

TEMPERATURE DISTRIBUTION IN A STIRRER-EQUIPPED VACUUM PAN BOILING C MASSECUITE

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Abstract

Temperature distribution and condensate flow measurements were made in a C pan equipped with an agitator. The overall temperature difference throughout the massecuite did not exceed 5°C. The agitator despite being underpowered reduced boiling time by at least one hour in boiling C massecuites from a grained footing.

Introduction

Initial work on a C pan at Darnall which was equipped with a stirrer had shown a fluctuation in massecuite temperature throughout the whole boiling mass when the stirrer was stopped and restarted. The temperature was, however, reasonably constant at all depths of the massecuite except for some seemingly unrelated peaks. As the stirrer had been removed from this particular pan, further work along these lines was carried out at Umzimkulu where there was another stirrer equipped pan.

Installation

The UK pan was built by James Brown and Hamer in 1966 and is equipped with a pan stirrer (or agitator) supplied by Dorman Long. The pan is therefore of modern design and construction.

Strike volume	42,5 m ³
Heating surface	223 m ²
Tubes	700 × 114 mm OD, mild steel.
Pan diam.	4 724 mm
Downtake diam.	1 829 mm

The stirrer specification calls for a 45 kW 1 450 rpm electric motor through a fluid drive coupling (with output range from 1 345 to 675 rpm) and 30/1 ratio gearbox to drive a stirrer at a variable speed of 45 to 22,5 rpm. This would give impeller tip speeds of 4,27 to 2,13 ms⁻¹. In practice, the shaft speed did not exceed 13,5 rpm.

The arrangement of the steam inlets must also be described as it is felt that this design contributes much to the vigorous circulation of this pan. A circumferential steam box surrounds the calandria and there are six wedge shaped steam inlets (with no tubes to about half the depth of the calandria) evenly spaced around the pan.

Condensate drains were led into a 150 mm pipe which was fitted with a bypass. The condensate measurements were made using this bypass connection.

Measuring equipment

Pockets for thermocouples were installed in 50 mm pipes inserted through the pan wall (see Figure 1). These were supported inside the pan from the pan wall or calandria as required. No. 1 was 1,5 m above

the calandria about 300 mm in from the wall. Nos. 2, 3 and 4 were all 300 mm above the calandria; No. 2 300 mm in from the pan wall, No. 3 150 mm in from the downtake edge and No. 4 close to the stirrer shaft. No. 5 was fitted midway down the saucer well below the calandria. A six-point temperature recorder with iron-constantan thermocouples was used.

Absolute pressure was recorded for each boiling.

Condensate was measured using a proportional head weir plate giving a linear flow characteristic and a low head (125 mm W.G.) differential pressure cell and recorder (see Figure 2).

In this way continuous monitoring of these conditions could be made.

Temperature distribution

The temperature plots made at DL by Warne in 1968, using previously described equipment,¹ are shown in Figure 3.

The scale is large in order to show detailed temperature changes but most of the readings remained grouped within the band which is shown heavily

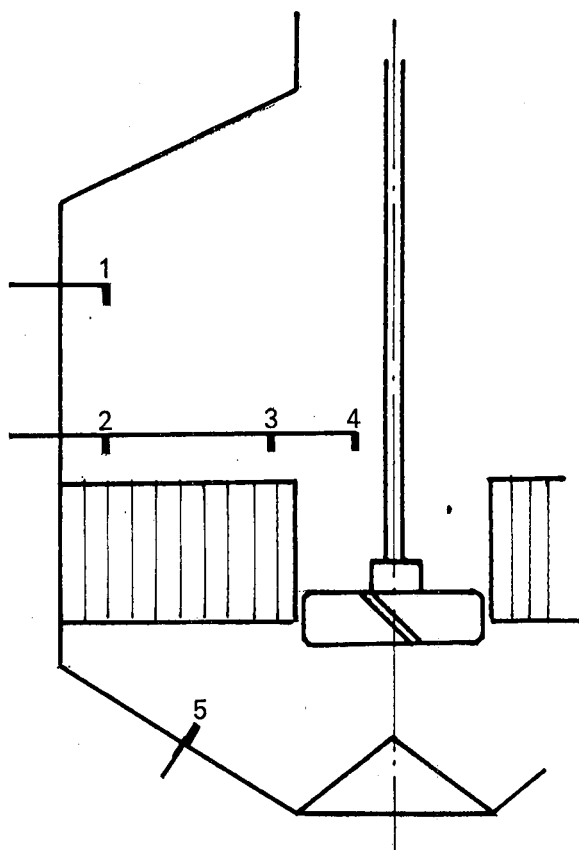


FIGURE 1: Location of thermocouples in C massecuites pan at UK.

