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RECOVERY OF JUICE FROM SUGAR BEETS BY RUPTURE OF THE BEET CELLS

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ABSTRACT

Experiments have been performed on the recovery of juice from sugar beets by rupture of the beet cells. Disintegration of the cellular structure was accomplished by accelerating beet cossettes to a high velocity and allowing the cossettes to strike a stationary impingement baffle. The high velocity particles were reduced to a pulp by the impact and shock from the sudden change of momentum.

The equipment use for the rupturing of beet cells was essentially a thermocompressor into which the beet particles were introduced with a stream of induced fluid. The quality of the "thin" juice prepared from the "pulp" juice compared favorably with the quality of the "thin" juice prepared from "diffusion" juice. Sugar recoveries of about 99 percent were obtained at drafts of about 130 percent by weight. A processing capacity of 23 pounds per minute (16-1/2 tons per 24 hours) was reached using an acceleration pipe of 0.822 inches ID. and 37-5/16 inches long. In high capacity runs 15 pounds of steam per 100 pounds of beets were used in the experimental disintegrator.

Main advantages of the equipment are its simple design, continuity of operation, short hold-up time, and small size for a comparatively high capacity.

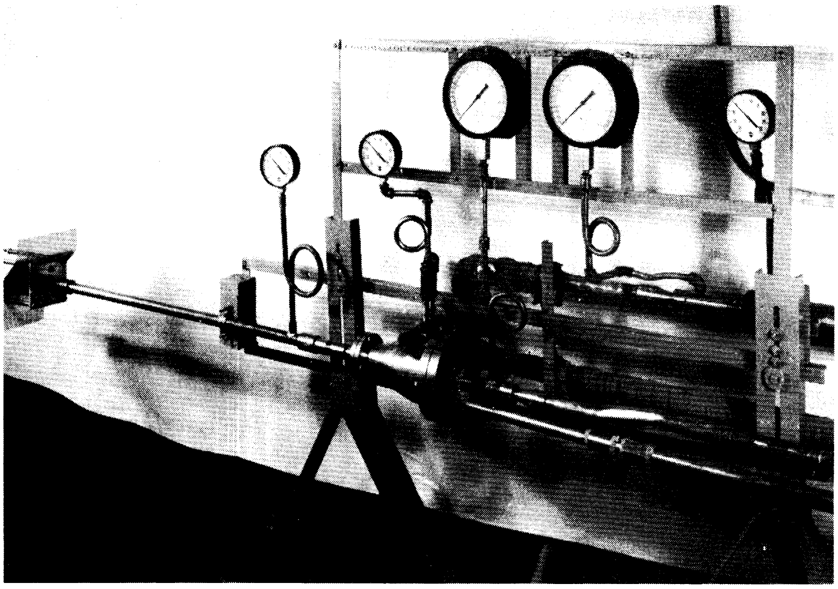

Fig. 3. The Disintegrator without Feeder

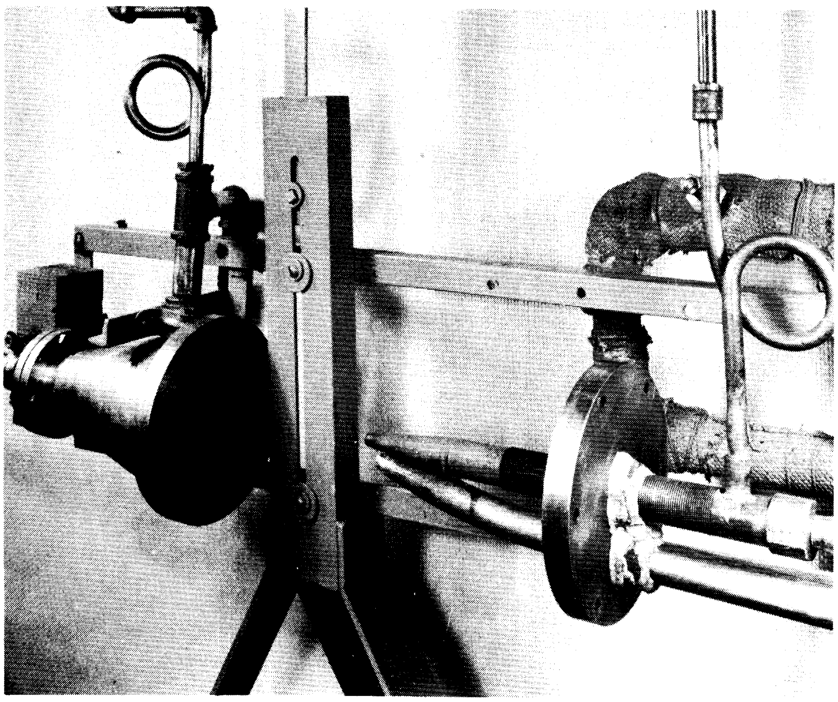

Fig. 4. The Ejector Chamber with the Nozzle and Inlet Pipe Withdrawn

DESCRIPTION OF THE EXPERIMENTAL EQUIPMENT

The disintegrator as shown in Figs. 2, 3, and 4 is essentially a thermocompressor into which the beet particles are introduced by the stream of the induced fluid (steam or air). It consists of the following main parts: The feeder, the ejector, the acceleration pipe and the impingement baffle.

