# SURVEY OF PAN BOILING PRACTICE IN THE SOUTH AFRICAN SUGAR INDUSTRY.

By R. M. BECHARD.

## PRELIMINARY.

In order to clear the way for any subsequent study of pan boiling conditions in South Africa, a questionnaire was prepared. This was sent to all factories whose results are included in the comparative statements of laboratory returns issued by the South African Sugar Experiment Station.

The response was very encouraging; all factories but two answered the questionnaire, and of these two one factory operates the Suchar process, and on that account did not see its way clear to separate the factory operations from those in the refinery. The other claims its technique to be so far in advance of common practice, that patent rights on the methods used are about to be registered. Until these are granted, the management is unwilling to publish them.

Factory No. 1 operates a double carbonatation process, making about 85 per cent. high grade white sugar. The others, 16 in all, operate a sulpho-defecation process. They make either a proportion of plantation white sugar or a high-grade raw of 98 to 99 polarization sugar.

## RATE OF THROUGHPUT.

The first question required both the average and the peak of milling and sugar production rates. With this were to be included the average and peak boiling house recovery.

Unfortunately, most of the factories did not realise that the boiling house recovery asked for, was that obtained while peak production was being maintained, and gave the peak boiling house recovery. No doubt this omission was primarily due to loose wording of the questionnaire. It is possible, however, to correlate high production rate and variations in recovery from the answers given. The answers to this question are summarised thus:—

Table 1.—**Rate of Throughput and Recovery.**

| Factory No.* | Tons of Cane per Hour. Average. | Peak. | Peak per cent. Mean. | Tons of Sugar per Hour. Average. | Peak. | Peak per cent. Mean. | Boiling House Recovery Average. |
|---|---|---|---|---|---|---|---|
| 1 | 127.0 | 135.5 | 106.7 | 14.90 | 15.90 | 106.7 | 89.36 |
| 2 | 71.8 | 76.1 | 106.1 | 8.04 | 9.30 | 115.6 | 87.15 |
| 3 | 12.7 | — | — | 1.66 | — | — | 89.43 |
| 4 | 61.6 | 65.9 | 106.9 | 7.06 | 7.92 | 112.2 | 89.27 |
| 5 | 125.8 | 131.6 | 104.6 | 15.0 | — | — | 89.79 |
| 6 | 90.6 | 93.2 | 102.9 | 10.07 | 11.43 | 113.5 | 88.24 |
| 9 | 27.7 | 29.6 | 106.9 | 3.36 | 3.91 | 116.4 | 89.09 |
| 10 | 73.5 | 76.5 | 104.1 | 8.29 | 9.36 | 112.9 | 87.55 |
| 11 | 80.6 | 82.1 | 101.9 | 8.70 | 9.50 | 109.2 | 85.20 |
| 12 | 102.5 | 108.5 | 105.9 | 11.44 | 13.34 | 116.6 | 88.14 |
| 14 | 71.2 | 73.8 | 103.7 | 8.52 | 9.54 | 112.0 | 89.08 |
| 15 | 38.2 | 38.5 | 100.8 | 4.30 | 4.60 | 106.9 | 86.77 |
| 17 | 22.1 | 23.1 | 104.5 | 2.47 | 2.65 | 107.3 | 88.88 |
| 18 | 35.0 | 37.2 | 106.3 | 4.14 | 4.80 | 115.9 | 89.30 |
| 19 | 30.0 | 32.5 | 108.3 | 3.20 | 3.50 | 109.4 | 83.13 |
| 20 | 37.7 | 39.0 | 103.5 | 4.50 | 5.00 | 111.1 | 90.60 |
| 21 | 44.1 | 47.0 | 106.8 | 5.61 | 6.36 | 113.4 | 89.84 |

* The numbers of the factories are identical with those used by the Experiment Station in the Annual Summary.

## PAN BOILING EQUIPMENT.

The next question asked for the following details of the pans: number in use, construction, area of heating surface and cubic capacity. From this data the square feet of heating surface and the cubic feet of capacity per ton sugar produced per hour were calculated. The highest, lowest and average ratio of heating surface, to that of capacity, was also worked out and are given in the next summary.