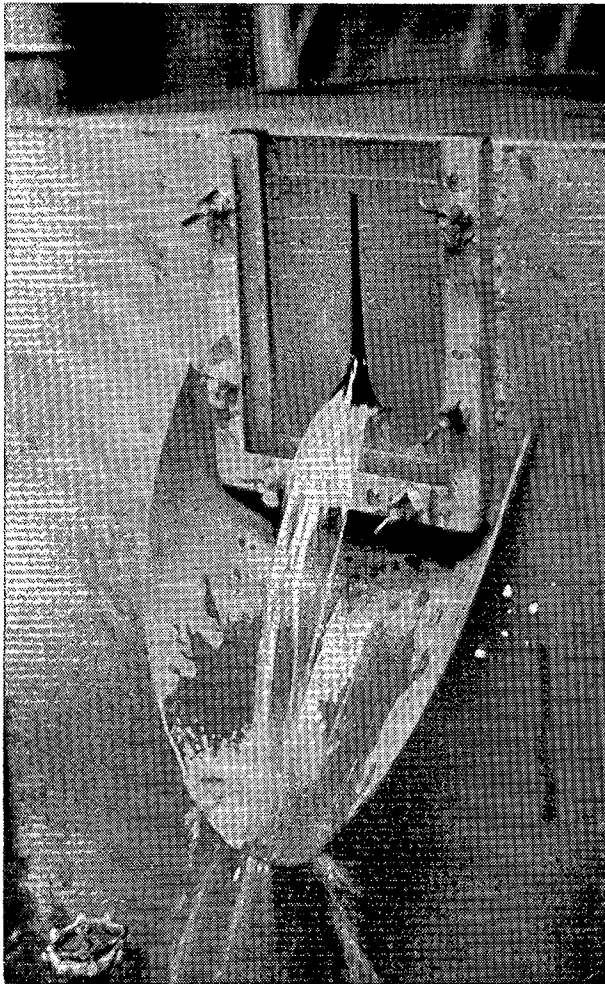


FIGURE 2: Weir plate used for measuring condensate flow.

dotted. It can be seen that a steep change in temperature occurred throughout the whole massecuite with the stirrer switched alternately on and off for half hour periods. From subsequent work at UK it is concluded that with the stirrer switched off the area of the impeller blades in the downtake was sufficient to cause a serious obstruction to the massecuite circulation resulting in a drop in heat transfer to the massecuite.

A point of interest arises with the peaks above the main broad temperature band. Two of these points (5, 8) are immediately above the calandria but the other two (7, 4) are below the calandria which certainly does not fit the usual pan circulation theory. From the work done by the Queensland S.I.R.² regarding pan circulation, the theory of "eruptive" boiling seems to fit very well with these bursts of high temperature regions above and below the calandria tubes.

At UK, with the stirrer in operation or not, no apparent difference in temperature of the boiling massecuite occurs (see Figures 4-6). The phenomenon of local high temperature spots can be seen as a series of small peaks (the scale is much less than the DL curve) near the end of the boiling. This measuring point (No. 2) was close to the edge of one of the wedge-shaped steam entry points and more than

usually vigorous boiling could be expected from this point.

One feature of interest here is with the stirrer not in use the bottom of the pan tends to cool off and this low temperature loop can be seen in Figure 4. With the stirrer at speed, this stagnant bottom pocket would be dispersed by massecuite swept towards the edge of the pan from the centre well.