A. The Feeder

The purpose of the feeder (Figs. 2 and 5) 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 of flow. This point is of special importance because of the small cross-section of the conduits in the experimental plant and the consequent danger of choking. Increasing the dimensions of the acceleration pipe and of the diffuser throat was impractical because such a design would result in a processing capacity too great for laboratory conditions.

Feeder A (Fig. 2) consists of three parts made of bronze. The upper 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 a 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

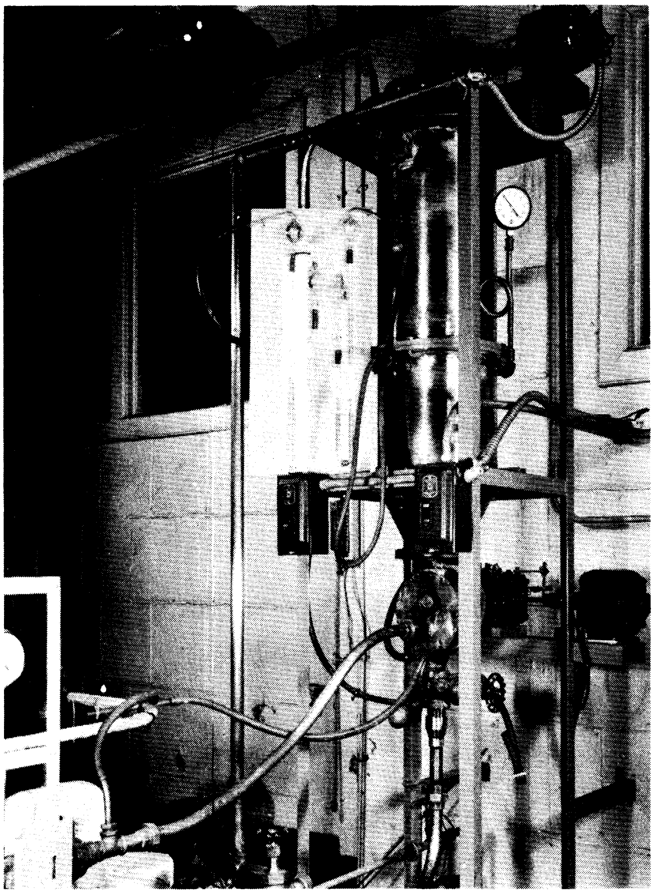

Fig. 5. The Feeder

RECOVERY OF JUICE FROM SUGAR BEETS BY RUPTURE OF THE BEET CELLS

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In the early days of the beet sugar industry the beet was first rasped to a fine pulp and the juice removed from the open cells either in helical or hydraulic presses. The recovery of juice by this mechanical processing of the beets was poor and also the sugar content of the beets grown during this period was low. These factors, in addition to the limitation of the mechanical equipment available, made it difficult for the early beet sugar industry to produce sugar economically.

Various attempts were made to improve the recovery of sugar from beets and the most successful was the development of the Robert's diffusion battery in 1864. For the past 90 years practically all sugar produced from beets has involved the use of the diffusion process. Since then little or no attention has been paid to the possible improvement of a mechanical process. The improvement of mechanical equipment such as centrifuges and filters justifies a

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reconsideration of mechanical methods of recovering juice from the sugar beet.

Acknowledging the merits of the diffusion process, the old direct method of juice recovery offers important advantages if successfully developed. One of the advantages which may be expected is the possibility of a considerable reduction in the time of recovery of juice as compared with the usual method of diffusion. In addition, with an efficient separation of juice from pulp the moisture content of the exhausted pulp can be reduced so as to eliminate the use of pulp presses.

The study described here is an investigation of whether with the use of modern engineering techniques the process of juice recovery by means of cell rupture and direct separation of the juice can compete with the diffusion process.

The more important requirements critical for the successful development of the cell-rupture process can be listed as follows:

1) The quality of the juice should not be decreased by the process.
2) The cell structure of the beet should be ruptured as completely as possible without, however, producing a greater amount of fines. This last point is of importance for easy centrifuging or filtering.
3) The equipment used to produce beet pulp should be simple in design, continuous in operation, and should have a relatively small size with a high processing capacity.
4) The sugar lost in the pulp-cake should be about 1 percent of the sugar in the beet at drafts of 130 percent or lower for the process to be competitive with the diffusion.