Table 2.—**Pan Equipment.**

| Factory No. | No. of Pans. | Types of Pans. | Ratio of Heating Surface to Capacity. Highest. | Lowest. | Average. | Per Ton Sugar Hour sq. ft. Heating Surface. | c. ft. Capacity |
|---|---|---|---|---|---|---|---|
| 1 | 5 | 4 f. cals., 1 coil ... ... | 1.44 | 1.33 | 1.36 | 549.7 | 402.8 |
| 2 | 4 | 3 fl. cals., 1 cal. ... ... | — | — | — | — | — |
| 3 | 2 | 1 in., 1 f. cal. ... ... | 1.14 | 0.98 | 1.05 | 441.6 | 421.7 |
| 4 | 4 | 2 st., 2 f. cals. ... ... | 1.75 | 1.52 | 1.63 | 582.5 | 357.0 |
| 5 | 6 | 5 cals., 1 coil . ... ... | 1.53 | 1.10 | 1.33 | 442.3 | 393.4 |
| 6 | 4 | 4 f. cals. ... ... ... | 2.16 | 1.73 | 1.92 | 772.0 | 402.2 |
| 9 | 3 | 2 coils., 1 f. cal. ... ... | 1.58 | 1.22 | 1.36 | 556.6 | 407.8 |
| 10 | 3 | 2 f., 1 fl. cals. ... ... | 2.25 | 1.65 | 1.95 | 458.4 | 235.2 |
| 11 | 5 | 1 fl., 4 con. cals. ... ... | 1.70 | 1.40 | 1.63 | 939.1 | 575.4 |
| 12 | 4 | 2 f., 2 st. cals. ... ... | 1.90 | 1.56 | 1.74 | 547.2 | 313.8 |
| 14 | 3 | 3 f. cals. ... ... ... | 1.42 | 1.32 | 1.36 | 370.2 | 272.2 |
| 15 | 4 | 2 f., 1 con., 1 fl. cals ... | 2.28 | 1.37 | 1.66 | 907.0 | 546.6 |
| 17 | 3 | 1 st., 1 con., 1 f. cals.... | 1.57 | 1.25 | 1.40 | 1121.5 | 799.2 |
| 18 | 4 | 3 f. cals., 1 coil ... ... | 1.45 | 1.00 | 1.33 | 676.3 | 507.2 |
| 19 | 4 | 4 f. cals. ... ... ... | 1.62 | 1.39 | 1.49 | 817.8 | 546.9 |
| 20 | 4 | 4 fl., 1 in. cals. ... ... | 1.78 | 1.32 | 1.47 | 456.7 | 311.2 |
| 21 | 4 | 3 f. cals., 1 st. li. ... ... | 1.58 | 1.47 | 1.55 | 731.0 | 472.4 |
|  |  | Average capacity per ton sugar hour ... ... ... |  |  |  | 648.1 | 435.3 |

Under the heading "types of pans": "cal." means a calandria pan and "coil" means a coil pan; "f." means flat, "fl." means floating, "con." means conical, "st." means stepped-in, "in." means inclined tube plate, and "st. li." means the new type of so-called stream-lined pan.

The largest pan in operation has a heating surface of 3,500 sq. ft. and a working capacity of 1,620 cubic feet of massecuite.

The 17 factories are equipped with:—

40 calandrias with flat tube plate.
7 calandrias with conical plate.
6 floating calandrias.
5 stepped calandrias.
2 inclined tube plates.
1 calandria with stream-line construction.
5 coil pans.

It is evident that some factories have ample capacity, provided, of course, that supply of injection water, vacuum pumps and steam are adequate. Capacities of others (more particularly as regards the least elastic, viz., heating surface) are, however, altogether too low, especially where the equipment has not been studied with a view of obtaining a high circulation rate, or where the ratio of heating surface to capacity is less than 1.50 sq. ft. heating surface per cubic foot capacity.

The highest ratio is found in a pan of heating surface of 1,400 sq. ft. and capacity 550 c. ft., this ratio being 2.55; while the lowest was found in a small pan with flat tube plate which has a ratio of only 0.98.

## PAN BOILING METHODS.

**Graining.**—One factory seeds by means of the sugar from third massecuites. These again are seeded in the general way.

Three factories claim to seed with sugar dust, the quantity per 100 cubic feet of finished massecuite being between 5 and 8 grams of fine sugar. This would mean a crystal growth of approximately 220,000, which appears optimistic.

Including these three, thirteen factories in all use fine sugar as an accelerant to graining. Some shock with syrup after dusting.