According to text books this point of the massecuite should be most seriously affected by the hydrostatic head effect and should be the hottest spot in the pan even resulting in re-resolution of sugar. In fact, it is the coolest, probably aided by an unlagged bottom saucer. Some pans have a steam jacket on the saucer and it appears from these results that it is not a superfluous piece of equipment.

The general massecuite temperature as can be seen lies within 5°C and for most of the time within an even narrower band. With the broad supersaturation band permissible in a C massecuite at this stage of crystal growth these fluctuations are quite safe with respect to the production of false grain.

Observations of pan circulation and massecuite quality

Any improvement in the speed and uniformity of circulation will tend to minimise the variation in supersaturation throughout the pan and also will increase the heat transfer from the heating surfaces.

It appears from the tests carried out that the pan has a good natural circulation, whether the stirrer is operating or not. During the early stage of the boiling, until the pan is three-quarters full (33 m³), the stirrer offers no better circulation than natural convection and the boiling time between these two does not differ much. However, towards the end of a tight boiling and during the brixing period, the stirrer action is very noticeable by the fact that the impeller creates a significant vortex round the shaft.

The average results of eight consecutive tests are shown in Table I.

Columns 1 and 8 in Table I refer to the boiling time from the moment the molasses is fed into the pan until it is shut for brixing. It must be mentioned that pan No. 6 (stirrer pan) receives a seed cut (± 15 m³) from a graining pan. Columns 2 and 9 are the brixing times; these reveal a net gain of 96% with the stirrer operating. Columns 3 and 10 are the overall boiling times and show a 30% gain on time with the use of the stirrer. The difference in boiling time therefore justifies the use of the stirrer.

Columns 5, 6, 7, 11, 12 and 13 are results obtained from routine analysis and indicate very little difference in massecuite. The discrepancy in results could be attributed to analytical errors.

Table II indicates a complete graining and boiling using the stirrer and continuous use of movement water (until brixing). It is the result of one test only.

Figures 7-10 illustrate the massecuite and grain quality between massecuites boiled with the stirrer on and stopped. It has been found during the tests that the continuous use of movement water together

