In treating the subject of sugar, the matter falls naturally into four divisions, namely, (1) The growing of the cane; (2) Bringing the cane to the mill; (3) The crushing and disposal of the cane; and (4) The extraction of the sugar from the juice.

In the planting and growing of the cane there is little to be said from an engineering point of view. There is, at present, a mechanical planter in operation, but owing to the shape of the cane sets it is often choking. Tractors are used extensively for ploughing and irrigating. If the weather is dry, a crop of cane requires the equivalent of three inches of rain every four to six weeks. In and around Townsville and the Burdekin district this water is obtained from underground sources, using ten 3 in. spearheads to an 8 inch pump, or eight 2 in. spearheads to a 6 inch pump, the average depth of the water being about 30 to 35 feet. An idea of the underground water resources of the district can be obtained from the fact that in the 1925-26 drought there were 450 pumps of size varying from 6 to 15 inch deliveries in operation, and the level of the underground streams were lowered two feet in 15 months, during which period only six inches of rain fell. This district grew 356,000 tons of cane, valued at £600,000 approximately, to the farmers.

For economical transportation around most of the mills there are light railway systems run by the mills themselves. The importance of getting the cane crushed quickly after cutting is a matter that concerns both the farmer and the mill owner. If the cane is delayed two days there is a loss of 0.5 per cent. in the sugar content, and the cane is much harder to crush. Wherever practicable the railways are built to either 3 ft. 6 in. gauge or else 2 ft. 6 in. As the Queensland Railways are 3 ft. 6 in., the utility to the farmer is evident. The locomotives used are generally 2-4-0 tankers, weighing about seven tons, while the trucks, which have a capacity of about 1½ tons, are generally of steel construction, and are loaded by hand but discharged by means of machinery.

In crushing there are several points to be borne in mind. The cane is bought by the ton at a price calculated on the percentage of sugar it contains. As a general rule quantity and quality do not go hand in hand. In the 1925 season around Pioneer the top was 22 per cent. sugar content, but
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the average was 15.25 per cent. This year was one of over production. In 1926, which was a dry season, the top was 21 and the average 18 per cent. Thus it will be seen that the sugar content per ton is lower in a wet season than in a dry one, but, on the other hand, crushing is easier in the wet season. This has rather a far-reaching effect on the milling routine cost.

Before going further I would like to point out that practically all my figures were obtained from five mills—Hambledon, Geru, Pioneer, Inkerman and Kalamia—and that I had the privilege of working in Messrs. Drysdale Bros.' Pioneer Mill for all the 1926 crushing season. Consequently I know the procedure of this mill best. Pioneer is about 35 years old, but has been kept abreast of modern developments to a very large extent. Inkerman, on the other hand, is ten years old, and gives an extraction of 95.637 per cent. for the last four years against Pioneer's 94.61 for three years. At Pioneer steam is used right through the mill except in the powerhouse, whereas Inkerman Mill is electric driven except in the crushing room.

The cane is brought to the mill in open-sided trucks, ticketed, numbered and run over a weighbridge. It is then shunted on to the “rake” siding, and brought to the entry point of the mill. A large set of moving rakes, equal in width to the length of the truck, is gradually lowered on to the cane, dragging the sticks on to a slat conveyor, the speed of which is under the control of a winch driver seated immediately over No. 1 set of rolls. The aim of the winch is to keep the hopper above the rollers full without choking the rollers.

At Pioneer the slat conveyor is 75 feet long by 5 ft. 6 in. in width, with three sets of strokers to make the cane lie parallel with the sides. The conveyor discharges into the shredder, which is merely two sets of knives running at about 300 r.p.m. The cane drops in in lengths up to seven feet, and comes out in lengths of less than nine inches. The engine driving the shredder is almost invariably steam of the horizontal totally enclosed type, running about 400 r.p.m. They have forced lubrication, and very often a water circulating coil in the oil pump. For a mill crushing between 28 and 43 tons per hour it would require 30 h.p. engine at 90 lbs. steam pressure. Every live steam user in the crushing room works against a back pressure of 15 to 25 lbs.