Two factories shock with syrup, one of which after mingling with blanket.

One factory grains by the waiting method, while another one, whose reply is not tco clear, appears to do the same.

**Feeding of Pan.**—The methods of feeding the pans, which can be either continuous or by repeated "drinks," appear to be well divided in equal proportions. It is fairly evident, however, that those with better boiling house recoveries favour the continuous method.

**Massecuites made.**—

1 factory works 2 massecuites and no jelly.
4 factories work 3 massecuites and no jelly.
5 factories work 2 massecuites plus jelly.
7 factories work 3 massecuites plus jelly.

Those factories producing jellies all boil the raw molasses from their lowest grained massecuite to string proof.

One factory works back the final massecuite sugars into a syrup magma to seed first and second massecuites.

One factory remelts almost all the sugar from the final massecuite so as to raise the proportion of the first massecuite.

All factories build their last massecuite from a footing of grained syrup, which is then fed by molasses from the immediately higher class so as to obtain the lowest purity possible from the combination. The majority use the smallest quantity of grain that will cover the heating surface.

All but one factory build the second massecuite from a footing of grained syrup built up from molasses of the preceding higher grade. In the case of those working second massecuites, the wash from all magmas is used.

One factory is believed to build the second massecuite from wash of mixed magmas, which is grained with dust plus a little syrup admixed, the whole boiling being done almost entirely out of wash. It is perhaps significant that this factory has for some years led in excellence of boiling house recovery.

Of the 11 factories which work a third massecuite, few operate on pure syrup, which in this country has a very high purity. It is preferred to reduce the purity of the syrup by boiling back a certain amount of wash from mixed magmas.

Most factories work a relatively low brix of syrup ranging from 47° to 58°, but most at a range of 54°. This comparatively low range is found more practical, as higher densities coupled with higher purities crystallize too rapidly to allow good control of crystal building.

**Molasses Working.**—Only two factories do not dilute, all factories heat, some being more particular than others in limiting the temperature to 65/67°C., whilst some heat even higher.

Only three factories settle after liming to neutral point plus heating and dilution.

The final brix of the treated molasses ranges from 55° to 75°.

**Circulation Water in Pans.**—Eight factories employ circulation water for promotion of crystal growth, and find its use particularly valuable during graining stages in clearing up unwanted crops in the final stages of the low grade massecuite.

One factory applies a discharge of water and molasses to ease striking, which is of course not circulation water.

Eight do not employ circulation or movement water; three factories apparently are not aware of the practice.

**Boiling Control Instruments.**—Only five factories make use of these instruments, of which only one continuously on all products. All instruments are of the electrical conductivity type, and all users report advantages, particularly in detecting poor pan circulation and faulty construction.

The control of low grade massecuites particularly benefits from its use. No success, however, is claimed for conductivity chart duplications, and it seems certain that there is no possibility of automatic pan boiling methods until pan construction and other requirements are improved.

**Boiling Cycles.**—Pan boiling practice appears to have three main variants.

No. 1 variant allows for further boiling from the original grain and a variation of quantity of molasses according to purity range, predetermined for the massecuite.

It is significant that the variants Nos. 2 and 3 are practised by factories which produce low purity exhaust molasses.

**Crystallizers.**—In operation there are :—

5 Lafeuille.
152 Herisson coil equipped.
8 other types water-cooled.
1 Werkspoor.
140 ordinary air-cooled type.

Capacities vary from 728 c. ft. of water-cooled types to 4,248 c. ft. of air-cooled per sugar hour, the equipment being fairly well distributed amongst the various grades of massecuites. Water-cooling is seldom if ever practised on low grades, though good results have been reported when preliminary cooling followed by reheating prior to curing has been tried. In general, however, observations are that the high viscosities found in this country make it essential that the time factor be allowed for in the lower grades of massecuites. The water-cooled crystallizers have been beneficial in the case of the higher grade massecuites with their lower viscosities, thus increasing the crystallizer capacity.

**Massecuite Dilution.**—In almost all cases massecuites are diluted during the cooling in the crystallizers. Water (through sprinklers and otherwise) and molasses of approximately the same purity of the mother liquid are used.

**Blowing-down of Pans.**—The practice of blowing-down of pans with steam is general. In one or two cases the "injection" is isolated and afterwards used for pan feeding, with good results reported; in other cases the injection simply goes to the crystallizers.