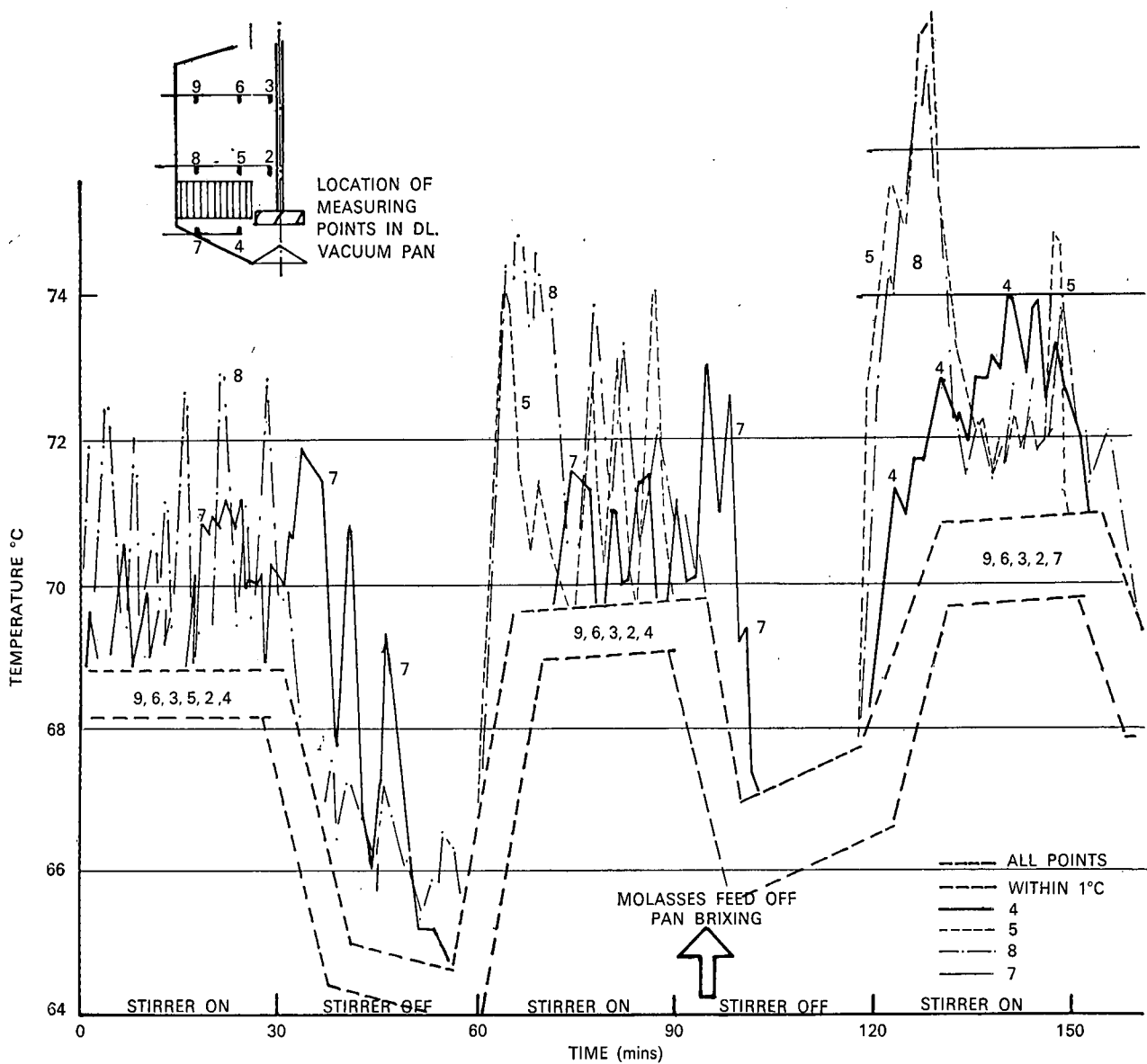


FIGURE 3: Darnall C pan temperature distribution curves. The scales are larger than the UK curves and the location numbers are different. Individual curves are not shown in the grouped band for the sake of clarity.

