VACUUM PAN CONTROL

PROGRESS REPORT No. 1

By D. H. JONES AND D. E. WARNE

Introduction

Consideration has been given to the effect of vacuum pan circulation on sugar quality — particularly with reference to filterability. It has been suggested[1] that the introduction of a mechanical circulator, or stirrer, would enable the process to be carried out within closer temperature limits, so that the occlusion of undesirable substances could be prevented. In considering the possible installation of a circulator, the likelihood of the massecuite short-circuiting into the eye of the impeller presented itself. It was considered that a movable sleeve, located within the downtake and rising as the level of the massecuite in the pan rises, would ensure that the heated massecuite could be constrained to approach the surface more regularly and short-circuiting would thus be avoided. A similar idea was proposed by Waddell.[2] Arrangements were therefore made in 1964 to install such a sleeve in an "A"-massecuite pan at Illovo. The experiment however proved inconclusive as the conditions under which sugar was boiled were too erratic, and examination of the data obtained showed that too many variables existed for a complete analysis of the results. It was consequently agreed upon that before continuing with any further experiments along similar lines, an examination should be carried out into pan boiling as normally practised in Natal to obtain more detailed information concerning techniques, circulation criteria and other phenomena.

An investigation was accordingly arranged at the Gledhow factory, where an "A"-massecuite seed pan was made available. It was originally resolved to record as many of the variables which occur during the boiling process as possible, but due to the shortage of time only a few experimental positions were chosen. This report therefore outlines the progress made to date, along with some of the more interesting results obtained.

Equipment

For the measurement of temperature, various methods were possible, but it was proposed that as the temperatures had to be measured at so many points, as was the original intention, that an electrical method was the most obvious. All temperature measurements were therefore recorded by a Yew twelve point recorder, which was adapted by additional circuits and stepswitches to be able to select the range or alter the sensitivity of the instrument as required. An accuracy of 0.1° C. was decided upon as being sufficient. Three positions for the measurement of massecuite temperature were chosen, being, (1) just beneath the calandria, (2) just above the calandria, and (3) just below the recommended strike level. The exact positions can be seen in figures 1 and 2. The temperature measurement was carried out by platinum resistance thermometers which were sealed into brass capsules and mounted into their respective positions in a supporting pipe. The leads from the thermometers were then passed along this pipe and out through the pan wall to the recorder.

With the same recorder, the conductivity of the massecuite was measured by placing an 8 volt AC current through a pair of electrodes mounted in the pan. Two pairs of identical electrodes were utilized, being situated (*a*) in the conventional position in the bottom of the pan, and (*b*) at a point 18 ins. above the calandria in the same vertical plane. The exact location of the electrodes can be seen in figure No. 1, while the positioning of the electrodes with respect to the steam inlet can be seen in figure No. 2. The measurement of conductivity was achieved by placing a resistance in series with the electrodes and rectifying any voltage drop across this resistance with a metal rectifier. A suitable proportion of this rectified DC voltage was then measured by the recorder. This conductivity circuit was built together with the recorder and all controls into a neat portable console (see photograph) all construction and design being carried out by J. Bruijn and N. Bowes of the staff of the S.M.R.I.

Vacuum control was effected by a Foxboro absolute pressure recorder/controller, operating on an 8 in. diameter Fischer pneumatic control valve. This valve was positioned in a bypass around the manual control valve on the existing 14 in. cooling water delivery pipe to the pan condenser.

The pan itself was a modern two diameter double bottomed pan, having a conventional calandria with a central downtake. Figure No. 1 shows the principal dimensions.

Procedure and Results

The procedure followed during the investigation, was to commence the recording of temperatures as the syrup inside the pan was being concentrated. This enabled the correct range to be chosen and allowed time for the sensitivity of the instrument to be checked. Thereafter, the recorder automatically recorded both temperature and conductivity values every minute. Further, a complete record of all the operations performed by the pan boiler was kept relative to time, so that at the completion of a boiling all alterations to the boiling procedure could be compared with the measurements made by the recorder.

At the outset of the investigation, it was resolved merely to record such measurements as were made available during the normal course of boiling operations as practised at Gledhow. It soon became apparent however that the results obtained would be very similar for each boiling, and it was therefore agreed upon to try to control at least one of the variables which affect the process, namely the absolute pressure. Consequently an automatic control of the cooling water to the pan condenser was effected.

As previously mentioned, the investigation was begun rather late in the season and is therefore by no means complete. However, even during the short period of time available some most interesting results have been obtained.

(a) Temperature Measurement

By measuring the massecuite temperature at three different levels, the results produced have shown that it appears as if the circulation in the pan tested was not in accordance with the simple theory generally accepted. Unfortunately temperatures were measured in one vertical plane only, but even so the effect was still noticeable. In Graphs 1 and 2 it can be seen that the temperature recorded beneath the calandria is very close to that recorded just above the calandria. It seems, therefore, that either a considerable proportion of the vapour formed is not liberated to the vapour space, but is entrained by the viscous medium and forced under the surface in the downtake, or this elevation of temperature occurs by short-circuiting of the hot massecuite to the cold downtake stream. This short-circuiting effect could be caused by sub-surface flow or possibly by mixing at the interface of the two streams. It will also be noticed that the difference in the temperatures between positions (1) and (2) (see Figure 1) becomes progressively smaller at the end of the boiling until they actually cross over, thus indicating a higher temperature for below the calandria than for above! This alteration is common to all the boilings carried out during the investigation, being more pronounced in some than in others. A more detailed record of this occurrence was therefore kept and it was found to occur when the level of the massecuite was approximately 4 ft. 6 in. above the calandria. At Gledhow this particular pan is used as a seed pan for the "A"-massecuites, and as no seed storage tank was available it was common practise to boil to 6 ft. above the upper tube plate, in order to have enough seed for 3 strikes. On examining the manufacturers' specifications for this pan, it was found that the recommended strike level was 1,300 cu. ft. or 4 ft. 11 in. above the calandria. The figures recorded at Gledhow appear to be in agreement with the conditions observed by Gillet,[3] who established for low grade boilings that when the massecuite level reaches a point about 4.5 to 5 ft. above the calandria upper tube plate, the natural circulation diminished to an objectionably low level.