The method of crushing is the same throughout Queensland. The cane is shredded, and then passes on to be crushed by No. 1 mill, after which it is sprayed to make it swell. No. 2 mill then crushes the cane. If it is a four-roller
null, the cane is again sprayed with hot juice and crushed a third time, and afterwards boiled in a mixture of juice and water called maceration. After passing through the fourth roller only 4 per cent. of sugar content is unextracted. If it is a three-roller mill the spraying after the second crushing is intensified, and the cane is boiled and crushed as before. This method leaves 5.5 per cent. unextracted, or a difference between the two methods of 1.5 per cent. The juice of Nos. 1 and 2 mills, which at this stage is a dirty white colour, is led to a tank and mixed with lime, and then pumped to the boiling stages. The extraction from the remaining mills is used as maceration. The addition of lime has the effect of arresting fermentation, and tends to form a scum with the impurities.

The machinery used in crushing naturally varies in detail at the different mills. The latest mills have small diameter rollers about 16 in. to 18 in. diameter running at a relatively high speed of two to three revolutions per minutes, with the pressure applied by hydraulic rams. The older installations had rollers about 28 in. diameter, working a speed of one revolution per 50 seconds normal crushing, with pressure held by bolts. The pressure applied to No. 1 roller is about five tons per square inch, No. 2 roller six, and No. 3 eight tons per square inch.

Perhaps a description of No. 1 mill at Pioneer would be of interest. This mill has the job of breaking down the cane, and gives an extraction of 89 per cent. of the available sugar contents. It comprises three 28 in. rollers (grooved), one on top and two underneath. The grooves are 5/8 of an inch deep and 7/8 pitch, and there is a clearance of 7/8 inch between the top and bottom rolls. The moving power is a 142 h.p. engine, 24 in. bore, 4 ft. stroke, running at 42 revolutions per minute, working through a double reduction gear of 35 to 1. All the engines work on 105 lbs. steam pressure from the boilers exhausting at 20 lbs. This exhaust steam is used in the boiling pans. The connection between the gear bed and the rolls is made by a cast iron coupling, which has to be renewed about every third season. The flywheel of the engine is 20 ft. diameter with a 0 in. by 4 in. rim section. The greaser on one shift, whilst greasing the rolls, slipped and fell into the hopper. The driver happened to be near, and instantly threw his link motion through neutral into full reverse without turning the steam off. There was a groan, and after about three-quarters of a revolution the engine went backwards. The greaser had the heel of his boot well into the rollers when it was released. He didn't do any more work that day.
The engines start at 11.30 on Sunday night, and, all being well, do not stop till 8.30 a.m. the following Saturday. During the crushing season of 18 weeks only three hours were lost in the crushing room through mechanical breakdown, and that was caused by a plate of steel, 5 ft. 6 in. x 14 in. x 3/8 in., breaking off the feeder on No. 3 rolls. It just got through. In the crushing room mechanical reliability is paramount, but other troubles come in. Owing to the design of the average sugar mill the steam machinery has to run against a back pressure of 20 lbs., as the exhaust is used for boiling sugar pans, triple effects and clarifiers, and, what is more important to the engine driver, boiling the cane as it enters the diffuser between Nos. 2 and 3 mills. For the satisfactory operation of No. 3 mill the meagass, i.e., crushed cane, should be at a temperature not less than 160 degrees F. when it reaches the rollers, and is taken by elevators and conveyor rakes from the final mill to the boiler room, where it is mechanically fired in the boiler. At Pioneer and Kalamia double-fired Lancashire boilers are used, but at the others water tube boilers. Pioneer has six boilers, giving a total heating surface of 9000 sq. ft., to supply all the calls upon the live steam. Behind the boilers are four exhaust steam receiver beaters. Induced draught of 2 in. W.G. is used, bringing the gaseous products of combustion from the fires through the exhaust heaters discharging into a 120 ft. stack. In 1926 there was perpetual trouble owing to the boilers not being large enough.

When the juice leaves the crushing room it is forced through a superheater, and arrives at the clarifying tanks at a temperature approximating 220 deg., where it is boiled. Impurities rise forming a scum with the lime that has been added. The scum is removed, leaving a brown mixture of molasses and water. There are two classes of clarifiers, power and hand, and each system has its staunch adherents. In either case, they are built on the second floor to facilitate disposal of the impurities.