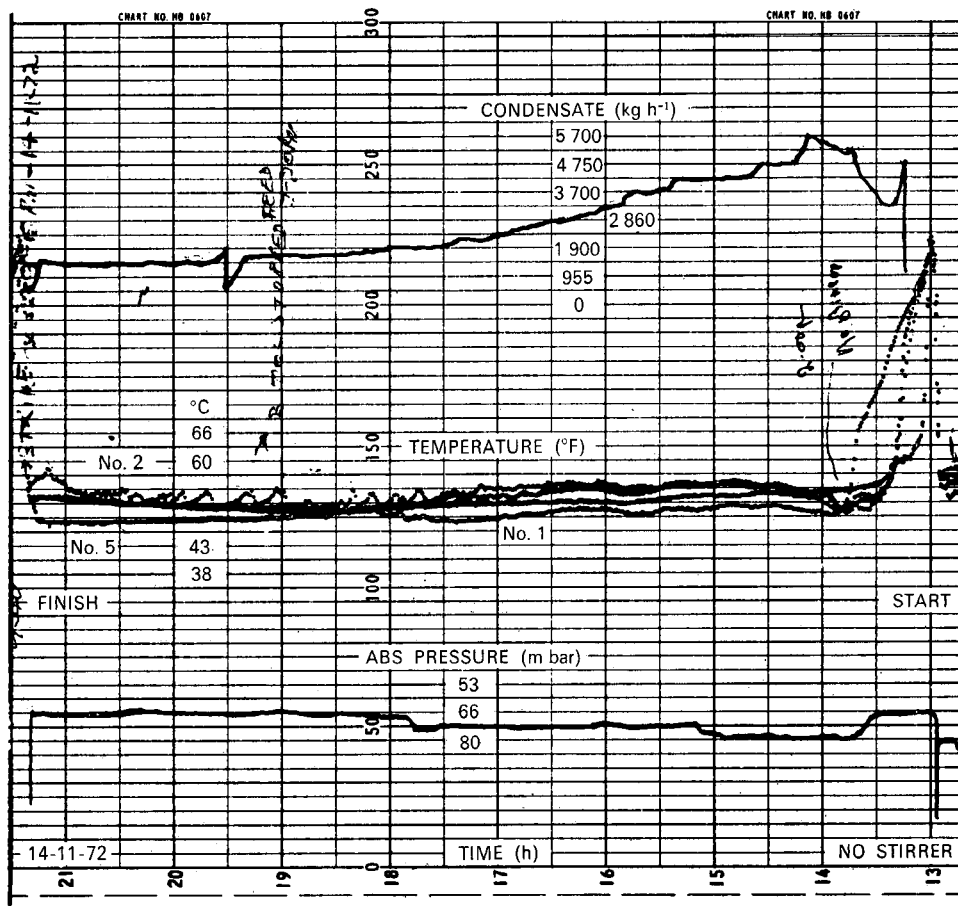
TABLE I

Stirrer on							Stirrer off					
1	2	3	4	5	6	7	8	9	10	11	12	13
Cut-over to Brixing mins	Brixing mins	Total mins	Amps @ strike	Brix of Mc	Purity of Mc	Nutch Pty @ strike	Cut-over to Brixing mins	Brixing mins	Total mins	Brix of Mc	Purity of Mc	Nutch Pty @ strike
316	55	371	60/65	94,36	59,74	44,79	375	108	483	94,05	59,64	44,56

TABLE II

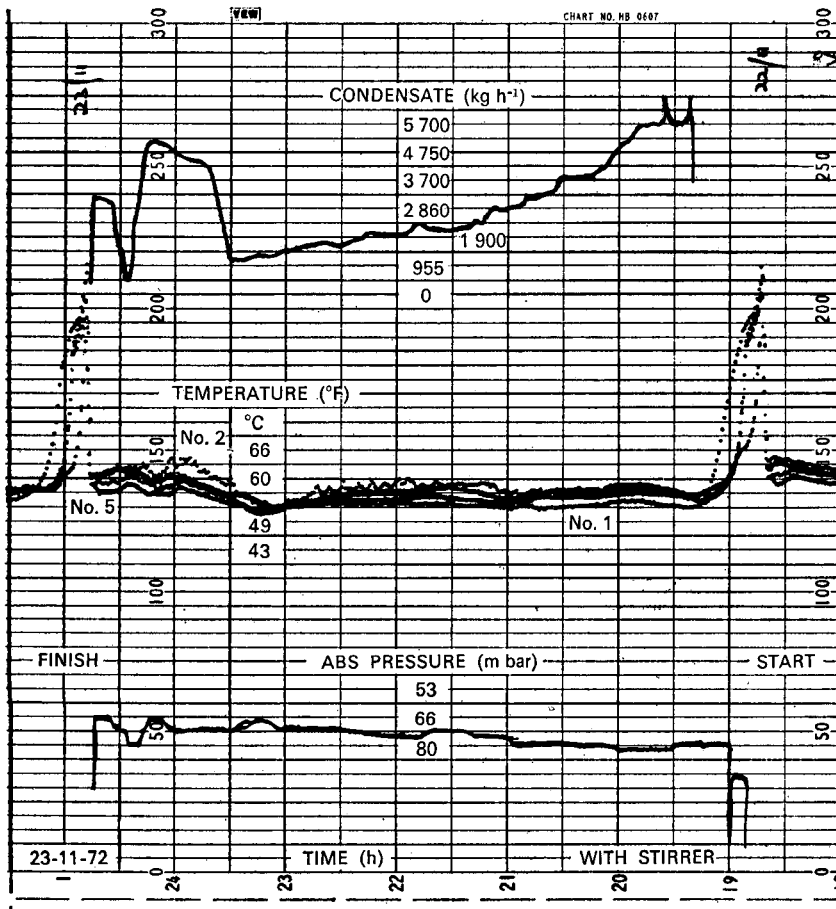
Graining and boiling mins	Brixing mins	Total mins	Amps @ strike	Brix of Mc	Pty-of Mc	Nutch purity
395	80	475	65	93,80	59,54	47,27

with the stirrer running offers the best practicable and "controllable" boiling technique. In Figure 9, a crop of "small grains" can be seen, from a masse-cuite which has been boiled with the stirrer running, but with no movement water used. It was found that molasses feeding into the pan contained a large amount of undissolved grains (molasses brix 76-78).