**Jelly Tanks.**—Twelve of the 17 factories boil jelly from the molasses from low-grade grained massecuites.

Few factories appear to have adequate capacity, since the cooling time varies from two weeks to several months. It is considered that a cooling period of from 6 to 8 weeks is required.

**Centrifugals.**—*Foreworkers.* Only one battery of 48in. machines is in operation, the majority being 42in. for higher grade and 36in. to 30in. for lower grade massecuites.

Various types of drives are in use, but belt drives from a shaft driven by a high-speed steam engine or a motor are most common. Direct electric drives are also in use, as also are the hydraulic types.

Almost all foreworkers are of the self-dumping conical bottom type; no mechanical ploughs are reported to be in service.

When white sugar is produced each grade of massecuite is handled separately. Ordinarily there is enough first massecuite to make a factory's quota of white sugar, and second and third massecuites are cured and bagged as raws.

For final low-grade massecuites the 30in. high-speed machine is mostly favoured, although one or two factories have the larger type of 36in. or 42in.

Capacities vary according to type of equipment—speed and size of machines. The average appears to be 0.9 machine of 42in. at 900 r.p.m. for foreworkers per ton of sugar per hour, which equals 1.4 machines of 36in. at 1,100 r.p.m.

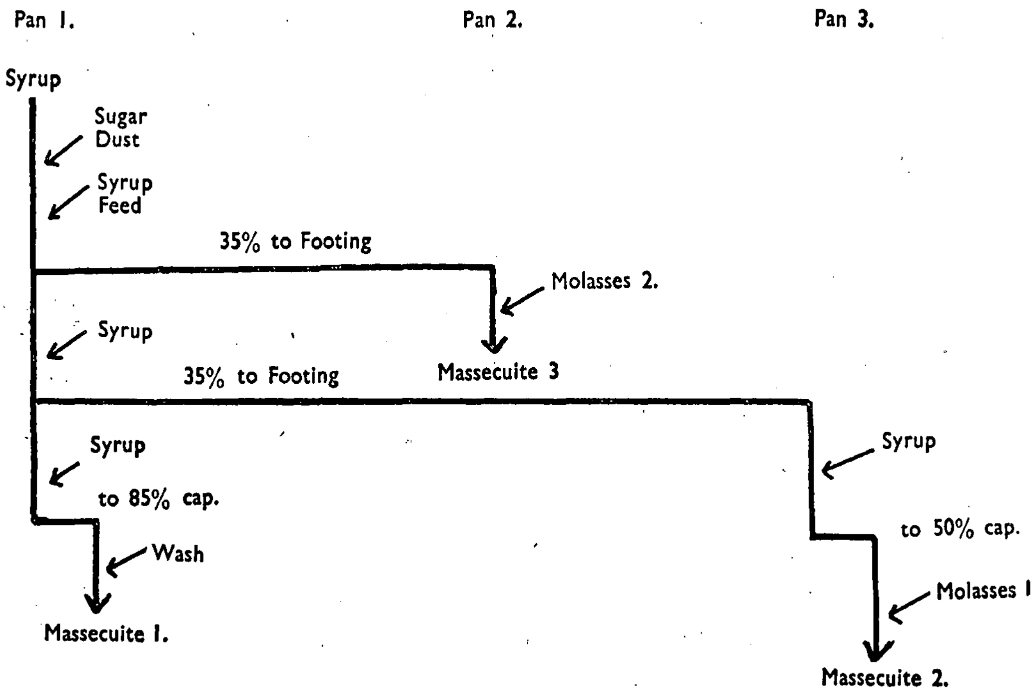
The following is the inventory of the machines in the 17 factories under review :—