In Australia,[4] similar circulation investigations on calandria pans have also indicated a very small temperature rise as the massecuite passed through the calandria. Here a value varying between 1.2° F. and 4.5° F. as the boiling progressed was recorded, with the thermometers positioned at 60° from the steam inlet. The particular pan under investigation enjoyed a heating surface to volume ratio of 1.88 and a total heating surface of 3,000 sq. ft. The suggestion was therefore made that there was a large steam side pressure drop across the tubes of the calandria. This did not mean that the pan was starved of steam, but rather that all the steam necessary to maintain a high rate of boiling could be condensed in less than the total heating surface. In other words the boiling was mostly occurring over the steam inlets. Subsequent experiments in Australia[5] have actually proved this, where temperature measurements taken in regions remote from the steam inlet have indicated even smaller temperature rises and often negative results were obtained.

At Gledhow the average maximum temperature rise across the calandria was in the order of 3.0° F. decreasing to a negative value at the end of the boiling. The positioning of the thermometers was approximately 30° from the nearest steam inlet. The heating surface to volume ratio of the pan was 1.83, and the total heating surface was 2,380 sq. ft. It would therefore be most interesting to see the influence of the steam distribution on this pan by re-positioning the thermometers at 90° from the steam inlet.

(b) Absolute Pressure

The consequence of having perfectly controlled absolute pressure is obvious from Graphs 1 and 2. With the control of absolute pressure, and irrespective of the boiling technique, the boiling process can be carried out within closer temperature limits and all temperature fluctuations are therefore kept to a minimum. Before the investigations were actually begun, a number of absolute pressure recorder charts were taken during the normal boiling operations at Gledhow (see Chart No. 1). From this record can be seen a large number of fluctuations. Chart No. 2 is another record of the absolute pressure, again recorded during a normal boiling by the pan boiler. A comparison of these two charts indicates that the pan boiler has improved his control by merely paying more attention to the boiling. In each case the flow of cooling water to the pan condenser was not altered. Chart No. 3 on the other hand is an example of what can be achieved by having automatic control.

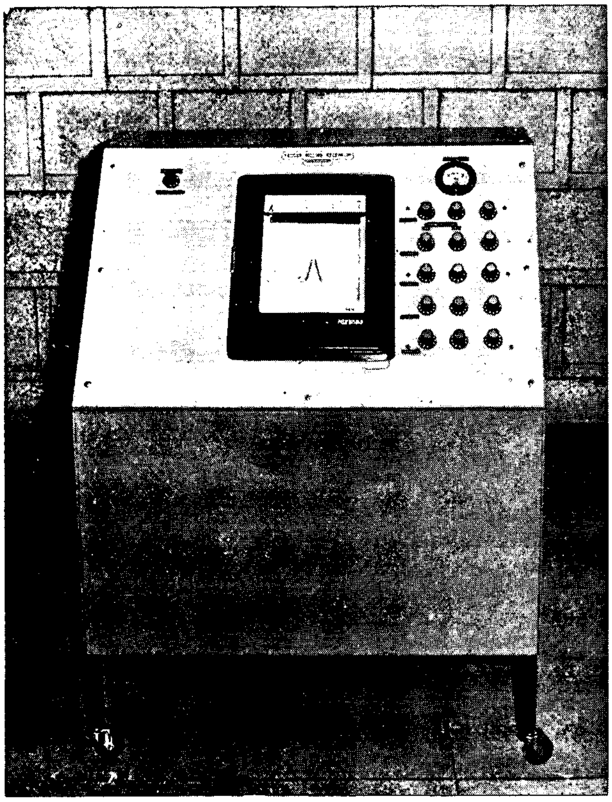
(c) Conductivity

Measurement of the conductivity was effected by two identical pairs of electrodes mounted in the positions shown in Figures 1 and 2. The fact that these two pairs of electrodes were mounted in these positions has in itself produced interesting results. It was seen during boiling operations that two distinctly separate readings could be obtained. In one example of this a deviation could actually be observed visually, where the recorder operating on the lower pair of electrodes was indicating that the massecuite was slack and becoming slacker, whereas at the boiling surface it could be seen that the massecuite was tight and becoming tighter. On changing over the recorder to the upper pair of electrodes, a lower conductivity value was recorded. This stratification effect was not just instantaneous, but required some little time before the influence of the syrup added by the pan boiler could be seen at the boiling surface.

This variation between two pairs of conductivity electrodes is in fact a further measure of the pan circulation, and has been used as such in Java by Honig.[6]

(d) General

Although the various results obtained have been reported on in different categories, it is realised that they are all influenced by each other. The more obvious



Conductivity and Temperature Recorder

results were however not commented upon as this would take up too much time.