Above:

FIGURE 4: Pan boiling with stirrer off (UK). Note stagnant No. 5 temp. plot at end of boiling. Boiling time 8 hours. (Chart direction right to left.)



Left:

FIGURE 5: Typical C massecuite boiling with stirrer (UK). Boiling time 6 hours. Condensate peak at end of boiling is due to change of vapour pressure. (Chart direction right to left.)



FIGURE 7: Pan full — Stirrer on — Boiled with movement water.



FIGURE 9: Pan $\frac{3}{4}$ Full — Stirrer on — Boiling "tight", no movement water.

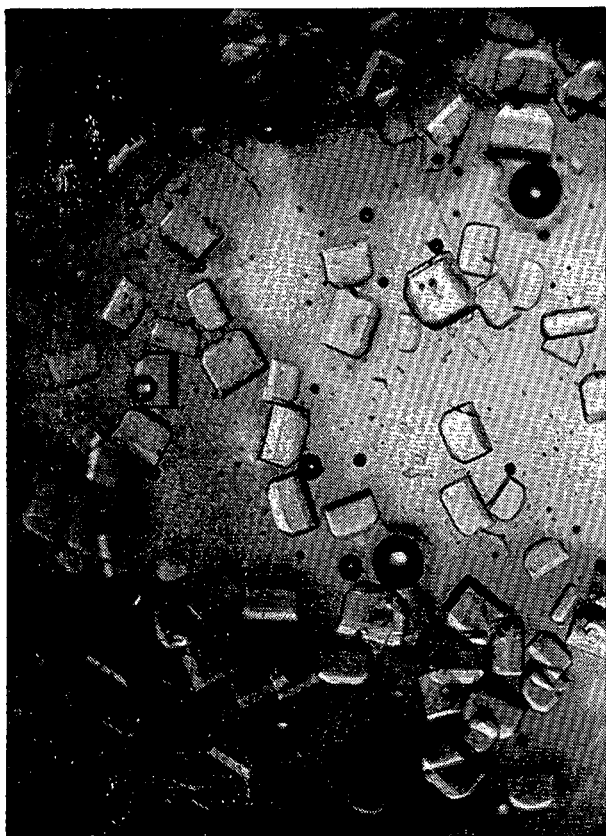


FIGURE 8: Pan Full — Stirrer off: Boiled "tight" with movement water.

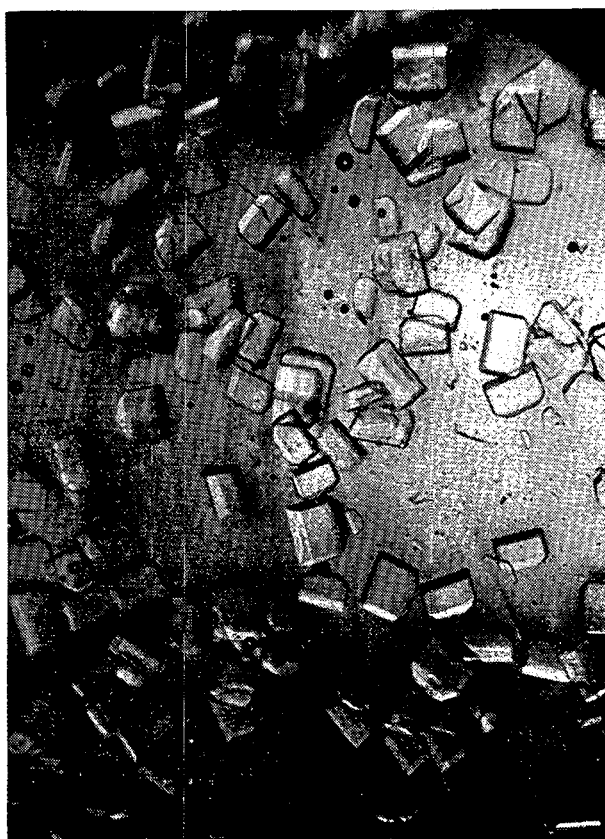


FIGURE 10: Pan $\frac{3}{4}$ Full — Stirrer off — Boiling "tight", with movement water.

