of the feeder. Since the upper part of the feeder was tightly closed, the part of the air which was used for stirring eventually entered the ejector chamber passing through the clearances of the rotary feeder. As the pressure of the air in the rotary feeder was always below critical with respect to the pressure upstream from the nozzle the regulation of flow was simple, accurate, and independent of changes of pressure in the feeder. Thus, the use of air not only simplified the experimental procedure, but also permitted accurate metering of the induced fluid. Obviously, in commercial operation steam should be used not air to minimize dilution of steam with air.

As the feeding device is an important part of the disintegrating unit a critical survey of its operation is given. The chief requirement for good operation of a feeder is the production of a uniform flow rate of particles so as to decrease the pulsations.

As a result of the reciprocating motion of the stirrer (150 to 250 strokes per minute) the charging of the compartments of the rotary feeder was not uniform. To improve the uniformity of flow the speed of the impeller was increased above the value necessary for a given capacity and an orifice was inserted in the outlet of the rotary feeder (see Progress Report IV, Drawing 12). The purpose of this orifice was to pass at a given flow of air a required amount of cossettes. When as a result of the fluctuation of the flow of cossettes some of the compartments of the impeller were overcharged a part of the cossettes would then be recirculated to compensate for any subsequent undercharging of compartments. But even assuming a perfect operation of this arrangement there will always be a certain pulsation of discharge from the rotary feeder. At the usual velocity (160 rpm) of the impeller consisting of six compartments the frequency of the discharge pulsation will be 16 pulses per second. Even though this frequency is small it cannot be neglected considering the high velocity of particles, especially at the outlet of the disintegrator pipe (see Fig. 3,F).

Therefore, it is most probable that at a given average capacity the ejector and the baffle may be temporarily overcharged. It is believed that further improvement in the uniformity of flow will considerably increase the steam economy of this system.

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*2.41 lb per minute in all experiments presented in this report.

B. Ejector

The feeder was connected to the ejector (Figs. 3, 5, and 6 of this report and Drawing 20 of Progress Report IV) with a 1-inch standard brass pipe 90 inches long.

In all experiments presented in this report a dry saturated steam of 110 psig was used as a motive fluid. The flow rate of the steam was 3.53 lb per minute in each of the experiments. The steam nozzle (Fig. 3, h) was of convergent-divergent type with a 0.200-inch throat diameter and 0.317-inch exit diameter.

The total angle of convergence of the entrance to the diffuser throat (Fig. 3, t) was 25° and the diameter of the diffuser throat was 0.625 inch. An important factor for good operation of the ejector is the way in which the cossettes and air are introduced into the chamber. Logically the best way would have been to introduce the cossettes axially with the direction of flow of the motive steam to avoid or decrease the change of direction of the flow of the cossette-air mixture. There are several ways of solving this problem, however, each of them presents serious constructional difficulties when applied to small-scale equipment. One possibility is to use an annular nozzle instead of the one described and to introduce the cossettes through the centerline of the nozzle. For an annular nozzle of 2-inch diameter and having the same cross-sectional area of the throat as that used in these experiments, the width of the annulus would be only 0.005 inch. This idea was disgarded because of the difficulty of construction and ease of damage and wear to an annulus of such a close tolerance. The use of a ring of small separate nozzles presented similar constructional difficulties. The actual solution is presented in Figs. 3 and 6. The cossette inlet pipe was introduced deep into the ejector chamber and was slightly flattened and bent in the direction of the flow of steam. For other constructional details see Progress Report IV.

C. The Disintegrator Pipe

The purpose of the disintegrator pipe is to provide a necessary length of path for acceleration of the particles. Two different pipes were used in the experiments presented in this report: (1) a 3/4-inch standard brass pipe 37-5/16 inches long which was connected with the ejector chamber by a short diffuser, D, (Fig. 3); and (2) a 0.5-inch standard brass pipe 16-5/8 inches long which was connected directly with the chamber by means of an adapter. In the latter case no diffuser was used, with the smallest cross section of the ejector being equal to the cross section of the pipe.