5) The equipment used for the separation of the juice should be continuous and inexpensive and should enable a uniform washing and a good dewatering of the pulp cake.

6) The drying of the pulp should not require any drastic changes in the existing dryers.

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

In the preliminary studies of this problem the rupturing of the cell structure of the beet was effected mainly by a combination of two factors: an increase of pressure inside the cell and a sudden change of momentum of beet particles accelerated to a high velocity. For this purpose the beet cossettes were first preheated for a short time with saturated steam at atmospheric pressure, then the steam pressure was suddenly increased and the cossettes blown out into atmospheric pressure. The fast moving cossettes were then allowed to strike an impingement baffle where they disintegrated to pulp. Although this method gave satisfactory results as far as the quality of the juice was concerned the regulation of process conditions such as time and temperature were difficult and a dilution of juice was unavoidable. A further study of this problem has shown that by using higher velocities and more efficient impact surfaces a high degree of disintegration can be reached by a sudden change of momentum alone. This principle being simpler and more adaptable to continuous operation was used as a basis for the design of a continuous disintegrator. The disintegrating equipment as well as the general outline of the proposed method are discussed on the following pages of this work.

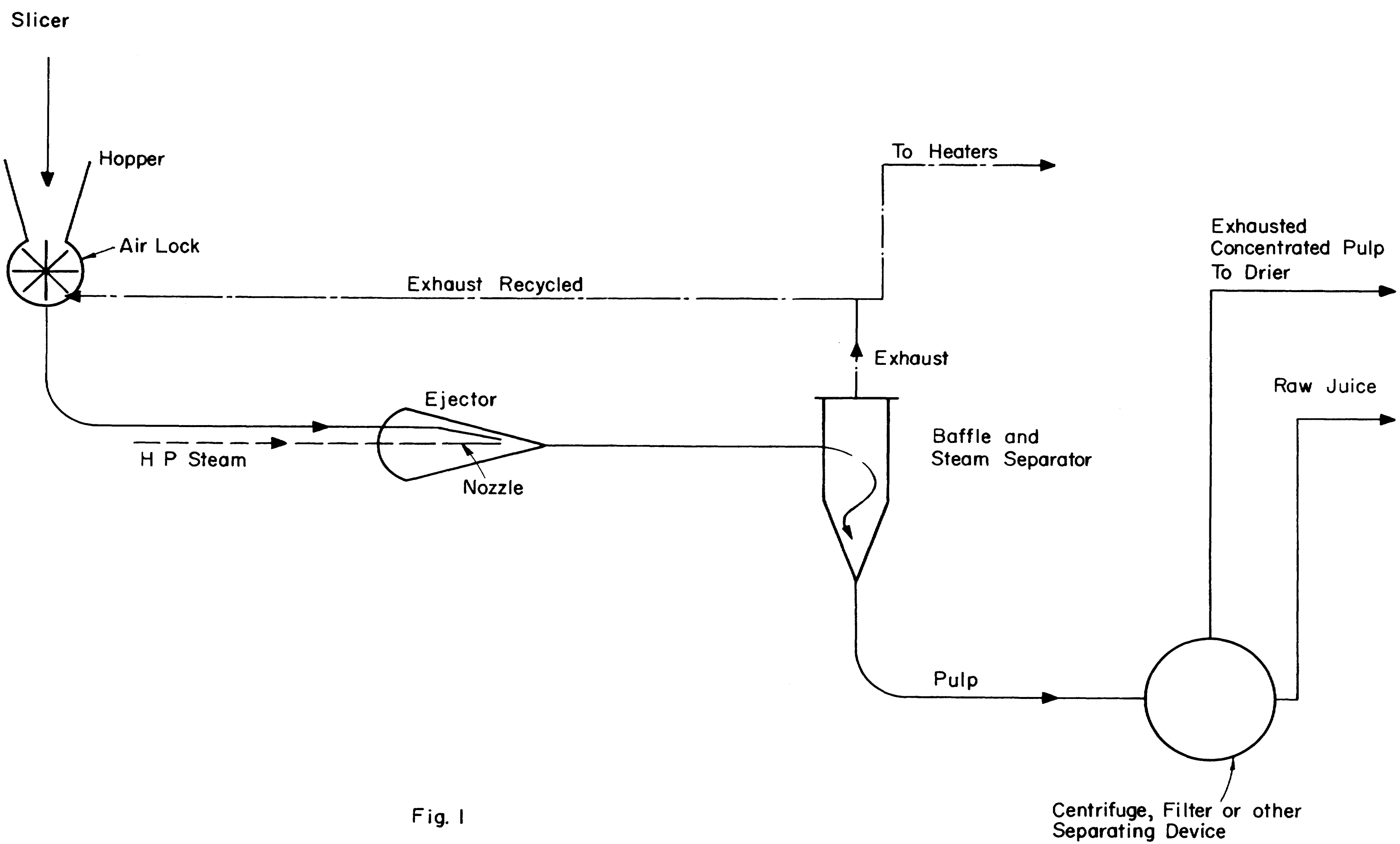

Fig. I

General Flow Sheet of the Proposed Method

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 equipment termed a disintegrator. The cossettes are removed from the hopper by the impeller of the air lock. A part of the low pressure 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 steam. The cossettes are accelerated to a high velocity and allowed to strike an impact surface arranged in the separator. This impact causes rupture of the beet cells. The resulting pulp is then removed from the separator either by keeping the pressure in the separator slightly higher than atmospheric or by means of a suitable revolving scraper. This separation should be accomplished as quickly as possible to minimize condensation of steam on the pulp and the resulting dilution of the juice. The expanded steam is partially recycled to the airlock and the rest used for juice heaters, etc. The juice is separated from the pulp in a centrifuge, filter or other separating equipment with the aid of a wash and the exhausted concentrated pulp is sent to a drier.

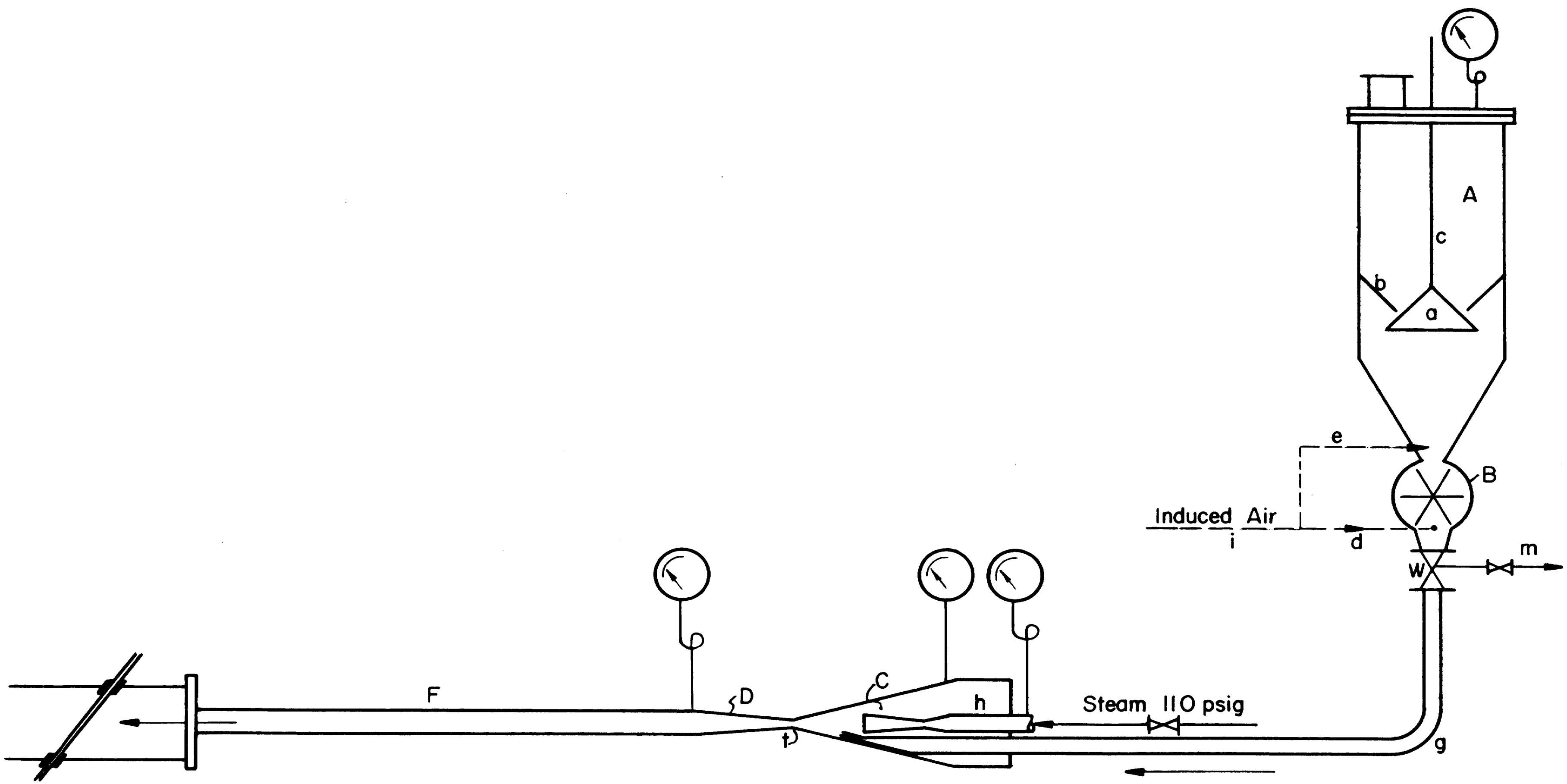

Fig. 2

Disintegrator and Feeder

feeder down to the conical bottom. From there the particles 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. 5). As a result of the vacuum existing in the ejector chamber C the particles, together with the induced fluid (steam or air), are carried away into the ejector chamber.