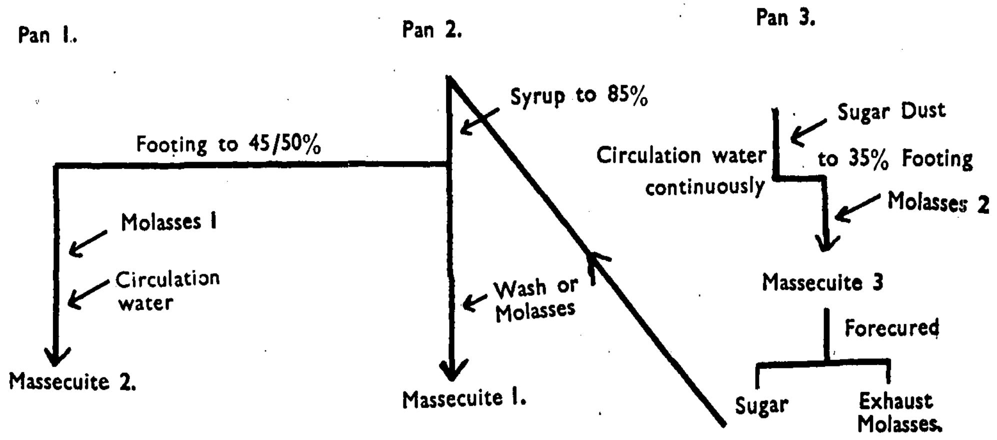
*Foreworkers.*

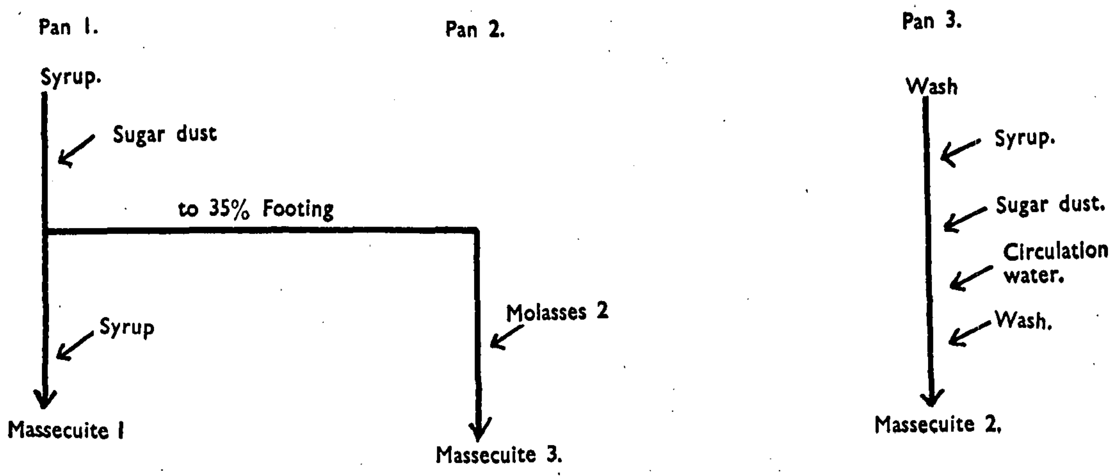
| Diameter. | First Massecuite. | Second Massecuite. | Third Massecuite. |
|---|---|---|---|
| 48in. | 5 | — | — |
| 42in. | 12 | 32 | 14 |
| 36in. | 21 | 25 | 24 |
| 30in. | 9 | — | 28 |

*Afterworkers.*

| Diameter. | | |
|---|---|---|
| 32in. | 12 | for first massecuite only. |
| 36in. | 125 | for general duty. |
| 30in. | 151 | for general duty. |


No. 1 MAIN VARIANT


No. 2 VARIANT BY ONE FACTORY


No. 3 VARIANT BY ONE FACTORY

## SUMMARY.

Boiling house equipment and technique of the South African Sugar Industry has been reviewed.

Wide variations are recorded in pan, crystallizer and centrifugal capacities, the indications are that 600 sq. ft. heating surface to 400 c. ft. capacity are required per ton of sugar made per hour.

Pan technique consists generally of grain production by shocking with sugar dust and building up massecuites with syrup and molasses of predetermined purity to the required standard.

Pan control instruments are not in general use and the use of circulation or movement water is gradually being accepted. The system of blank boiling of low grade molasses is still much in evidence.

Herisson coil-equipped crystallizers are in common use throughout the industry, but the cooling of low grade massecuites is not favoured. Crystallizer capacities vary widely. It would appear as if approximately 1,000 c. ft. of water cooled plus 2,000 c. ft. of air cooled capacity per ton of sugar per hour would fill our normal requirements.

As regards centrifugals, the South African practice seems to prefer the smaller diameter machine, and the requirements are approximately as follow :—

0.9 machines of 42in. diameter *or*
1.4 machines of 36in. diameter as foreworkers, and
2.0 machines of 36in. diameter *or*
3.0 machines of 30in. diameter as afterworkers.