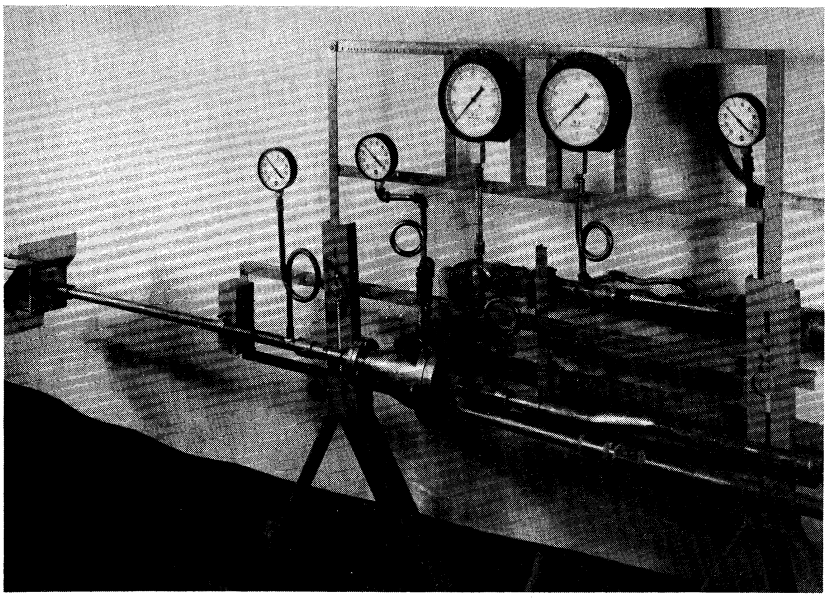

Fig. 5. The Disintegrator without Feeder

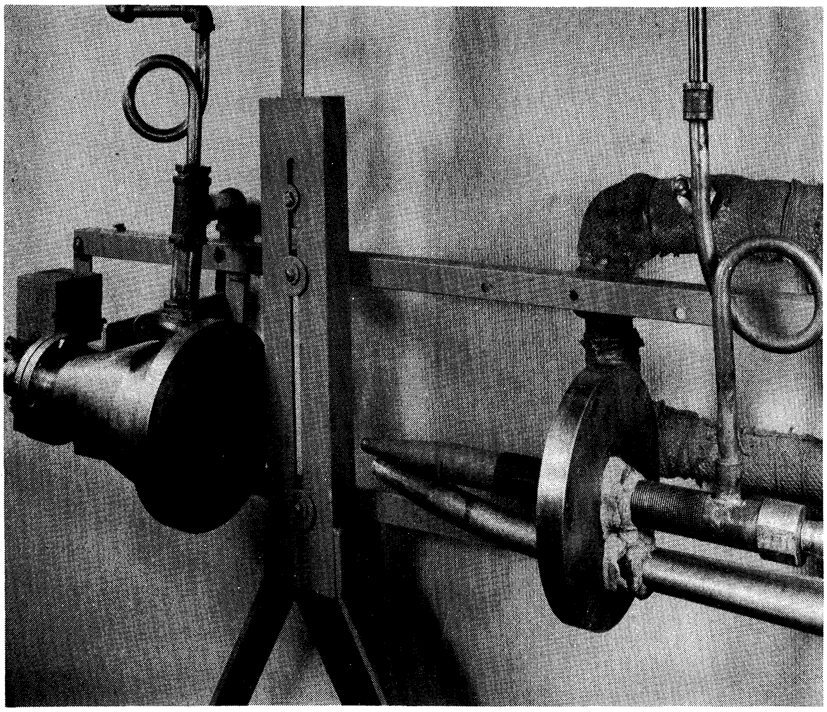

Fig. 6. The Ejector Chamber with the Nozzle and Inlet Pipe Withdrawn

D. The Impingement Baffle

The main purpose of the baffle is to provide an efficient impact surface for the cossettes. As the baffle is the part of the equipment where the particles undergo disintegration its design and construction affects the efficiency of the whole system. On the basis of the observations made a good baffle should fulfill the following requirements:

1. It should permit every particle to strike its bare surface.

2. Its shape and construction should decrease or prevent the deflection of the incoming particles caused by those rebounding from the baffle.

3. The pulp should be removed from the surface of the baffle as soon as it is formed to decrease the harmful cushion effect.

4. It is also believed that the impact surface should exhibit a cutting or abrasive action on the particles to assist in their disintegration.

In general a baffle of low efficiency would require a higher velocity of particles and a greater steam consumption to give an adequate disintegration as compared to that obtained with a more efficient baffle.

Several types of impact surfaces have been investigated and the results are presented and discussed in the later part of this report.

IV. THE EXPERIMENTAL TECHNIQUE

A. Preparation of Cossettes

As a result of the small diameter at the diffuser throat (0.625 inch) the length of the particles used in the experiments varied between 1/4 to 1/2 inch.

In order to prepare cossettes of approximately equal length all the beets used for an experiment were first cut to the same length (6 inches) and then a number of incisions were made in the direction perpendicular to the long axis of the beet. The distance between the incisions was equal to the required length of cossettes. A small portion of the beet was left uncut so that after removal of the beet from the cutter the slices were held together by the uncut portion. After the incisions were made the beet was transferred to the slicer (see Fig. 7 and Figs. 1 to 5 of Progress Report IV) where it