Under the heading General Observations, one engaging experience noted during the investigation was the manner in which the weather influenced the boiling operations. Cold wet days could be expected to give a considerably lower absolute pressure for boiling, whereas the temperature of the cooling water on hot days was not conductive to good absolute pressures.

Any attempt to correlate boiling proceedings with sugar quality was unfortunately unsuccessful.

Conclusions

Wide variations from accepted theory with regard to circulation in a vacuum pan and allied phenomena make it obvious that a great deal of work still has to be done before any definite conclusions can be reached. During the past season the investigation carried out at Gledhow forms merely the opening paragraph as to what must be undertaken in the future.

The coming season will see more elaborate massecuite temperature measurements to try to evolve a definite circulation pattern. Attempts to determine the most suitable position for conductivity measurements means further electrodes must be constructed and placed in various positions within the pan. It was also obvious from the results recorded that many variables occur during the process and before any deductions as to their effect can be made, these variables will have to be measured and suitable methods made available for their control.

In conclusion it is evident that the programme for next season must be extensively modified and enlarged and can therefore be expected to produce some most interesting results.

Acknowledgments

Acknowledgments are due to the management of the Gledhow factory, for allowing the use of a vacuum pan for this investigation, and also to the staff personnel for their generous co-operation during the tests.

References

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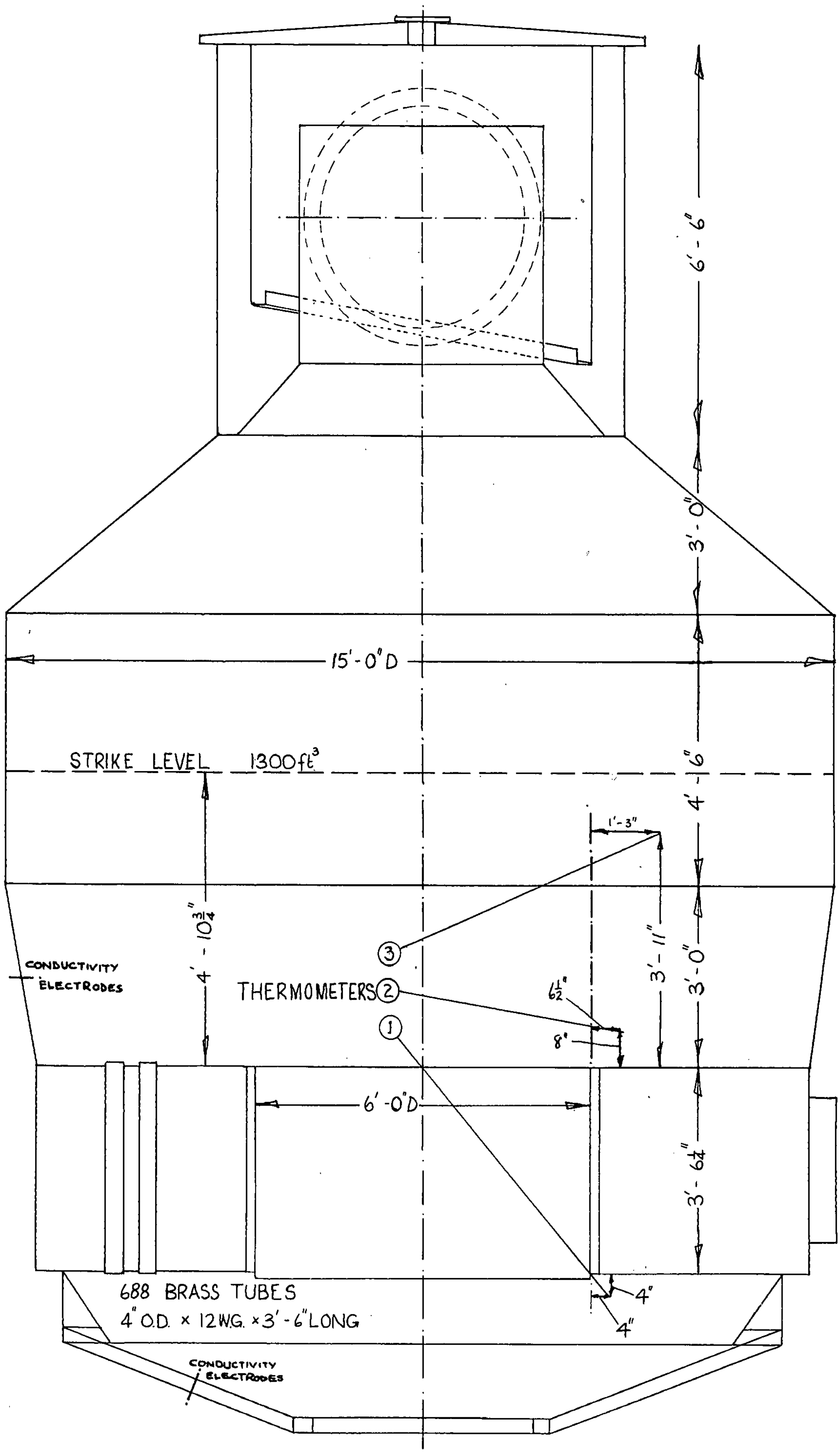


FIGURE No. 1
Sectional elevation of Pan showing positions of thermometers and conductivity electrodes.