The development of high-speed curing together with preheating of massecuite has not made much headway in this country, although those who have introduced the moving heating coil in the centrifugals mixers speak highly of the results obtained.

# ADDENDUM.

By G. BOOTH.

It is to be hoped that in the not too distant future this survey will develop into an opportunity to have all individual factory installations examined for capacities and efficiencies. An analysis of the questionnaire points out the necessity for this. One cannot but be impressed by the wide variations existing in pan designs and capacities per ton of cane crushed or sugar made.

In particular, as Mr. Bechard has indicated, in calculating the ratios of heating surface to volume of completed massecuite, and more especially in comparing the diameter of the centre well with the pan diameter, this lack of uniformity in pan design is obvious.

In the past pans and evaporators were sold on area of heating surface and not on performance. Recent years, however, have brought new ideas, which now compel the question whether our older types of calandria should not be rebuilt so that increased circulation and, in consequence, increased capacity may be obtained.

Tromp[3] quotes the case of a 1,200 c. ft. capacity 12 ft. diameter pan having a central downtake of only 3 ft. diameter. The ascending tubes (418 by 5in. diameter by 4ft. long) provided a free area of 7,600 sq. in. and the downtake area was only 1,017 sq. in., thus the circulation going down had to be seven times as fast as the upgoing, with consequent impaired circulation efficiency. Tromp further mentions a modern pan whose proportion of face tube area to area of downtake is about 2.1 : 1. Walter E. Smith of Hawaii[2] also stresses this point in discussing designs, giving the ratio of central well to diameter up to 50 per cent. The proportion of heating surface to volume is also surveyed.

In Natal pans this figure is fairly constant, being about 1 c. ft. of capacity to about 1.5 sq. ft. heating surface, although one factory reports 1 to 2.54. This may be a special design.

Another point of importance is the ratio of graining volume to total massecuite volume.

So far as can be observed, most of our pans are out of balance judged by modern design, in that the graining volume occupies too much space in the pan, the result being that the pan is boiled far too high before striking.

This extra capacity to over full mark (fixed by the chief factory operator and invariably over the maker's mark) is required, especially in raw sugar work, for the purpose of boiling massecuites to a prescribed purity, which of course is essential in an organized boiling scheme. Nevertheless, the fact remains that this is bad practice ; it is wasteful in pan capacity, since the speed of boiling is reduced and, incidentally, a loss of available sugar results.

Webre[4] gives his observations that it is quite common practice to boil 7 or 8 feet above the top tube place, which, together with the 4 feet length of tube, makes 11 to 12 feet under the surface. At normal vacuum on top the theoretical temperature at 12 feet below is 200°F. No boiling takes place at this depth. Destruction of crystals and under-saturation takes place, the extent of which depends largely on the pan operator and the design of the pan itself. The pan thermometer shows only the average temperature resulting upon the balance of the temperatures of the explosions. In localized spots, however, variations in temperature up to 50°F. have been observed.

These points are of supreme importance in the judging of a pan's performance. It is interesting to recall that Mr. Bechard himself made observations on comparative yields from massecuites boiled by two separate pans of identical design, the work of one being consistently better than the other.

Yet another point follows, namely, the system and layout of the condensing plants, the air line, water line and steam supply.

There can be no doubt that the central condensing system, with or without the separate condensers, has many disadvantages. Continuous density recorder on the outflow from the last pot of an evaporator will reveal large variations due to fluctuations in steam pressure and condenser water supply, especially where the one pipe supplies all the condensers.

Continuous cuitometer records on low purity massecuites boiling over a long period in a pan coupled up to the same vacuum pump as quick boiling high grade pans, demonstrate the tremendous obstacles placed in the way of such a pan maintaining its equilibrium. It is obvious that, where several pans and the evaporator are coupled to the same air and water line, and especially where one pan at time of concentrating for grain has an evaporating rate up to and exceeding 17lbs. of water per square foot of heating surface, the other pans, particularly at an average thermometer temperature of 130°F., are simply having a bad time. They stop working, the massecuite becomes slack and undersaturated.

The limited use of the cuitometer control and movement (or circulation) water in our factories is a matter for surprise, considering the publicity these aids to pan boiling have received these past ten years. The use of movement water, especially at graining time, is "as old as the hills."