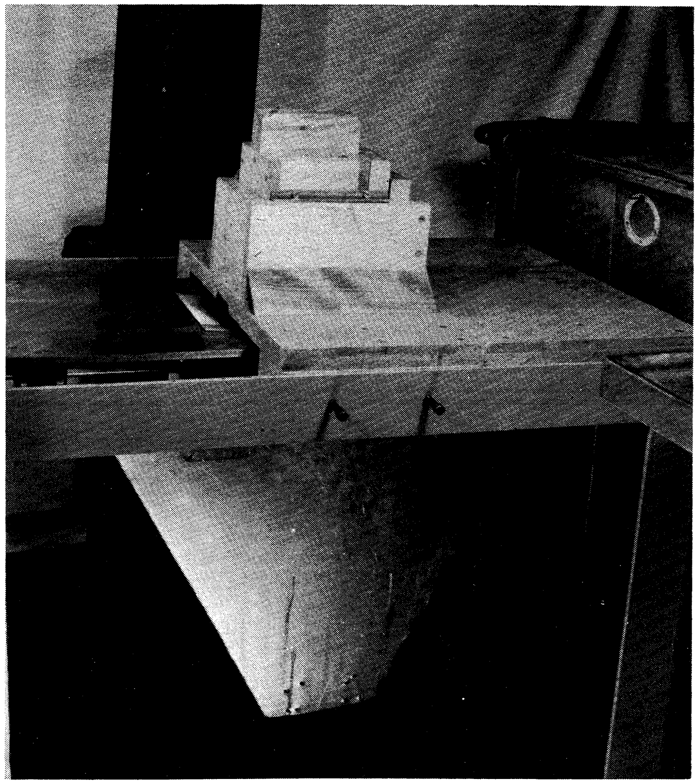

Fig. 7. The Slicer

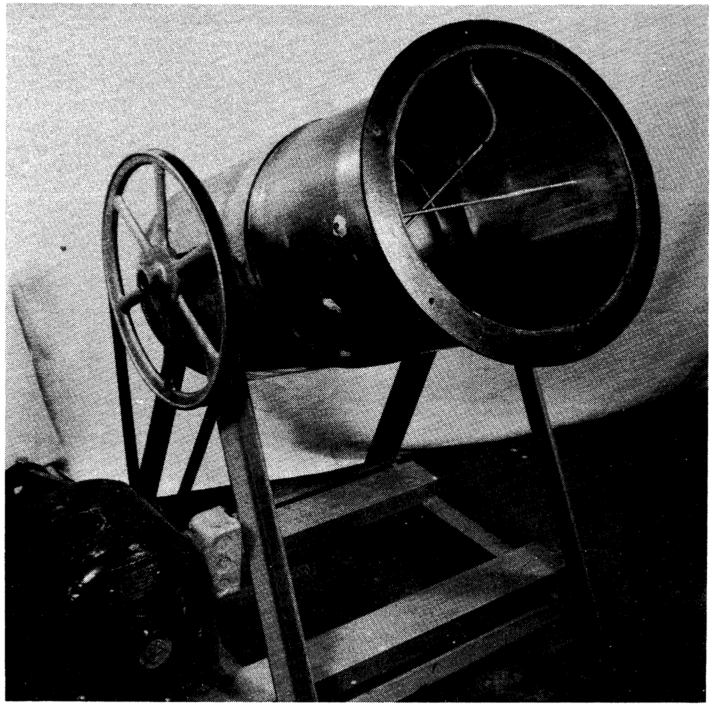

Fig. 8. The Mixer

was cut with a beet slicer knife with vertical splitter, 46 divisions in 165 mm length. The setting of the knife was the same in all experiments. The V-shaped cossettes had a total length of 13.3 mtr per 100 gm and the length of particles varied from 6 to 12 mm. It was difficult to obtain a better uniformity of the length of the particles due to the irregular shape of the beet. The particles prepared from each beet were then passed through a screen to remove slabs and chunks.

B. Preparation of a Uniform Sample

As a portion of the prepared cossettes was used for the actual experiment and the rest for preparation of reference juices it was imperative to have a uniform sample of cossettes. For this purpose the cossettes were placed in a tumbling type of mixer (see Fig. 8 of this report and Fig. 6 of Progress Report IV) and mixed for 6 minutes. This typeof mixer was found to be very reliable. It has a good mixing efficiency and does not damage the comparatively soft particles. It was made entirely of brass and adjusted to 10 rpm.

Table I gives the results of a test in which 20 lb of cossettes (length 6 to 12 mm) were mixed for 6 minutes. The sugar content of the cossettes was then determined in six small lots taken at random from different areas when the whole mass was spread on a flat surface. Table I shows that the difference in sugar content was within the experimental error of determination.

TABLE I

MIXING TEST

Sample	Pol
1	18.27
2	18.30
3	18.23
4	18.30
5	18.20
6	18.23

C. Disintegration Test

In the upper compartment of the feeder 6000 and 7000 gm of cossettes were placed and the cover tightly closed. Dry saturated steam was introduced into the nozzle of the ejector and the pressure adjusted to 110 psig. The required amount of induced air was then introduced into the upper and lower part of the rotary feeder and its speed adjusted to 160 rpm. By starting the reciprocating stirrer of the feeder the cossettes were introduced into the ejector. The pulp was collected in a brass container placed under the baffle. To decrease the variation in feed rate the experiment was stopped before all cossettes charged in the feeder were passed through the ejector. After the experiment the cossettes remaining in the upper compartment above the closing cone were removed from the feeder and weighed to determine the actual processing capacity. The duration of the experiment varied from 30 to 60 seconds depending on the capacity used. The temperature of the pulp was determined and a well-mixed sample of about 2 lb was collected in a closed jar, cooled in ice, and used for the recovery test. In experiments where flat or screen baffles were used the outlet of the disintegrator pipe including the baffle were covered with an aluminum hood to prevent splashing of the pulp and to direct the pulp-stream mixture into the receiver. It has already been mentioned that in experiments presented in this report no steam separator was used. As a result of not using a steam separator, some of the exhausted steam condensed on the pulp and on the walls of the receiving container causing a dilution of the pulp. This dilution varied from 6.5 to 10 percent per beet and was calculated for each experiment on the basis of the sugar-content difference in cossettes and in pulp. Since by the use of a steam separator this dilution could have been substantially decreased, a correction was introduced.

In addition to the draft obtained with the dilute pulp a corrected draft is reported for all experiments. The corrected draft was calculated by subtracting the dilution in percent per beet from the draft experimentally determined. In case a steam separator were used the actual draft would be between those two values and would approach the value of the "corrected draft" with more efficient steam separation. The pulp obtained had a consistency of a semiliquid paste from which a part of the juice separates easily by gravity. Therefore, it is imperative to mix the pulp well before a sample is taken for centrifuging or sugar determination.

For the separation of juice from the pulp the following procedure was used: The well-mixed pulp was weighed into four stainless-steel cylinders, each containing a filtering medium consisting of one layer of cloth and two bronze screens resting on a support (see Progress Report II, Fig. 6). The cylinders were then inserted into centrifuge tubes and the juice spun off at a relative centrifugal force of 666 gravities. After 5 minutes the cake was washed with small lots of hot water and each wash was followed by 3 minutes of spinning. When the required amount of water had been added, the cylinders were evacuated through a small hole and the cake steamed with wet steam of atmospheric pressure for 1 to 2 minutes and centrifuged again. This steaming proceudre was used in all experiments presented in this report except in the preliminary recovery tests (see Table II).

The draft, the amount of wash-water used, and the cake were determined by direct weighing and the corresponding values expressed in percent per beet. The sugar content in the cake and the apparent purity (Refr.) of the juice were also determined. In preliminary experiments the purity of the juice was compared with that of a hot digestion juice prepared by digesting a sample of cossettes (taken from the mixer) with water for 50 minutes at 75-80°C. The details of this method were given in Progress Report II. In case of complete tests in which qualities of thin juices were compared, the diffusion juice was used as a standard of comparison. The methods of preparation of the diffusion juice, its subsequent purification and the analytical methods used were described in the Progress Report III.