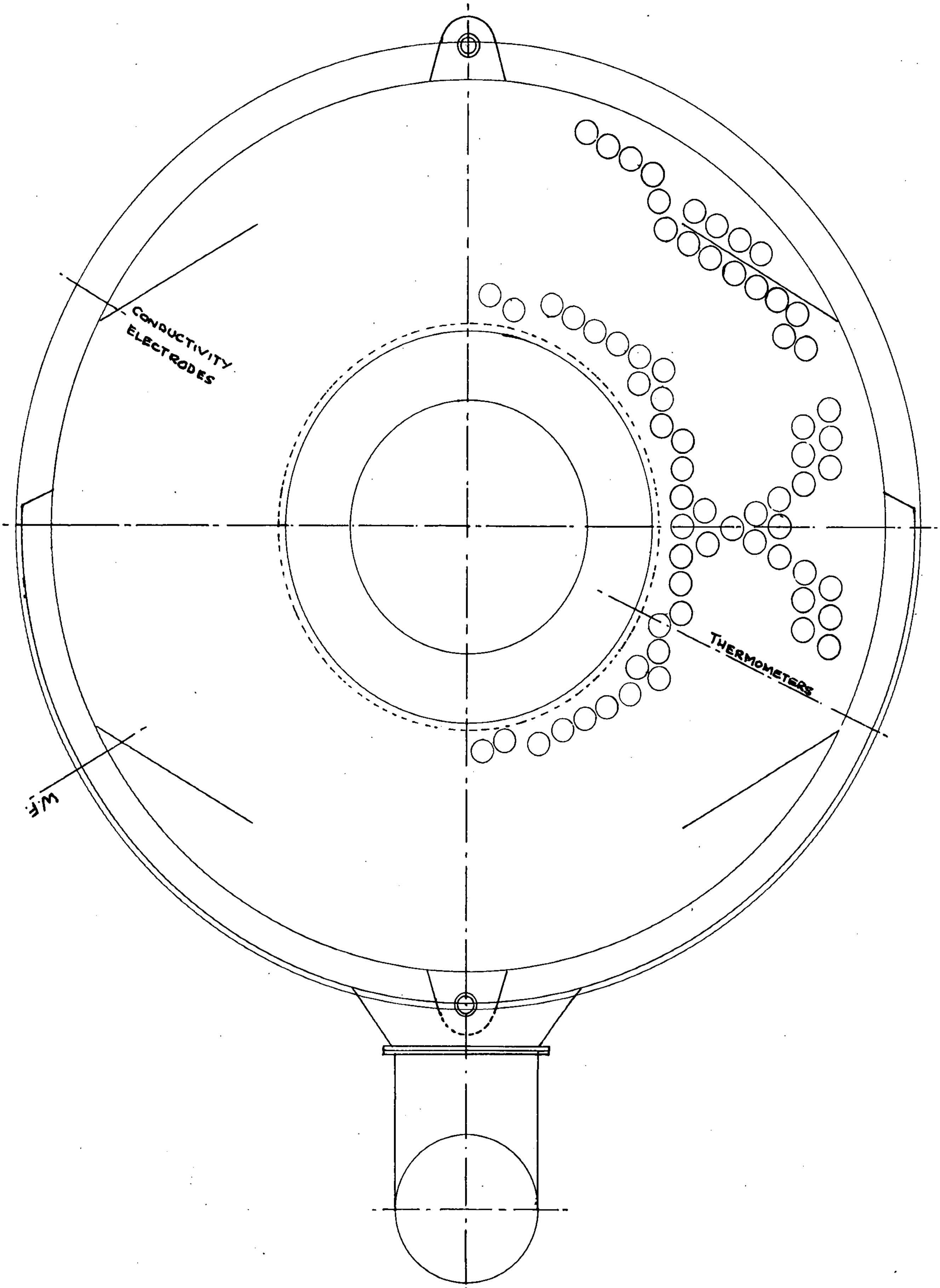
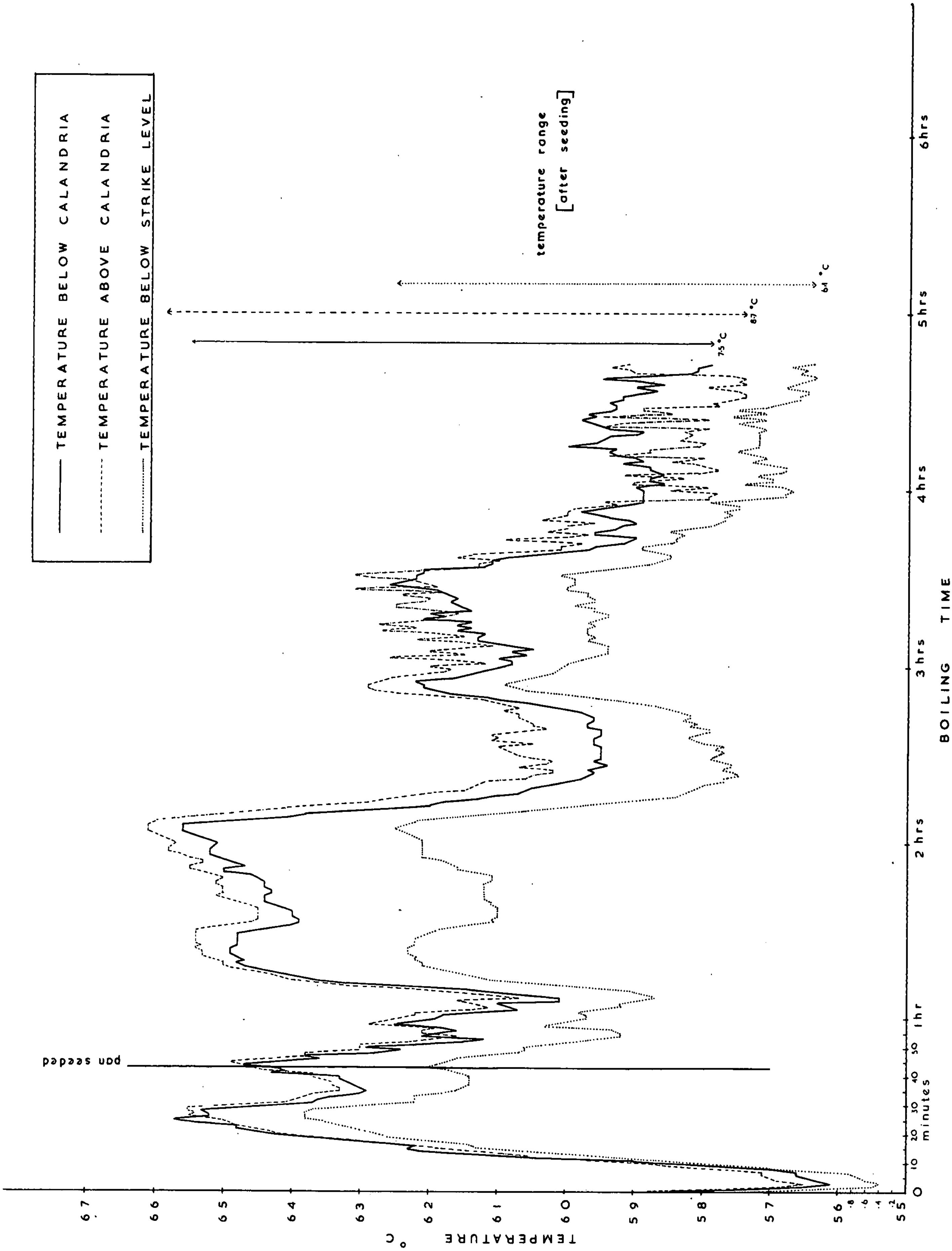