In all experiments air was used as induced fluid instead of steam. The main reason for the use of air rather than steam was the inadequate air-locking property of the rotary feeder used. If steam were used and if the pressure in the rotary feeder increased even slightly above atmospheric, a leakage of steam would occur in the direction upwards to the cossettes resulting in some condensation on the cossettes and in a change of process conditions.

A known amount of air was introduced through pipe, i, (Fig. 2) at two points of the rotary feeder. The majority of the air used was passed directly through branch "d" and the rest introduced at the bottom of the cone (see branch "e") to prevent choking of the relatively small inlet to the rotary 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. Thus the use of air not only facilitated the experimental procedure, but also permitted accurate metering of the induced fluid. Obviously in commercial operation steam should be used rather than air, so as to minimize dilution of steam with air. However, if steam were used a certain condensation of steam on beet particles would be unavoidable especially in the zone of initial acceleration.

One of the chief requirements for good operation of the feeder is the production of a flow as uniform as possible. In small scale equipment as used in this work a high degree of uniformity of flow was more difficult to reach than in large size equipment where the size of particle is small relative to the cross sections of conduits.

As a result of the reciprocating motion of the stirrer the charging of the compartments of the rotary feeder was not uniform. To improve the uniformity of flow the rotary feeder was so adjusted that a part of the cossettes was recirculated to compensate for any undercharging of compartments. But even assuming a perfect operation of this arrangement there would always be a certain pulsation of discharge from the rotary feeder. At the usual velocity of the impeller (160 rpm) consisting of six compartments the frequency of the discharge pulsation was 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 acceleration pipe.

Therefore, it is most probable that at a given average flow rate of cossettes the ejector and the baffle might have been temporarily overcharged. It is believed that further improvement in the uniformity of the flow would considerably increase the steam economy of this system.

The cossette-air mixture leaving the rotary feeder was introduced into the ejector chamber through a 1-inch standard brass pipe 90 inches long.

B. Ejector

In all experiments reported a dry saturated steam of 110 psig was used as motive fluid. The flow rate of steam was 3.53 lb per minute in each of the experiments. The steam nozzle (Fig.2h) 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. 2) was 25^{o} 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 presents serious constructional difficulties when applied to small-scale equipment. The solution used is presented in Figs. 2 and 4 . The cosset inlet pipe was introduced deep into the ejector chamber and was slightly flattened and bent in the direction of the flow of steam.

C. The Acceleration Pipe

The purpose of the acceleration pipe is to provide a necessary length of path for acceleration of cossettes. Two different pipes were used in the experiments presented in this work: (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. 2); 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 and the smallest cross section of the ejector was equal to the cross section of the pipe.

D. The Impingement Baffle

The main purpose of the baffle is to provide an efficient impact surface for the ccssettes. As the baffle is the part of the equipment where the cells of the beet particles undergo rupture its design and construction affects the efficiency of the whole system. On the basis of the observations made the most important requirement for a good operation of an impact surface is an easy and quick removal of the pulp formed. Any accumulation of pulp on the baffle "insulates" the impact surface and decreases the efficiency of disintegration. In addition it is 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 will require a higher velocity of particles and therefore a greater steam consumption to give an adequate disintegration as compared with that obtained with a more efficient baffle.

Several types of impact surfaces have been investigated and the results are subsequently discussed.

The Experimental Technique

As a result of the small diameter of the diffuser throat (0.625-inch) the length of cossettes used in the experiments varied between $\frac{1}{4}$ to $\frac{1}{2}$ inch.

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. The beet was then transferred to a reciprocating slicer where it was cut with a beet slicer knife with vertical splitters, 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 gr and the length of particles varied from 6 to 12 mm. The cossettes prepared in this manner were then passed through a screen to remove slabs and then were mixed in a tumbling type of a mixer to obtain a uniform sample. This type of mixer was found to be very reliable. It has a good mixing efficiency and does not damage the compartively soft particles. A part of the sample was used for the actual experiment and the rest for preparation of reference juices (Diffusion and Hot Digestion Juices).