A short review is given below:

The diffusion juice was prepared in a small-scale diffusion battery consisting of 10 cells, each with a capacity of 200 gm of cossettes. The time of diffusion was 60 minutes and the maximum temperature of the juice about 80°C. The diffusion juice and the raw juice prepared by the new method from the same lot of cossettes were then quickly heated to 90°C and submitted to a hot progressive preliming, followed by main liming at the same temperature. The first carbonation was carried out by Silin's method with a known amount of CO_2. The first carbonation juice obtained (Ph = 11) was then adjusted to 75°C and its rate of filtration determined by the Spengler, Tödt, and Böttger method. The filtered juice was then saturated with CO_2 to a reaction neutral to phenolphthalein, boiled for 10 minutes, and filtered, and the resulting thin juice was analysed. The reproducibility of the above method of purification has been studied in previous work (Progress Report III) and found to be good.

V. PRELIMINARY RECOVERY TESTS

In the preliminary recovery tests presented in Table II, a 0.5 inch-standard brass pipe was used as the disintegrator pipe (Fig. 3,F). This pipe was connected directly to the ejector chamber, C, and had a total length of 16-5/8 inches and an inside diameter of 0.625 inch. The impingement baffle used in this group of experiments was of a double screen type. The characteristics of this baffle are described in the following section of this report. About 90 percent of the cossettes striking the baffle were

TABLE II

PRELIMINARY RECOVERY TESTS AT LOW CAPACITY

'low Rate of Steam, 3.53 lb/min

Flow Rate of Induced Air, 2.41 lb/min

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
un		% Sugar		Temp. of Pulp, °C	Dilution gm/100 gm Beet	Wash-Water, gm/100 gm Beet	Draft, % by Weight	Corrected Draft, % by Weight	Cake, % of Beet	% Sugar in Cake	Sugar lost in Cake, % of Beet	Juice			Average Capacity, lb/min	Ejector Chamber Pressure, In. Hg.
		in Cossettes	in Pulp									Bx	Pol.	Q		
I	New Process	17.52	16.10	73	8.8	53	127.3	118.5	33.7	1.35	0.45	14.97	13.52	90.3	6.9	2-3 (vac.)
	Reference Juice (Hot Digestion)	-	-	-	-	-	-	-	-	-	-	8.19	7.36	89.8	-	-
I	New Process Exp. 1	17.62	16.22	63	8.6	52.5	130.5	121.9	30.6	1.47	0.45	14.48	13.28	91.7	7.2	2-3 (vac.)
	New Process Exp. 2	17.62	16.22	63	8.6	46.3	125.1	116.5	29.8	1.24	0.37	15.01	13.74	91.5	7.2	2-3 (vac.)
	Reference Juice (Hot Digestion)	-	-	-	-	-	-	-	-	-	-	8.15	7.36	90.3	-	-

forced through. The rebounding part (about 10 percent) of less finer pulp was collected separately and was not used in the tests. In Run No. I the wash-water, which amounted to 53 percent per beet, was applied in seven equal lots and after washing the cake was not steamed. The increase of temperature to 73°C resulted mainly from the condensation of steam on the pulp in the receiver. Columns 8 and 9 in Table II give the actual and corrected drafts respectively. It is expected that with efficient steam separation a value closer to the corrected draft could have been obtained. The amount of sugar lost in cake (col. 12) was 0.45 percent per beet. The comparison of the apparent purities (col. 15) of the raw juice and of the hot digestion juice shows that the former has a slightly better purity.

Run II of the same table was carried out in the same way as Run I except that in Experiment 2 (see col. 7) a smaller amount of wash-water was used (applied in six lots) and the cake steamed. In this experiment after washing with water the cylinders were removed from the centrifuge. The lower part of the centrifuge cylinder was evacuated through a hole located below the cake and the upper part was connected to a flask containing 200 ml of water at 92°C. As a result of the decrease in pressure a certain amount of water flashed from the flask, condensed on the cake, and passed to the lower evacuated part of the cylinder. After steaming the cylinder was centrifuged again for 5 minutes. For Experiment 2 the amount of wash-water given in column 7 includes the amount of steam condensed on the cake. It can be seen from columns 9 and 12 that by using steam as a last wash (Exp. 2) a lower draft and a smaller loss of sugar in the cake was obtained with the same lot of beets. It can also be seen from column 15 (Exps. 1 and 2) that the steaming did not affect the purity of the juice which in both cases was practically the same. The processing capacity used in Runs I and II (see col. 16) was adjusted to about 7 lb per minute, which was less than one-third of the design capacity (25 lb per minute) of the disintegrator.

VI. INFLUENCE OF THE TYPE OF IMPINGEMENT BAFFLE ON THE DEGREE OF DISINTEGRATION AND ON SUGAR RECOVERY

In this series of experiments a 3/4-inch standard brass pipe was used as the disintegrator pipe (Fig. 3,F). This pipe, 37-5/16 inches long and 0.822 inch inside diameter, was connected with the ejector chamber through a diffuser (Fig. 3,D) having a throat diameter 0.625 inch. The following four different types of impingement baffles were investigated in this group of experiments.

(1) The Double-Screen Baffle consisted of two 9-mesh brass screens (0.045-inch wire thickness) placed one on the other so that the openings of

the screens partially overlapped. The double screen was then arranged at an angle of about 45° to the direction of flow.

(2) The Double-Screen Baffle Covered with Fine Screen was the same as described under (1) except that a fine screen, 285 openings per square inch (0.010-inch wire thickness), was put on the side of the double screen facing the outlet of the disintegrator pipe.

(3) The Flat Baffle consisted of a steel plate machined with fine grooves in a diamond pattern. The plate was fixed at an angle of 45° to the direction of flow.

(4) The Cylindrical Baffle (see Fig. 2 and Drawing 25 of Progress Report IV) consisted of a bronze cylinder with vertical grooves along half of its inside surface. The cossettes were introduced tangentially in the direction perpendicular to the grooves and allowed to travel along the grooved portion. A helical partition arranged inside the cylinder directed the pulp to the conical outlet of the baffle.