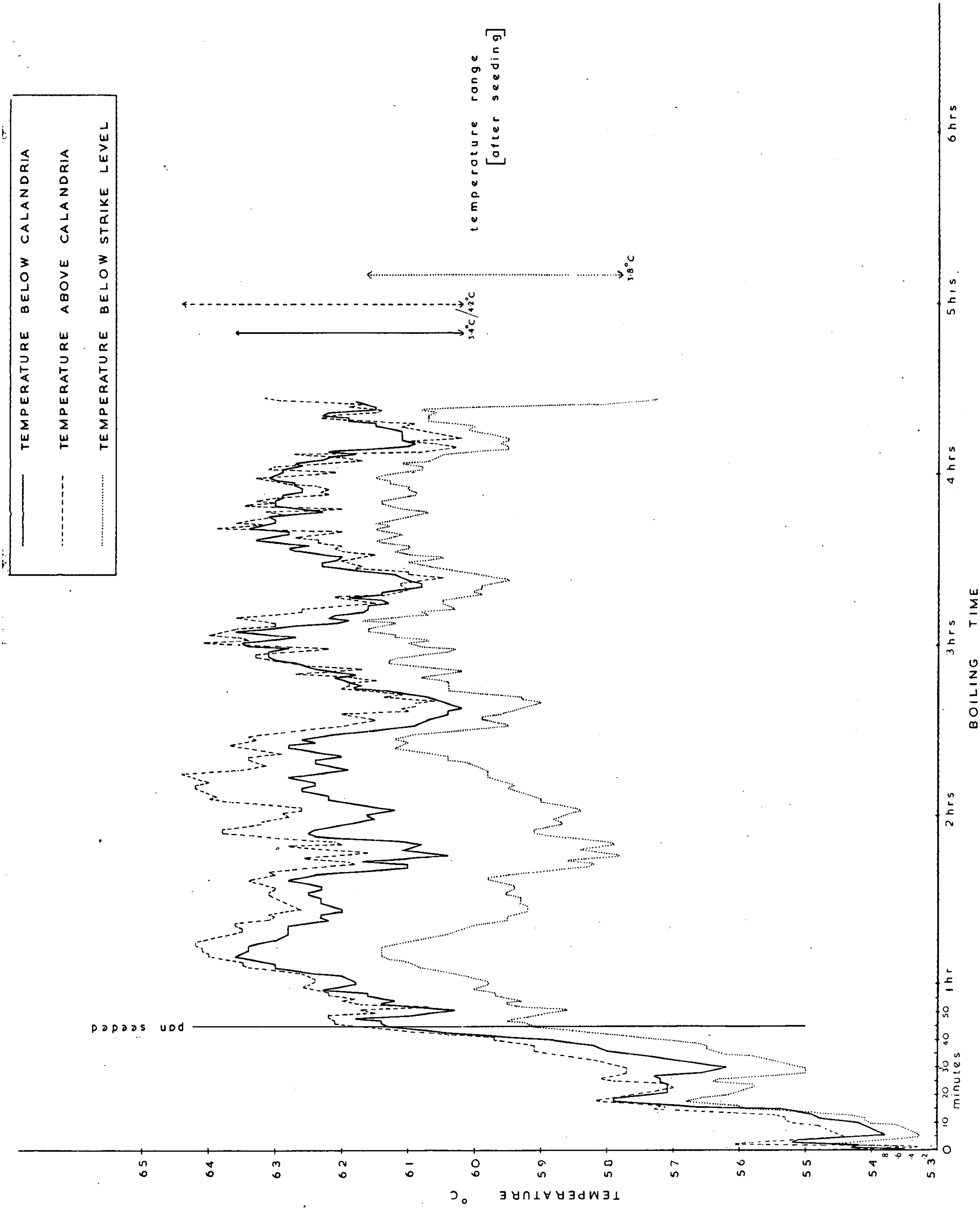