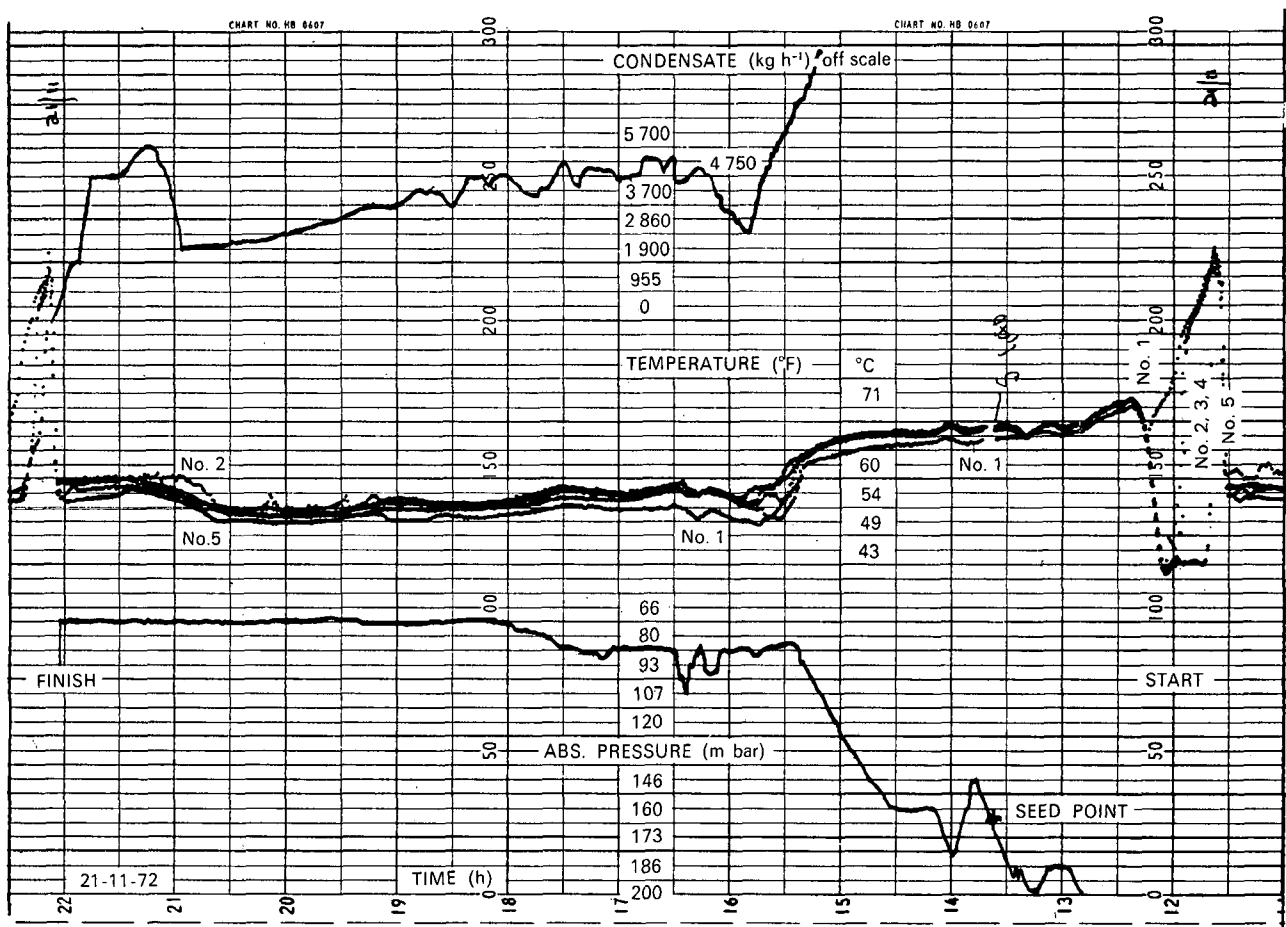


FIGURE 6: Complete C boiling including graining using stirrer (UK). Total time 10½ hours. Condensate flow was too high for instruments during initial period of boiling. (Chart direction right to left.)