From the clarifiers the juice is pumped into the triple effects, of which there are invariably two or more sets. When the juice enters the pans about 15 per cent. of it is crystallisable sugar, when it leaves there is 60 per cent. A set of effects consists of three steam-heated vacuum pans exhausting into a Torricellian condenser and wet air pump. Each pan is about 7 ft. diameter and 15 ft. overall, holding about 1200 gallons at normal working level. The first of the set has about a 12 in. vacuum, the second 19 in, and the third 25 in. or higher, with a heating surface of 2000 square feet each. The two sets at Pioneer evaporate 25 to 33 tons
of water per hour on exhaust steam. This works out at $4\frac{1}{2}$ to $6\frac{1}{2}$ lbs. per square foot per hour.

From the time the cane enters the carrier to when the juice leaves the effets is about three hours 45 minutes. The juice at this stage is very thick, but has not commenced to crystallise.

From the effets the syrup is stored until a sufficient quantity is collected for the sugar boilers. I had considerable trouble to get any information from the sugar boilers concerning the operations on the pan stage, but there was not much to find out. The pans are jacket heated. Occasionally you will find a tubed boiler made usually from a converted effet. They operate on a vacuum as high as can be economically maintained; at Pioneer it was 26.5 in. mercury. It takes about six hours boiling at a temperature of 140 deg. before the syrup is ready to be crystallised. The crystallisation is done by mixing 7 lbs. of castor sugar per ton of syrup, and boiling again until samples withdrawn show the required size of crystal. After this process the syrup is run into agitators above the centrifugals to cool before drying.

There is great divergence of opinion regarding the type of vacuum pump most suitable for the job—vertical Edwards or horizontal tandem steam driven with water sealed stuffing boxes. In the modern mills the vertical type running at about 90 r.p.m. is mostly favoured. All the older mills use the horizontal type.

Each sugar pan has its own vacuum pump, but there is only one set of pumps for the effets.

The centrifugal separators are driven in three ways—electric, hydraulic and belt. It is hard to say which is the best, but the men who use them prefer the hydraulic. The usual peripheral speed is about 3600 to 4400 feet per minute. At this speed a complete cycle in a 90 lb. basket can be done in less than $3\frac{1}{3}$ minutes. The cycle comprises filling, starting, $1\frac{1}{2}$ minutes full speed, purging with steam, braking and discharging into a screw conveyor.

The sugar as it comes out of the fugals varies from a sandy colour to dark brown, depending on the amount of boiling in the effets and impurities present.

The molasses from the first fugalling is boiled again and refugalled, the second crop of crystals being called jelly sugar. This is an inferior grade, and does not get a good sale.
The percentage of sugar in a farmer's cane is carefully ascertained by a Government analyst every day, and the total extraction checked against the possible extraction. At Pioneer, 1926, our best figures gave an extraction of 95.7 per cent. of the sugar in the cane in the crushing room, and 98.7 per cent. of that appeared as sugar crystals. The average, of course, was lower for the season.

If the cane has been burnt to clear it of trash, the extraction is lower and the cane harder to crush. There were 15 varieties of cane around Burdekin, but either Badilla or C509 was the easiest crushing. From the time the cane entered the carrier to reaching the boiler room was seven minutes, and a crushing of 33 tons an hour represented approximately 120-160 bags per shift. The sugar as it is bagged at the mill is not the finished product we are all so familiar with. The crystals are sent to the refinery, where they are boiled with lime again, and a second scum removed.

If there is anybody sufficiently interested, there is a wonderful field for improvement even in modern mills. As an example: If you can design a continuously operating centrifugal separator which works efficiently you will be rushed, as the present method is very unsatisfactory.