Attention might be drawn to Alewyn's articles[1] on the use of movement waters. It is interesting to record that the variant No. 2 in Mr. Bechard's survey was tried with much success in one Natal factory after private communication with Alewyn in Java. The method was eventually adjusted only because of the difficulty of maintaining the massecuites equilibrium during the constant interruptions inherent in a central condensation system as referred to above. Shortage of crystallizer capacity was also a drawback. The scheme, however, marks a definite advance on the orthodox ideas where the plant and layout are suitable for its addition, and Mr. Bechard's remarks on the excellence of the boiling house recovery of the factory that practices this or a similar method are to be noted.

These points are contributed to Mr. Bechard's paper because the best way of recognising its importance is to broaden the scope of the work. As already mentioned, our Association hopes that some day it will be in the position to open up an intensive study on the economy and efficiency of our vacuum pans and methods employed. The term "undetermined losses" is anathema to all conscientious technicians, and many of these losses can surely be attributed to faulty pan designs, inadequate condensing systems and also, of course, to operating methods that are capable of improvement.

## References.

[1] Alewyn, W. F. (1933) : Simple Method of Boiling After-product Sugars, *and* Further Notes on Boiling After-product Sugars. I.S.J., **35,** 352, 465.
[2] Smith, Walter E. (1935) : Vacuum Pan Design and Operation. I.S.J., **37,** 20.
[3] Tromp, L. A. : Machinery and Equipment of the Cane Sugar Factory. Norman Rodger.
[4] Webre, Alfred (1935) : Temperatures in Vacuum Pans. Proc. Int. Soc. of Sugarcane Tech., 536.

Mr. WOUTERS wanted to know whether it would not be possible to use sodium carbonate instead of lime for neutralising molasses.

Mr. BOOTH said that very few factories ever attempted to neutralise molasses. A few gave the molasses for the final boiling a small drink of lime in the pan; but he did not believe in adding any alkali to molasses. In fact, the tendency in recent years had been not to add any chemicals to molasses.

Mr. RAULT regretted that cubic feet of individual massecuites per ton of cane were not given. Tons of sugar actually bagged per hour did not give a true indication of pan work, especially where a lot of remelting had to be resorted to in making white sugar. He would have liked to see a record of the cubic feet of individual massecuites boiled per ton of cane or per hour. Mention was made of a 48-inch battery of centrifugals. These machines were in use at Natal Estates, but they were not very satisfactory, as it was found that they did not cure the sugars dry enough. During the war it might be difficult to get crystallizers; but he thought the days of making jelly boilings were past. Ours was one of the few countries which still persisted in this inefficient method of crystallization, which could not be controlled and was dependent on time of cooling and luck for results. Water-cooling for last massecuites should not be condemned without further experimentation. At Natal Estates, working admittedly with a rather higher purity product of less viscosity than that of sulphitation factories, excellent results were obtained. At Ewa, in Hawaii, water-cooling of low massecuites had been very favourably reported upon and no false grain was noticed with massecuites of less than 60 purity. Water-cooling increased crystallizer capacity.

Mr. VIGER said he could not agree with Mr. Booth that no chemicals should be added to molasses. There was a big drop in pH from syrup to molasses, and lower grade molasses might become so acid as to cause inversion. Two years ago he was asked to do the pH of molasses from a certain factory; the undetermined losses had increased to a high level. The management was rather surprised to find the pH so low. He thought it necessary to add a small quantity of trisodium phosphate to molasses. In normal times the cost of this chemical was not excessive, the amount used was very small, therefore the increased manufacturing cost would be negligible. The use of trisodium phosphate in molasses gave good results because it consolidated the alkalinity.

Mr. BOOTH agreed with Mr. Rault that cubic feet of massecuites referred to the ton of cane was a valuable figure, but as many factories did not have this information it was omitted.

In regard to adding chemicals to molasses, the practice of liming molasses was now practically abandoned, although some chemists add a little lime water to their low grade massecuites whilst in the pan to guard against a drop in pH.

Referring to pan steamings, Mr. Booth gave his opinion that to isolate steamings into a special tank, with all its attendant fittings, was not worth while, although admittedly a certain amount of resolution of sugar took place when running steamings into the crystallizer. The best method was to guard against excessive steaming. A surprising amount of time and steam could be wasted in this operation.