In the two runs made in this group of experiments (see Table III) the pulp was centrifuged at 666 gravities and the same washing procedure was used in each test. The wash-water was applied in seven portions. After the last wash the centrifuge cylinders were evacuated through a side hole below the level of the cake and wet saturated steam at atmospheric pressure introduced through a thin glass tube above the surface of the cake. The duration of steaming was 1 minute. After steaming, the tubes were centrifuged for 5 minutes. Column 7 gives the total amount of wash-water including the condensate formed during steaming. The latter, determined from the difference of weight of the cylinder before and after steaming, amounted to 1.8 percent per beet. This steaming procedure was used in the rest of the tests presented in this report, except that in a few tests the time of steaming was different. Only a part of the total amount of condensate formed during steaming was formed directly on the cake, a part was formed on the inside wall of the cylinder and the rest was introduced in the form of small droplets by the stream of wet steam. It should be expected that in a continuous operation the efficiency of steaming would be better. This point will be discussed in a later part of the report. Both the runs presented in Table III were carried out with a different sample of beets. In order to eliminate the influence of the different beet material and to allow a better comparison of the types of baffles used, the experiment with the double-screen baffle was repeated in each run.

It can be seen from Run I of Table III that the double-screen baffle is decidely better than the cylindrical type.

TABLE III

INFLUENCE OF TYPE OF IMPINGEMENT BAFFLE ON SUGAR RECOVERY

Flow Rate of Steam, 3.53 lb/min — Flow Rate of Induced Air, 2.41 lb/min

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Run	Impingement Baffle	% Sugar in Cossettes	% Sugar in Pulp	Temp. of Pulp °C	Dilution, gm/100 gm Beet	Wash-Water, gm/100 gm Beet	Draft, % by Weight	Corrected Draft, % by Weight	Cake, % of Beet	% Sugar in Cake	Sugar lost in Cake, % of Beet	Average Capacity lb/min	Vacuum in Ejector Chamber, In. Hg
I	Double Screen	17.47	15.69	75	11.3	55.5	136.7	125.4	30.1	0.69	0.21	10.6	5
I	Cylindrical	17.47	15.88	75	10.0	53.2	126.4	116.4	36.8	2.34	0.86	10.6	4
II	Double Screen	17.70	15.92	67	11.2	55.3	135.9	124.7	30.5	0.90	0.27	9.8	5
II	Double Screen and Fine Screen	17.70	16.20	70	9.3	53.7	131.7	122.4	31.2	1.10	0.34	9.3	5
II	Flat Baffle	17.70	16.35	45	8.3	53.8	127.6	119.3	34.4	3.61	1.24	9.2	6

Using the same lot of cossettes and the same processing capacity the amount of cake was 36.8 percent per beet for the cylindrical baffle and only 30.1 percent for the double-screen baffle. The amount of sugar lost in the cake was four times greater when the cylindrical baffle was used (see col. 10 and 12). The smaller draft in case of the cylindrical baffle was caused mainly by the greater amount of cake. Although the results point against the use of the cylindrical type, it is possible that by decreasing the area of the grooved surface the efficiency of the baffle could be increased. It is believed that this would facilitate the passage of the pulp and keep the grooved portion cleaner, and therefore, more efficient. The advantage of this type of baffle is that it (if successfully developed) could be used at the same time as a steam separator. A comparison of the flat with the double-screen baffle (see Run II) shows that in the case of the flat baffle the amount of cake (see col. 10) is higher and the loss of sugar in the cake almost five times greater than when operating with the double-screen baffle. The results with a double-screen baffle covered with a fine screen do not show much difference when compared with the results obtained with the double-screen baffle. This can be explained by the fact that just at the beginning of the experiment a hole was punctured in the fine screen by the stream of cossettes so that essentially the double-screen arrangement was restored. Due to the lack of time no further baffle experiments were made and the double-screen arrangement which gave the best results was used in the rest of the experiments. It is possible that the better efficiency of the screen baffle may be due to its self-cleaning action which decreases the cushion effect.

The importance of the baffle design cannot be overemphasized. The baffle is the part of equipment where the actual disintegration takes place. The active surface of the baffle is comparatively small, being approximately equal to the surface area of the projection of the disintegrator outlet on the baffle.

It may be assumed that in case of a screen baffle the majority of the disintegration occurs on this projected area. In the experiments with 3/4-inch pipe this small surface area of less than 1 square inch had to take care of a processing capacity of about 10 lb per minute. A further study of the design of baffles (stationary and rotary types) should be considered as a most important point in the future development of this process.

VII. THE INFLUENCE OF CHEMICAL PRETREATMENT ON THE DEGREE OF DISINTEGRATION AND SUGAR RECOVERY

The purpose of this group of experiments was to investigate to what extent the changes in the hardness and the brittleness of the particles affect their disintegration.

In Run I reported in Table IV, 7000 gm were taken from a well-mixed sample of cossettes and mixed with 700 ml of 3 percent milk of lime (0.3 percent CaO per beet) for 10 minutes in the cossette mixer. After treatment the cossettes were transferred to the feeder and disintegrated in the usual way.

The treated cossettes were hard and greenish in color and there was no spare liquid left in the mixer. To have a standard of comparison a second disintegration test was made from the same lot of cossettes, but without pretreatment.

Run 2 was carried out in the same way as Run 1 except that 700 ml of 2 percent milk of lime was used for 7000 gm of cossettes (0.2 percent per beet).

In Run 3 the cossettes were treated with a solution of aluminum sulfate. The procedure was essentially the same as that used for lime pretreatment. For 10 minutes 7000 gm of cossettes were mixed with 700 ml of 1 percent solution of aluminum sulfate (0.1 percent of aluminum sulfate per beet).