Stirrer design

The current operation of the stirrer (Figure 11) without doubt reduces boiling time. That it is fully loaded is shown from the curve of current/time (Figure 12) and any increase in speed would merely cause it to trip out on overload earlier in the boiling when it is hardly required (with this particular pan).

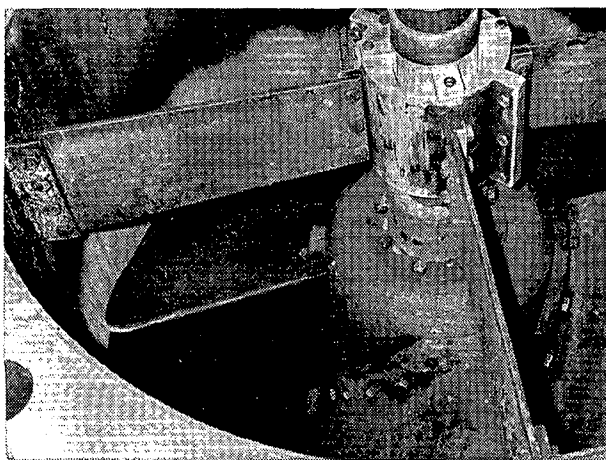


FIGURE 11: UK C pan impeller. Note the open bearing for lubrication by massecuite. The horizontal centre line of the impeller is level with the underside of the calandria.

Design data from overseas would indicate that to maintain an impeller tip speed of about 4,27 ms⁻¹ (given in the specification) at a massecuite viscosity of 2 000 poise at 57°C, an 85 kW motor would be required for a pan of this size.

Condensate measurements

Condensate measurements were made with a view to establishing typical heat transfer rates from the boilings with and without the stirrer. However the pan main steam valve was not fully open throughout the boilings and changes in pressure in the vapour main when nearby pans were started and stopped caused considerable fluctuations. Typical fluctuations in flow rate can be seen in Figures 5 and 6, and were

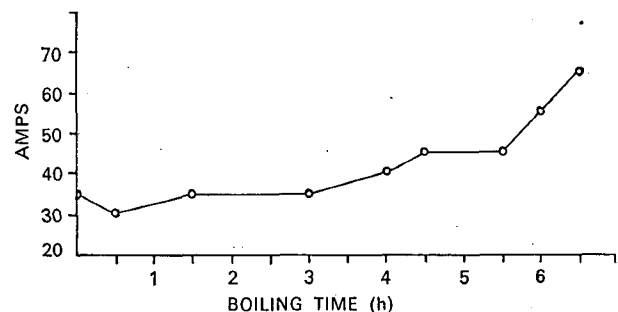


FIGURE 12: Stirrer motor current vs boiling time.

caused (without the main steam valve being touched by the pan boiler) by changes in pressure of the vapour supply.

The weir box and D.P. cell worked reliably throughout the test and by altering the weir shape and the D.P. cell range the apparatus can be used for other pan tests.

Measurement of condensate flow, massecuite quantities and molasses brix gave a pan factor, i.e. steam used divided by theoretical evaporation of about 1,3. As mentioned previously a small water feed was run throughout the boiling and molasses Bx varied from 76 to 78, so the above figure would appear to be very reasonable.

Conclusions

The temperature distribution in the pan is very even, a maximum diversion of 5°C being encountered during short periods of the boiling.

Peak temperatures (hot spots) have been recorded above and (DL) below the calandria tubes.

The stirrer caused no perceptible false grain or grain damage to the massecuite.

The stirrer, even though underpowered and running well below optimum speed, reduced boiling time by at least one hour per cycle.

Acknowledgements

We would like to thank the management and staff of both Darnall and Umzimkulu for permission to run these tests and for the co-operation of their process and engineering sections in overcoming the inevitable minor on-site problems encountered in the tests.

REFERENCES

1. Allan and Warne, Vacuum Pan Control, Progress Report No. 2, 41st Congress SASTA 1967.
2. Wright, P. G. Sugar Research Institute, Technical Report No. 88, Further Pan Tests using a Radio-isotope.