From the sample prepared in this manner a known amount of cossettes (6000 to 7000 gr) was placed in the upper compartment of the feeder after which the cover was closed. Dry saturated steam was introduced into the nozzle of the ejector and the pressure adjusted to 110 psig. The selected amount of air* was then introduced into the rotary feeder and its speed adjusted to 160 rpm. By starting the reciprocating stirrer the disintegrator was put into operation. The pulp formed was collected in a brass container placed under the baffle. The duration of the experiment varied between 30 to 60 seconds depending on the capacity used. A well-mixed sample of pulp was collected in a closed jar, cooled and used for the recovery test. In the experiments reported no steam separator was used and the pulp-steam mixture was passed directly into the receiver with a result that some of the steam condensed on the pulp and on the wall of the container causing a

* 2.41 lb/min in all experiments

dilution of the pulp. This dilution varied from 6.5 to 11 percent per beet.

Since by the use of a steam separator this dilution could have been decreased, a correction was introduced. In addition to the draft obtained with 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 have been between these two values.

The pulp obtained had a consistency of a semiliquid paste from which a part of the juice separates easily by gravity. Therefore, the pulp was well mixed before a sample was taken for centrifuging or sugar determination.

For the separation of juice from 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. The cylinders were then inserted into centrifuge tubes and the juice spun off at a relative centrifugal force of 666 gravities. The cake was washed with small lots of hot water and each wash was followed by 3 minutes spinning. When the selected amount of wash water had been added, the cylinders were removed from the centrifuge, evacuated through a small hole below the level of cake and wet steam was introduced through a thin glass tube above the surface of the cake. After 1 to 2 minutes of steaming the cylinders were spun again for 3 minutes.

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. When complete comparative tests were made in which the qualities of thin juices were compared, the raw pulp juice and the diffusion juice (prepared from the same sample of cossettes) were subjected to the same purification process including hot progressive preliming, main liming, first and second carbonation, boiling and filtration.

EXPERIMENTAL RESULTS

It has already been mentioned that the design of the impact surface has an important influence on the degree of disintegration. To arrive at the optimum design of the impact surface would require a comprehensive study of a number of different types of impingement baffles which would have been beyond the scope of this work. In order to obtain some information about the magnitude of this influence the following three different types of impingement baffles have been studied

(1) The Double-Screen Baffle consisted of two 9-mesh brass screens (0.0 inch wire) placed one on the other so that the openings of the screens partially overlapped. The double screen was then arranged at an angle of 45° to the direction of flow.

(2) 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.

(3) The Cylindrical Baffle 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

TABLE I

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
Run	Type of Baffle	% Sugar in Cossettes	Dilution % per Beet	Wash Water % per Beet	Draft % by Weight *	Corrected Draft % by Weight	Cake % per Beet	% Sugar in Cake	Sugar Lost in Cake % per Beet	Vacuum in Ejector Chamber in. Hg	Capacity lb/min
I	Double Screen	17.47	11.3	55.5	136.7	125.4	30.1	0.69	0.21	5	10.6
I	Cylindrical	17.47	10.0	53.2	126.4	116.4	36.8	2.34	0.86	4	10.6
II	Double Screen	17.70	11.2	55.3	135.9	124.7	30.5	0.90	0.27	5	9.8
II	Flat Baffle	17.70	8.3	53.8	127.6	119.3	34.4	3.61	1.24	6	9.2

to travel along the grooved portion. A helical partition arranged inside directed the pulp to the conical outlet of the cylinder.

In this series of experiments a 3/4-inch standard brass pipe was used as the acceleration pipe. This pipe 37-5/16 inches long was connected with the ejector chamber through a diffuser (Fig. 2D) having a throat diameter of 0.625 inch.

In the two runs made in this group of experiments (see Table 1) the pulp was centrifuged at 666 gravities and the same washing procedure was used in each test. The wash-water was applied in seven lots and after washing, the cake was steamed with wet steam at atmospheric pressure for 1 minute as previously described. Column 5 gives the total amount of wash-water including the condensate formed during steaming. The latter amounted to 1.8 percent per beet. Each of the runs presented in Table 1 was 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 1 that the double-screen baffle is decidedly better than the cylindrical type. With 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 cake was four times greater when the cylindrical baffle was used (see col. 10). The smaller draft in case of the cylindrical baffle was caused mainly by the greater amount of cake.

Although the results shown in Table 1 do not favor the use of the cylindrical baffle, it is possible that by decreasing the area of the grooved surface the efficiency of this baffle could be increased. It is believed that this change in design would facilitate the passage of the pulp and keep the grooved portion cleaner and thereby make it more efficient. The advantage of this type of baffle is that, if successfully developed, it would also serve as a steam separator.