There was no spare solution left after mixing. The cossettes retained their natural color and were slightly harder than untreated cossettes.

A 3/4-inch disintegrator pipe (37-5/16 inches long) and a double-screen baffle was used throughout this group of experiments. The pulp was centrifuged at a relative centrifugal force of 666 gravities. The wash-water was applied in seven lots and after washing the cake was steamed for 1 minute. The percent of wash-water per beet given in column 7 of Table IV includes the condensate formed during steaming. Its amount as determined by the difference of weights before and after steaming was slightly less than 2 percent per beet. In case of chemical pretreatment the dilution given in column 6 is the total dilution caused by pretreatment and condensation of steam on the pulp in the receiving container of the disintegrator. The draft was corrected only by the dilution resulting from the latter cause.

TABLE IV

INFLUENCE OF CHEMICAL PRETREATMENT ON SUGAR RECOVERY

Flow Rate of Steam, 3.53 lb/min

Flow Rate of Induced Air, 2.41 lb/min

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Run	Method	% Sugar in Cossettes	% Sugar in Pulp	Temp. of Pulp, °C	Dilution, gm/100 gm Beet	Wash-Water, gm/100 gm Beet	Draft, % by Weight	Corrected Draft, % by Weight	Cake, % of Beet	% Sugar in Cake	Sugar lost in Cake % of Beet	Average Capacity lb/min	Ejector Chamber Vacuum, In. Hg
I	Liming 0.3 % CaO per Beet	17.32	14.26	62	21.4	61.7	148.5	137.4	34.6	1.15	0.40	7.2*	6
	No Liming	17.32	15.69	67	10.4	56.7	135.6	125.2	31.5	0.80	0.25	7.5	6
II	Liming 0.2 % CaO per Beet	17.34	14.81	76	17.1	58.0	143.8	136.3	31.3	1.06	0.33	8.2*	7
	No Liming	17.34	16.20	73	7.0	53.8	131.6	124.6	29.1	0.64	0.18	10.3	5
III	Aluminum Sulfate 0.1 % per Beet	18.85	15.80	74	19.3	60.5	146.3	134.9	33.5	1.24	0.41	7.3*	6
	Without Pretreatment	18.85	17.66	75	6.7	53.5	127.9	121.2	32.3	1.47	0.47	12.8	3

*of wet pretreated cossettes

In Runs 1 and 2 the disintegration of limed cossettes was decidely less satisfactory than that of untreated cossettes. The amount of cake per beet (col. 10) was higher and in spite of a greater amount of wash-water per beet the sugar loss in cake was almost twice as great as in the case of untreated cossettes.

In Run 3 where cossettes were treated with 0.1 percent per beet of aluminum sulfate the difference in the amount of cake per beet and sugar loss in cake is too small to warrant any deductions. In addition, the amount of sugar lost in cake in the case of untreated cossettes was exceptionally high, 0.47 percent per beet which was much higher than in Runs 1 and 2, which were 0.25 and 0.18 percent per beet respectively.

In summary of these tests it may be said that the chemical treatment in the above described set of experimental conditions was not advantageous and gave poorer disintegration and smaller recovery. It is, however, possible that with other types of impingement baffles the increased brittleness of cossettes may be of advantage.

There are some other reasons against the use of chemical pretreatment apart from the additional complication of the process there will always be an unavoidable dilution of the juice if the chemical is added in the form of a solution and it will be more difficult to fluidize the wet and sticky particles.

VIII. INFLUENCE OF STEAM PRETREATMENT OF COSSETTES ON THE DEGREE OF DISINTEGRATION AND SUGAR RECOVERY

In the experiment presented in Table V the cossettes were first steamed for 3 minutes at 1 psig. For this the feeder containing a known amount of cossettes was evacuated to 18 inches Hg vacuum and saturated steam was introduced into the upper compartment of the feeder until the pressure increased to 1 psig. The condensate formed, together with the excess steam, was removed through the side tube, m, (see Fig. 3) mounted above the disc of the gate valve, W. After 3 minutes steaming the feeder was quickly evacuated to 18 inches Hg vacuum. The cooled cossettes were then disintegrated in the usual way. In this experiment a 0.5-inch standard brass pipe (16-5/8 inches long, 0.625 inches ID) was used. It was connected directly to the ejector chamber. The baffle was of the double-screen type previously described. The pulp was centrifuged at a relative centrifugal force of 666 gravities. The value for wash-liquid given in column 6 (62.5 percent per beet) includes the total amount of the sugar-containing condensate (24.96 percent per beet),

TABLE V

INFLUENCE OF STEAM TREATMENT ON SUGAR RECOVERY

Flow Rate of Steam, 3.53 lb/min

Flow Rate of Induced Air, 2.41 lb/min

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	% Sugar in Cossettes	% Sugar in Pulp	% Pulp per Beet	% Condensate per Beet	Wash-Liquid gm/100 gm Beet	Cake, % Beet	% Sugar in Cake	Sugar lost in Cake, % Beet	Draft, % by Weight	Condensate			Juice			Average Capacity lb/min	Ejector Chamber, psig
										Bx	Pol	Q	Bx	Pol	Q		
New Process (Cossettes Steamed)	18.34	17.40	93.22	24.96	62.5	40.6	5.22	2.12	115.20	9.42	8.49	90.1	15.78	14.33	90.8	9.06	1
Reference Juice (Hot Digestion)	18.34	-	-	-	-	-	-	-	-	-	-	-	8.31	7.56	90.9	-	-

which divided into two lots was used as a first wash. The remaining part of the wash-liquid was water which was applied in six lots. No steaming of cake was used in this experiment.

The disintegration was decidely less satisfactory as compared with other experiments made in similar conditions with unsteamed cossettes. The amount of cake was exceptionally high (40.6 percent per beet) and so was the sugar loss in the cake. The comparatively low draft of 115.2 (col. 10) can be explained by the greater amount of cake and by evaporation of some of the water during evacuation of the feeder after steaming. This exceptionally poor disintegration of steam treated cossettes was also found in some of the preliminary experiments.