FIGURE No. 2
Sectional Plan of Pan showing positions of thermometers and conductivity electrodes.



GRAPH No. 1 Boiling without control of vacuum.



GRAPH No. 2 Boiling with automatic control of vacuum.

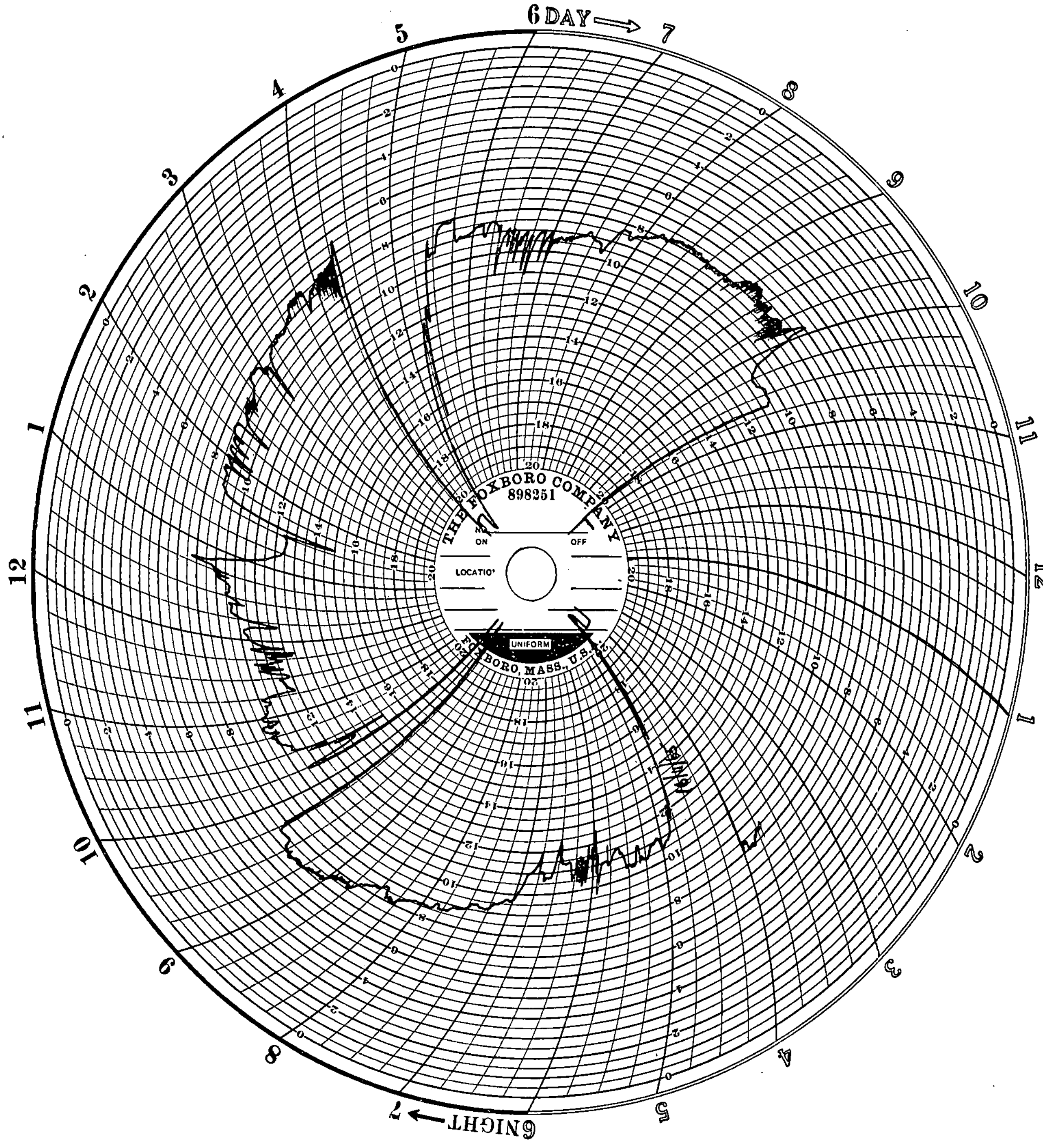


CHART No. 1

Showing vacuum recorded during boilings before commencement of investigations.