A comparison of the flat baffle with the double screen baffle (see Run II) shows that in the case of the flat baffle, the amount of cake (see Col. 8) is higher and the loss of sugar in the cake (sol. 10) almost five times greater than when operating with the double-screen baffle. 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 outlet of the acceleration pipe on the baffle. It may be assumed that in case of a screen baffle the majority of the disintegration occurrs on this projected area. In the experiments with 3/4-inch pipe this small surface area of less than 1 square inch had to handle a processing capacity of about 10 lb/min. It is believed that considerable improvement can be made in the design of the impingement baffle.

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 (previously described) and the thin juices analysed.

Table 2 in which the results of these experiments are presented is divided into two parts. Part 1 gives data concerning production of the pulp and sugar recovery. Part 2 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 acceleration pipe. This pipe was connected directly with the ejector chamber.

In Run 3 a 3/4-inch standard pipe was used (length 37-6/16 inches) which was connected with the ejector chamber by means of a diffuser with a throat diameter of 0.625 inches. The double-screen baffle was used in Runs 1 and 2 and a single screen baffle (9 mesh, 0.045 inch. wire thickness) in Run 3. Both the baffles were placed at an angle of about 45^{o} to the direction of flow and in all runs the pulp was centrifuged at 666 gravities. The washing procedure was the same except that in Run 1 the wash-water was divided into 6 lots while in Runs 2 and 3 the wash-water was applied in seven lots. The cake was steamed with wet steam of atmospheric pressure, as previously described, and

TABLE II (Part 1)

JUICE PREPARED FROM PULP VS. DIFFUSION JUICE

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
Run	Process	% Sugar in Cossettes	Temp of Pulp °C	Dilution % per Beet	Wash Water % per Beet	Draft % by Weight	Corrected Draft % by Weight	Cake % of Beet	% Sugar in Cake	Sugar Lost in Cake % of Beet	Average Capacity lb/min	Pressure in Diffuser psig	Pressure in Ejector Chamber in. Hg	Pressure in Rotary Feeder in. Hg	I.D. of Pipe in.
I	From Pulp	17.74	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
II	From Pulp	17.15	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
III	From Pulp	17.69	65	6.95	54.6	132.3	125.4	29.2	0.92	0.27	23	2-3	0 to 2	-	0.822

TABLE II (Part 2)

JUICE PREPARED FROM PULP VS. DIFFUSION JUICE

1	2	3	4	5	6	7	8	9	10	11	12
		Raw Juice		1-st Carbonation Juice				Thin Juice			
					Rate of Filtration						
Run	Process	Purity (Refr)	Pectin (Silin) gm/100 ml	Alkalinity % CaO	50 ml	100 ml	150 ml	Purity (Refr)	-Log T at 560 mμ	Lime Salts mg CaO/100 Bx	Sp Cond at 18°C and 5 Bx mhos/cm
I	From Pulp	89.9	0.24	0.06	56"	3'0"	7'32"	93.9	-	28	-
	Diffusion	90.9	0.30	0.06	50"	2'23"	5'45"	93.9	-	34	-
II	From Pulp	89.7	0.28	0.066	49"	2'31"	6'08"	94.0	0.002	22	0.00135
	Diffusion	90.2	0.29	0.06	41"	2'04"	5'38"	93.4	0.036	41	0.00146
III	From Pulp	90.2	-	0.064	-	-	-	94.0	0.008	26	0.00132
	Diffusion	90.2	-	0.079	-	-	-	93.3	0.044	21	0.00142

the steaming condensate in the amount of about 2 percent per beet is included in the total amount of wash-water given in Column 6.

In Runs 1 and 2 about 90 percent of the pulp formed passed through the screen. In Run 3 where the processing capacity was much higher (23 lb/min.) only about 70 percent of pulp passed through the screen. The coarser pulp which did not pass through the baffle was not used in the recovery tests. The smallest draft (col. 7 and 8) was obtained in Run 1 where a smaller amount of water was used for washing the cake (col. 6) but the sugar loss in cake (col. 11) reached the highest value of 0.3 percent per beet. The best recovery was obtained in Run 2 where the capacity was small (col. 12) and the amount of wash-water increased. The amount of cake and the loss of sugar in cake in Run 3 was comparatively small (29.2 and 0.27 percent per 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. 3, part 2 of the table) shows that the apparent purity of the diffusion juice was slightly higher, except in Run 3 where the purities had the same value. The situation becomes reversed when the purities of thin juices are compared (col. 9). Except in Run 1 where the purities were the same, the purity of the thin juice prepared from the pulp juice was higher. This fact is in aggreement with observations made in a similar series of experiments carried out last year.