This poor disintegration of steam treated cossettes needs a more comprehensive investigation before a satisfactory explanation can be given. The steaming procedure does not seem to affect the apparent purity of the juice which shows the same value as that of the hot digestion juice (col. 16).

IX. QUALITY OF THE JUICE PREPARED FROM PULP AS COMPARED WITH THAT OF THE DIFFUSION JUICE

In order to obtain a better comparison of the qualities of juices prepared by these two different methods three complete experimental runs have been carried out in which both the raw juices were submitted to the usual purification process. The experimental technique has already been described in section IV of this report.

Table VI in which the results of these tests are presented is divided in two parts. The upper part gives data concerning production of the pulp and sugar recovery. The lower part presents the characteristics of juices prepared in each run from the same lot of beets. Before the results of the experiments are discussed, an explanation concerning the washing procedure and the setting of the equipment is given.

In Runs 1 and 2 a 0.5-inch standard brass pipe (16-5/8 inches long) was used as the disintegrator pipe. This pipe was connected directly with the ejector chamber. In Run 3 a 3/4-inch standard pipe was used (length 37-5/16 inches) which was connected with the ejector chamber by means of a diffuser with a throat diameter of 0.625 inches.

A double-screen baffle was used in Runs 1 and 2 and a single-screen baffle (9 mesh, 0.045 wire thickness) in Run 3. Both baffles were placed at an angle of about 45° to the direction of flow and in all runs the pulp

TABLE VI (Part 1)

JUICE PREPARED BY THE NEW METHOD VS DIFFUSION JUICE

w Rate of Steam, 3.53 lb/min

Flow Rate of Induced Air, 2.41 lb/min

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Process	% Sugar		Temp. of Cossettes °C	Temp. of Pulp, °C	Dilution gm/100 gm Beet	Wash-Water gm/100 gm Beet	Draft % by Weight	Corrected Draft % by Weight	Cake, % of Beet	% Sugar in Cake	Sugar lost in Cake, % Beet	Average Capacity, lb/min	Pressure in Diffuser, psig	Pressure in Ejector Chamber, In. Hg	Pressure in Rotary Feeder, In. Hg.	ID of Pipe, Ins.
	in Cossettes	in Pulp														
New	17.74	16.15	17	71	9.8	48.9	126.9	117.1	31.7	0.95	0.30	8.3	-	1-2 (vac)	1 1/2 to 2 1/2	0.625
New	17.15	15.95	17	68	7.5	54.1	135.6	128.1	26.3	0.51	0.13	7.1	-	2-3 (vac)	1 to 2	0.625
New	17.69	16.54	18	65	6.95	54.6	132.3	125.4	29.2	0.92	0.27	23	2-3	0 to 2	-	0.822

TABLE VI (Part 2)

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Raw Juice				1st Carbonation Juice				2nd Carbonation Juice							
						Rate of Filtration									Alkalinity % CaO	
Process	Bx (refr.)	Pol	Q	Pectin (Silin) gm/100 ml	Alkalinity, % CaO	50 ml	100 ml	150 ml	Bx (refr.)	Pol	Q	-LgT at 560 mμ	Lime Salts, mg/100 Bx	Sp. Cond. at 18°C and 5 Bx mhos/cm	Phenolphthal	Methyl Red
New	15.28	13.74	89.9	0.24	0.06	56"	3'0"	7'32"	14.83	13.93	93.9	-	28	-	0.019	0.024
Diffusion	12.69	11.54	90.9	0.30	0.06	50"	2'23"	5'45"	11.83	11.12	93.9	-	34	-	0.019	0.023
New	13.96	12.52	89.7	0.28	0.066	49"	2'31"	6'08"	13.00	12.22	94.0	0.002	22	0.00135	0.015	0.026
Diffusion	13.24	11.95	90.2	0.29	0.06	41"	2'04"	5'38"	12.21	11.41	93.4	0.036	41	0.00146	0.014	0.019
New	14.35	12.94	90.2	-	0.064	-	-	-	14.45	13.59	94.0	0.008	26	0.00132	0.021	0.025
Diffusion	13.66	12.32	90.2	-	0.079	-	-	-	12.46	11.63	93.3	0.044	21	0.00142	0.017	0.017

was centrifuged at 666 gravities. The washing procedure was the same except that in Run 1 the wash-water was divided into 6 lots and the time of steaming was 2 minutes, while in Runs 2 and 3 the wash-water was applied in seven lots and the time of steaming was cut to 1 minute. The processing capacity in Runs 1 and 2 (see col. 14) was small, about one-third of the design processing capacity (25 lb per minute) and the amount of coarse pulp which did not pass through the screen was approximately 10 percent. In Run 3 where the capacity was increased almost to the design value the amount of coarse pulp increased to almost 30 percent. This coarse pulp was not used in the recovery tests. The smallest draft (cols. 9 and 10) was obtained in Run 1 where a smaller amount of water was used for washing the cake (see col. 8), but the sugar loss in cake (col. 13) reached the highest value of 0.3 percent per beet. The best recovery was obtained in Run 2 where the capacity was small (col. 14) and the amount of wash-water was increased (col. 8). The amount of cake and the loss of sugar in cake in Run 3 was comparatively small (29.2 and 0.27 percent of beet respectively) in spite of the fact that the capacity was increased about three times and a single-screen baffle was used.

A comparison of purities of raw juices (col. 5, Part 2 of the table) shows that the apparent purity of the diffusion juice is slightly higher, except in Run 3 where the purities have the same value.

The situation becomes reversed when the purities of thin juices are compared (col. 13). Except in Run 1 where the purities are the same, the purity of the thin juice prepared from the pulp juice was higher. This fact is in good agreement with observations made in a similar series of experiments carried out last year and presented in Table I of Progress Report III.