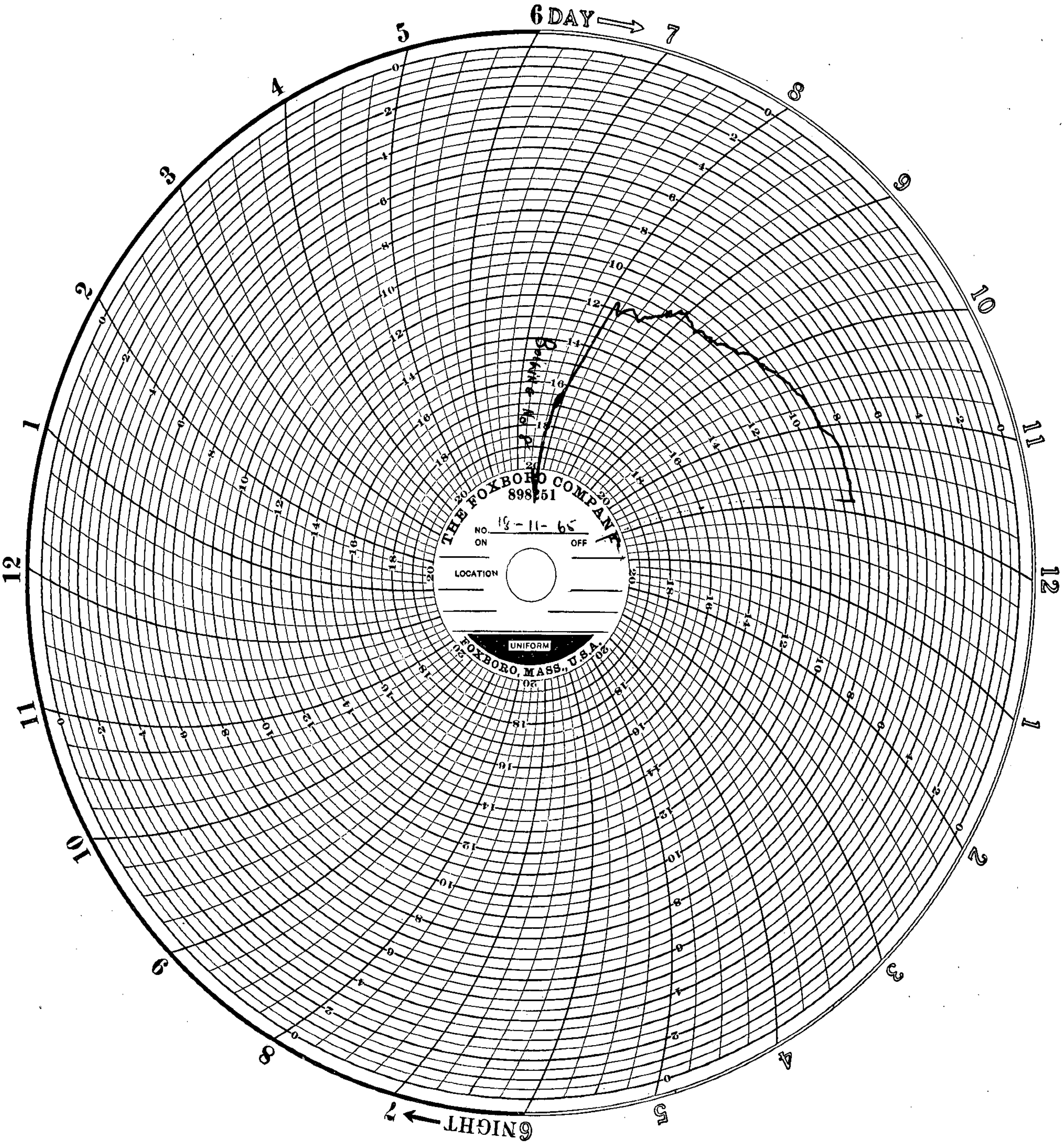


CHART No. 2

Showing vacuum recorded during investigation without control of cooling water.