As for the rate of filtration of the first carbonation juice the juice prepared from diffusion juice gave a better rate of filtration although the difference was not great as can be seen from Columns 6, 7, 8. The color of the thin juice prepared from pulp juice was much lighter. In Run 2 the thin juice prepared from pulp juice was almost colorless. The difference in lime salts content (col. 11) 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. It seems that the juice obtained directly from pulp has a tendency to give upon purification a juice of a better quality than that prepared from the diffusion juice. However, no definite answer can be given to this problem until a greater number of tests are made with different beet materials.

Recovery Test at Higher Centrifugal Force

In the already described experiments the juice was separated from the pulp in a centrifuge at a R.C.F. of 666 gravities. It was to be expected that an increase of the centrifugal force used would result in a smaller amount of pulp cake in percent per beet, which in turn would decrease the amount of wash-water required to reach the desired degree of exhaustion of pulp. To obtain some information as to what extent the centrifugal force used influences the above process variables an experiment was carried out in which the juice was separated from the pulp at a R.C.F. of 1460 gravities.

In that experiment the setting of the disintegrating equipment (baffle and acceleration pipe) and the washing procedure used was the same as in Run 3, Table 2. With the same beet material and at a processing capacity of 18.9 lb/min. the amount of pulp cake dropped from the usual value of about 30 percent to 21.4 percent per beet. Using a smaller amount of wash-water (45 percent per beet) it was possible to decrease the sugar loss in cake to 0.14 percent per beet. The values of the actual and of the corrected drafts were 133 and 125 percent per beet respectively. The apparent purity of the pulp juice was in this experiment 91.2 that is slightly higher than the purity of the diffusion juice* which amounted to 90.8.

The Influence of Chemical and Heat Pretreatment on the Degree of Disintegration

A number of experiments were carried out with cossettes pretreated with milk of lime and aluminum sulfate. The purpose of these experiments was to find out to what extent the changes in the hardness and brittleness of the particles affect their disintegration.

In no case was an improvement in the degree of the disintegration observed, on the contrary cossettes pretreated with milk of lime gave poor disintegration which resulted in greater amount of pulp cake and higher sugar losses than when operating with fresh untreated cossettes. Similar results were obtained with cossettes steamed for a short time with steam at atmospheric pressure. In summary of these tests it may be said that the chemical and steam treatment of cossettes does not improve their disintegration. This statement applies to the equipment and experimental conditions used, it is however possible that with other types of impingement baffles the increased brittleness (or softness) of cossettes may be of advantage.

Conclusions

A number of experiments have been carried out in which the cellular structure of the beet was ruptured by a sudden change of momentum and the juice recovered directly from the resulting pulp.

* Prepared from the same sample of cossettes.

The equipment used for the rupturing of beet cells was essentially a thermocompressor into which the beet particles were introduced with a stream of the induced fluid and then accelerated to a high velocity by a stream of motive steam. The high velocity particles were ruptured by impact at the surface of a stationary impingement baffle. A processing capacity as high as 23 lb/min (16.5 tons/24 hr) were reached using an acceleration pipe of 0.822 inch. I.D. and 37-5/16 inches long. It is believed that the main advantages of the equipment are its simple design, continuity of operation and a small size for a comparatively high capacity. Sugar recoveries of about 99 percent were obtained at drafts of about 130 percent by weight when using a relative centrifugal force of 666 gravities for separation of juice and wash from the pulp. The amount of wash-water used was 50 to 55 percent per beet and the amount of pulp cake about 30 percent per beet. No difficulty was experienced with separating the juice from the pulp in a centrifuge. The juice separated easily, the remaining cake had good washing property and no clogging of the filter cloth was observed. The quality of thin juice prepared from pulp juice compared favorably with that of thin juice prepared from the diffusion juice.

In the test with the highest processing capacity (Run 3, Table 2) 15 lb. of steam per 100 lb. of beet were used in the experimental disintegrator. It is believed that the steam requirement can be reduced to a value below 10 lb. per 100 lb. of beet by increasing the efficiencies of the thermocompressor and of the impact surface, and by the improvement of the uniformity of flow of beet particles. On the basis of observations made it appears that the efficiency of the impact surface of the baffle plays a very important role in this respect.

Still more data are required for the selection of the optimum type of the juice separator. For this purpose the total time of draining including washing and dewatering of the cake should be determined as a function of the fineness of the pulp and of the pressure difference or centrifugal force applied. Another part of the problem which has not yet been studied is the drying of the pulp in existing types of pulp driers. The main difference between pulp cake and exhausted cossettes is in the degree of subdivision. The pulp cake has a much larger surface area of particles per unit of weight and therefore a much greater rate of drying.

To avoid damage to the pulp particles and loss of fines in the drier it seems logical that the surface area of the particles should be decreased prior to drying, by means such as flaking, pelletizing, etc.

Although further study is required to improve the efficiency of rupturing beet cells, and to investigate the separation of juice from the pulp and the drying of the pulp, the feasibility of the process has been demonstrated.