As for the rate of filtration of the first carbonation juice, the juice prepared from diffusion juice gives a better rate of filtration although the difference is not great. Previous experiments (Progress Report III) indicate that the use of cold preliming of pulp juice may considerably improve the rate of filtration. As can be seen from column 14 the color of the thin juice prepared from pulp juice is much lighter. In Run 2 the thin juice prepared from pulp was almost colorless. The difference in lime salts content (col. 15) of thin juices was small, except in Run 2 where the thin juice obtained from diffusion juice contained a much greater amount of lime salts.

In Run 3 the total amount of nitrogen was determined by Kjeldahl method in raw and thin juices. The results are given in Table VII.

TABLE VII

TOTAL NITROGEN IN RAW AND THIN JUICES

Process	Total Nitrogen in mg/100 Bx	
	Raw Juice	Thin Juice
New	559	437
Diffusion	505	441

It can be seen from the table that the comparatively small difference in total nitrogen in raw juices disappears after purification.

Both the thin juices contain practically the same amount of total nitrogen.

X. RECOVERY TEST AT HIGHER CENTRIFUGAL FORCE

In the experiment presented in Table VIII the setting of the equipment was the same as in Run 3, Table VI, that is a 3/4-inch standard pipe and a single-screen (9 mesh) baffle were used. The pulp was centrifuged at a relative centrifugal force of 1460 gravities, more than twice the value used in previous experiments. The amount of wash-water used for washing the cake (see col. 6) was 45 percent per beet and divided into eight lots. The condensate formed during steaming of the cake was about 2 percent per beet and is included in the amount of wash-water used. The use of the higher centrifugal force resulted in a smaller amount of cake which dropped from the usual value of about 30 percent per beet to 21.4 percent with a corrected draft of 125.7 percent. Because of the smaller amount of cake it was possible with a smaller amount of wash-water to decrease the sugar loss in cake to 0.14 percent per beet. The purity of the pulp juice was slightly higher than that of the diffusion juice, although the difference was rather small.

TABLE VIII

RECOVERY TEST AT HIGHER CENTRIFUGAL FORCE

ow Rate of Steam 3.53, lb/min

Flow Rate of Induced Air 2.41, lb/min

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
oc-s	% Sugar		Temp. of Pulp °C	Dilution gm/100 gm Beet	Wash-Water, gm/100 gm Beet	Draft, % by Weight	Corrected Draft, % by Weight	Cake, % of Beet	% Sugar in Cake	Sugar lost in Cake, % of Beet	Average Capacity, lb/min	Raw Juice			Pressure in Diffuser, psig	Vacuum in Chamber, In. Hg.	Pressure in Rotary Feeder, In. Hg.
	in Cossettes	in Pulp										Bx	Pol	Q			
w	17.93	16.62	70	7.8	45.0	133.5	125.7	21.4	0.68	0.14	18.9	14.70	13.41	91.2	3	1 to 0	2 to 3
f-sion	17.93	-	-	-	-	-	-	-	-	-	-	13.70	12.44	90.8	-	-	-

XI. CONCLUSIONS AND PLANS FOR FUTURE

In the experiments discussed in this report the greatest processing capacity used was 23 lb of cossettes per minute, which at a flow rate of steam equal to 3.53 lb per minute gives a steam requirement of 15 lb per 100 lb of beets.

Further improvement on the economy of the system was not studied. The steam consumption of the disintegrator depends on a number of factors. One of the most important variables influencing the degree of disintegration and steam consumption is the baffle design. A more efficient baffle will require a lower velocity of particles and will result in a smaller steam consumption for the same degree of disintegration. The baffle should also be designed to simplify the construction and installation of an efficient steam separator to avoid an unnecessary dilution of pulp. The great differences in efficiencies of the four types of baffle investigated show that there is great opportunity for improvement in baffle design. Another important factor for the economy of the disintegrator is the uniformity of flow. As the flow rate of steam through the system is constant any decrease in the flow of cossettes will result in a higher steam consumption per weight of beet. A considerable saving on steam can be expected by further improvement in the uniformity of flow of cossettes.

The efficiency of the thermocompressor should be improved to increase the ratio of the induced steam to motive steam. The manner in which the cossettes are introduced into the stream of steam, as well as the length of the disintegrator pipe, should be studied further to determine the optimum conditions. The use of higher steam pressure should also be investigated.

The filtering and washing properties of pulp prepared in the disintegrator were very good. With a comparatively small amount of water (about 50 percent per beet) a sugar recovery of more than 99 percent was obtained at drafts of about 130 percent. The amount of cake was about 30 percent when centrifuged at a relative centrifugal force of 666 gravities and 21.4 percent at 1460 gravities. In all experiments presented in this report a centrifuge was used for the separation of the juice from the pulp. Although this method of separation proved successful, it is possible that the use of rotary filters or rotary filters with pressing rolls would be advantageous. Also, the juice separator (of whatever type it might be) will concentrate (dehydrate) the cake and the saving on pulp presses will to a certain extent offset the cost of the juice separator.

The problem of selection of equipment for juice separation was beyond the scope of this project and has not been studied. It is expected that a continuous washing of the cake with a uniform spray of water may give even higher recovery or a smaller draft than obtained by washing with separate lots as was the case in the experiments reported. However with the type of equipment used a uniform and continuous washing would have been difficult, if not impossible. The steaming of the cake although advantageous in the experiments reported should not be considered as a necessity for good recovery.

The quality of juices prepared by the new method compared favorably with that of juices obtained by the usual diffusion process. Chemical pretreatment of raw cossettes with lime and with aluminum sulfate did not improve the disintegration, but on the contrary appeared to be harmful in the experimental conditions studied.

The experiments reported using continuous equipment have demonstrated the feasibility of the new process with regard to quality of the juice, draft, and sugar recovery.