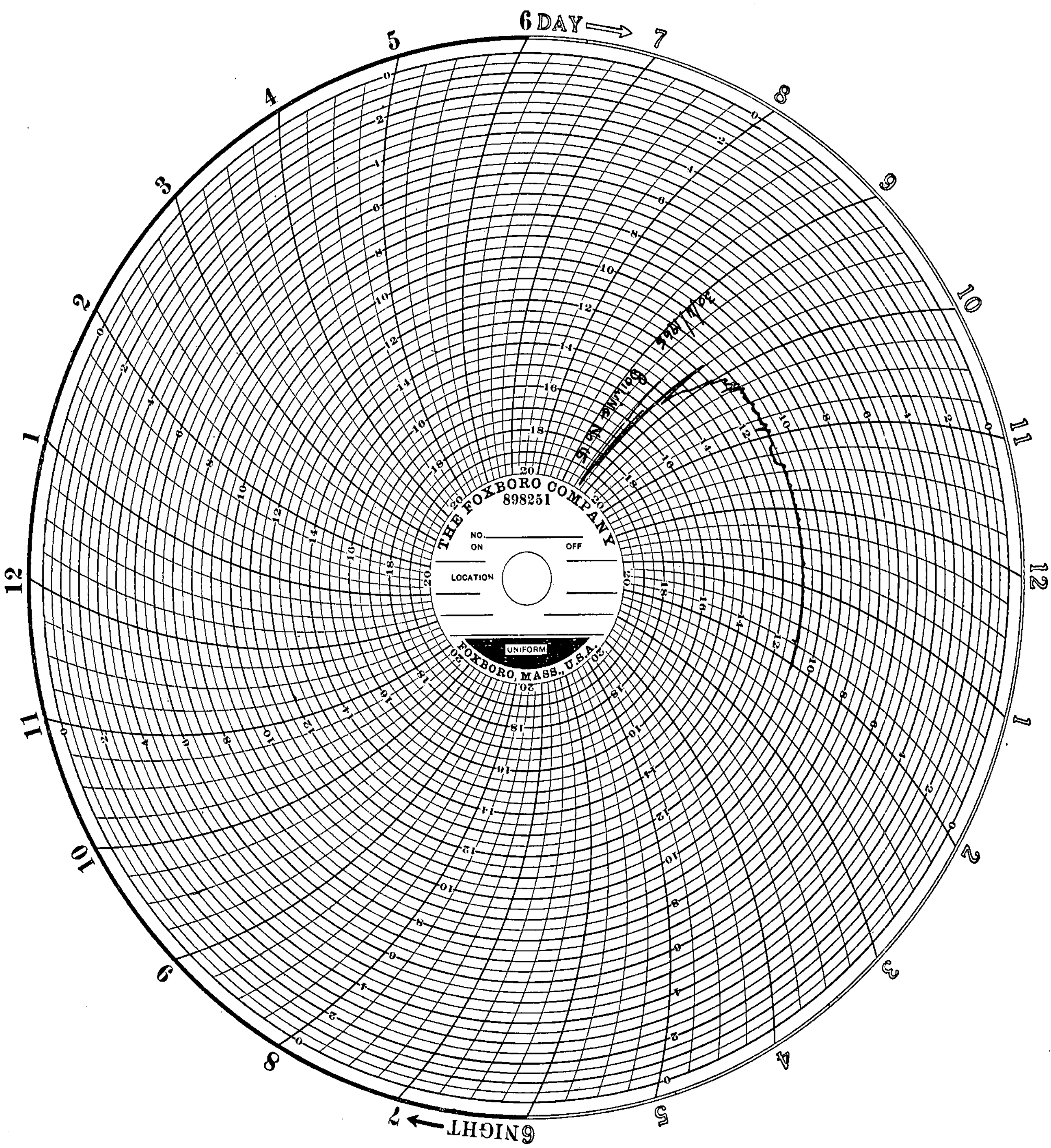


CHART No. 3

Showing vacuum recorded when cooling water is automatically regulated.

Mr. Robinson: We have a "C"-massecuite pan at Darnall equipped with a mechanical stirrer and independent vacuum supply. The feed to the pan is controlled by an automatic valve which is in turn controlled by the load on the electric motor driving the stirrer. With this arrangement we have found that a fairly good control of vacuum can be obtained just by controlled feeding. The temperature of the massecuite as indicated by a pan thermometer is very steady during boiling; unfortunately, as you have mentioned in your paper, the temperature of the cooling water does affect the vacuum.

Mr. Warne: I am very pleased to hear that you have achieved such results but as most of the other factories do not have independent vacuum systems on their pans the automatic vacuum control as used by us would benefit them greatly. With an automatic control of the cooling water to the condenser it is possible to produce boilings at exactly the same absolute pressures regardless of the cooling water temperature, throughout the entire season.

Mr. Jones: If you look at the second chart I would like to emphasise the improvement in the pan boiling by the operator without any assistance whatsoever, purely because he was taking note of what he was doing. This confirms what Mr. Deon Hulett said in his paper "Where should the downtake be"—no matter what you do unless you can have some sort of control over the conditions existing in the pan, you are very much in the hands of the pan boiler. We found quite a remarkable difference in the attitude of the pan boiler after 2 or 3 weeks and he certainly boiled a very much better controlled pan without any of the extra aids that we provided.

There are many variables involved in this project, and if you look again at the diagrams of the graphs nos. 1 and 2—graph no. 2 does not really line up with the control we had of the vacuum on the pan itself if that is related to the other readings we took of opening of valves and other actions on the part of the pan boiler. You can correlate some of the variations even in graph no. 2 with the controls operated and the way they were operated and I think that points again to the fact that control of two elements is by no means sufficient. This is only the first report of what promises to be a long investigation.

Mr. Renton: If the temperature recorded just below the calandria is higher than that just above the calandria surely this shows that the massecuite is being forced downwards through the tubes.

Mr. Warne: We assume that is what happens. In Australia, where similar investigations have taken place, they too have found this negative value and have also come to the conclusion that the circulation is less definite at these points with a strong possibility that the massecuite is being forced downwards through the tubes.

Mr. Ashe: The temperature increase recorded below the calandria appears to occur right at the end of the boiling. In my opinion the circulation in the pan is due to the fact that you have water being evaporated which forms a vapour bubble and forces itself through the massecuite to the boiling surface. At the end of a boiling your concentration of massecuite is almost complete and there is consequently very little water left to evaporate, therefore circulation slows right down and must rely on convection currents and it is due to these convection currents that the figures which were recorded are all over the place.

Mr. Warne: Graph No. 2 on page 7 records a boiling which had an automatic control of the vacuum and you will see that this so-called switch over of temperatures occurred after about three hours of boiling time leaving a further hour of boiling to be completed. At this stage the massecuite in this pan was cut over completely to two further pans for use as a footing and as such it was not concentrated above the normally accepted boiling concentration. It would appear therefore that this switch over of temperatures above and below the calandria is more likely due to the hydrostatic head than to a concentration effect.

Mr. Hulett: With regard to the massecuite being hotter beneath the calandria than above when the pan is getting full, I notice that all the temperature measurements were carried out in the tubes close to the downtake and maybe that indicates that the downtake is too small and with the pan getting fuller the effect would be for the massecuite to come down the downtake and also the surrounding tubes.

Mr. Grieves: Was the controller used a proportional plus reset model?

Mr. Warne: The controller was a proportional plus reset model. The proportional band was set at approximately 5% whilst the reset time was approximately half a minute. We must not forget however, that the control valve was on a bypass which was not ideal under the existing conditions. However, it appeared to suffice.