Mr. A. E. Hughes said Mr. Robison was to be congratulated upon the able manner in which he had dealt with the sugar industry—an industry which in its importance to Australia was parallel with wheat and wool. The sugar industry was far removed from the coal fields, consequently it had to depend for fuel upon something situated conveniently to the mill. The main problem was to run the mill without extraneous fuel. That could only be done when every advantage was taken of the thermal units received into the mill. A ton of cane would give one-eighth of a ton of megass, which was the crushed fibrous vegetable matter of the sugar cane. In the process of crushing boiling water was applied, consequently it was high in water content—45 per cent. was a good average figure. He submitted a table showing the relative thermal value per ton of megass. For instance, megass had a B.T.U. value of 4400 as against molasses 4000. In modern mills it was the practice to use triangulated rollers, the single roller on top and two below. Thus the cane had a double crush in going through. In the first mill there would be a depth of cane varying from eight to 12 inches, the length of the cane being about five or six feet, from which they were cut to about eight or nine inches. The first crush would be about one inch; the second 13/16th; then the blanket would be megass, with about 30 per cent. sugar. The third roll would be about 1/4 inch. The enormous
amount of pressure on those rollers might be imagined when it was remembered that a blanket ranging from six to nine inches thick was compressed between them. The rollers were 32 inches diameter and six feet long. From the rollers to the boiler the megass would lose about five per cent. of its moisture. Necessarily the engine discharged its steam at a little higher than atmospheric pressure, simply because the steam, after it had done its work in the engine, must do useful work elsewhere. The pressure was kept as low as would serve to do the evaporating work. The substance went into a system of multiple feed evaporators. He had shown in his diagram the quadruple style, because it carried a little more than the treble. The initial steam was 5.2 lb. pressure, which was equal to a temperature of 227 deg. F. They took in about 2,000,000 lbs. and evaporated up to 500,000 lbs. The vapour that was driven off by the action of boiling went up through a pipe into the heating chamber of the second still. The condensed steam served as feed water for the boilers. The condensed water in the second still was used for maceration. The vapour was reduced from 75 lb. in the first still to about 40 lb. in the second; it then passed on to the third, and from then arrived at the fourth at a temperature of 130 deg. Finally the vapour from the fourth still went into the barometric condenser. It was necessary to use every endeavour to conserve heat. The mills that turned out the best grade of sugar were generally those that were conducted on the most economical lines. As to the centrifugals, they were all good. He had used every variety. They all did similar work and at about the same cost.

The President asked if the same conditions would obtain at the refineries as at the mills.

Mr. Hughes said there was no crushing at the refineries. The sugar reached the refineries with a very high content of molasses, and certain mechanical and chemical impurities. The cane itself varied from a dark yellow to almost a purple black. The dark cane carried a fair proportion of colouring matter. He had seen juice at the mills which was distinctly greenish. That had to be eliminated, and that was the work of the refineries. When the grey sugar arrived at the refinery it was submitted to a process of washing with a liquor made from the previous batch, by means of which a large amount of the original molasses impurities was remover. The resultant crystals were melted up and underwent various further processes. One method was to treat them with lime; while another treatment was with phosphoric acid. A third method was a combination of the first two. A fourth was to treat it with lime and neutralise it with carbon dioxide.
When the mechanical impurities had been removed it was treated with one of the synthetic carbons to decolourise it. It then became clearer than water. After discolorisation the liquor was evaporated in a vessel until it arrived at a density of about 37 per cent. water. Crystallisation would take place at about 32 per cent. of sugar. From there it went into vacuum pans. The liquor was drawn into one of the evaporating vessels and heat applied. The application of the heat reduced the vacuum, and as the vapour was driven off and the liquid was concentrated the vacuum might rise to 25\frac{3}{4} inches. During that process the liquid became denser, until it arrived at a stage when if a sample were placed upon glass it would have somewhat the appearance of diamond dust. Sugar crystals were longer than wide, and the aim of the boiling process was to separate the crystals.

The President thanked Mr. Hughes for his lucid explanation. He referred to the brown sugar in use during war time.

Mr. Hughes said that was the raw sugar. In the initial stages the raw sugar was mixed with syrup; and the syrup that came from that mixture went to make the basis of treacle. As the sugar was refined it was boiled and the syrup strained off; the resultant syrup was made into golden syrup. Golden syrup was not a cane sugar. It was un-crystallisable, and had been converted into a fructose. The difference between golden syrup and treacle was that the golden syrup was strictly a refinery product, while treacle was the product of raw sugar.
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