VACUUM PAN CONTROL

PROGRESS REPORT NO. 2

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Continuing the project started at Gledhow last year (1965) it was decided to divide the work into two inter-related aspects:

(1) Temperature measurements in order to establish a circulation pattern and,

(2) Installation of controls to stabilise conditions in the pan.

Temperature Measurements

Nine 2½" diameter pipe probes were built into the pan at three levels, below calandria, above calandria and four feet above the tube plate. (See Fig. 1). The probes were arranged vertically in three planes at 10°, 45° and 90° to one of the steam inlets, thereby ensuring that a symmetrical cross-section of the massecuite could be obtained. The platinum resistance thermometers were mounted in brass capsules on each probe, one on the pan centre-line, one at the edge of the downtake and one clear of the outside wall. The three centre thermometers were common to the three vertical planes.

Numerous readings were taken throughout the season, both with and without control, in all three vertical planes and these were then plotted out on a large scale. No significant circulation pattern can be deduced from the readings so obtained. The readings show very small differences in temperature across the calandria, mainly of the order of 1.8°F. As this is a seed pan and is cut over at 85°Bx. the mobility is still reasonable and it is hoped to boil a pan up tight and see if any significant difference appears. Owing to operational demands this has not so far been possible, but next season a seed mixer is being installed and this will facilitate pan floor operation, enabling this point to be checked.

The three top level thermometers are clear of the massecuite for the early stages of the boiling and thus record the vapour temperatures in the pan. This has averaged about 16°F super-heat above saturated vapour temperature for the set point vacuum. With vacuum control the condenser tailwater has averaged 126°F. Lyle[6] maintains that vapour cannot be superheated and any measurements which purport to show this are merely measurements of droplets which have condensed on the thermometer. These droplets will be at the elevated boiling point of the solution. Badger together with Webre and Robinson disagree and say that vapour can be superheated. We are carrying out more detailed checks of tailwater and injection water temperatures.

The pan temperature readings show that despite accurate vacuum control sudden syrup feeds, water feeds and closing of the steam valve can create undesirable temperature fluctuations in the pan. Two temperature charts are shown, Figs. 2 and 3, one without control and the other with vacuum and liquor feed control. It can be seen that temperatures can be held to within about 2°C in a controlled boiling. The tolerance of a resistance thermometer is within 0.2°C and the curves shown are the averages of three points at the three levels. The curves of both boilings show that the temperature below the calandria is higher than that above it at some points, but we feel that further checks are required before offering an explanation for this. Boiling a complete strike should show us a greater spread of temperatures across the calandria, and when we have done this type of boiling we shall feel more confident to comment. Temperature readings of massecuite can also be used for Boiling Point Elevation measurement and it is planned to correlate these figures with Webre Chart readings and again with conductivity values to give two workable systems of pan control.

Pan Control

A control panel (Fig. 4) comprising absolute vacuum control, calandria steam pressure control and a syrup feed control based on a conductivity signal was installed at Gledhow. All three instruments record and are of the proportional plus reset type of controller.

A 10" diameter butterfly valve and a 6" diameter bypass valve have been fitted to the injection water inlet main (Fig. 5) and a 12" diameter butterfly valve on the steam main. These valves are operated by Hagan Power positioners. An air pressure controlled rubberlined pinch valve has been supplied for the liquor feed but a null-balance controller to balance the vacuum on the inside of the valve has not yet arrived from America. Temporarily, a double-seated 2½" diameter Fischer and Porter valve (Fig. 6) is in use on the pan control system. A small bore water valve is still required.

The steam control system proved disappointing owing to the rapid rate of condensation in the calandria. No more than two or three p.s.i.g. could be obtained as a signal and for the initial part of the boiling no pressure at all was registered. With a maximum syrup brix of 55, and it was quite often around 51, the pan is called upon to do a considerable amount of evaporation before graining, and during this period the condenser and/or cooling water just cannot cope and vacuum is reduced. The 12" steam valve itself presented some mechanical difficulties, but is now coupled up to work on an over-riding signal from the absolute vacuum controller. The steam is opened with the isolating valve which is then infrequently adjusted until completion of the boiling. Should the evaporation rate be too high for the condenser to maintain vacuum, the 12" steam butterfly valve slowly closes off until equilibrium is maintained, the controller being set with a wide proportional band.

The conductivity electrodes are supplied with an alternating current at 8 volts, and the measuring circuit current is converted to D.C. and then measured by a Conoflow electro-pneumatic transducer having a linear output of 0-20 p.s.i.g. air pressure. This signal is fed into a pressure recorder controller and thence to the liquor feed valve.

Electrodes are positioned as shown in the sketch, but for control we have so far used the pair in the centre of the downtake. Frequent stops for low syrup supply occur and to cope satisfactorily with this, and to supply mobility water, a 1" bore water valve has still to be installed. A change-over switch from syrup to water would effect the necessary change of controller output signal to the required valve.

Accurate vacuum control is absolutely essential for any form of pan control and in addition there is a marked smoothing of temperature and vacuum curves once the automatic syrup feed valve is switched in (Fig. 7). A simple vacuum control valve devised by Webre is shown (Fig. 8) and a full description is in Sugar Y Azucar, April, 1965, issue. This type of valve does not, of course, reduce water supply to the condenser but merely bleeds in air at a set vacuum and maintains a steady condition.

There is a difference in conductivity signal which varies from boiling to boiling and this has still to be calibrated.

Conductivity is sensitive to temperature, crystal content and molasses purity,[3] as indicated in Fig. 9, and therefore before graining syrup purity and temperature differences must be taken into account.[1] Possibly the Ash/R.S. ratio must also be examined.

The difference in "slackness" or crystal content of a boiling can be readily controlled by alteration of the set point on the syrup feed controller. There is a timelag of about 10 minutes to follow up a 2% shift.

Saturation Point

A paper was published in Spanish by Diago giving tables for saturation and super-saturation based on refractometer brix.[4] One of these tables (86 A.P.) has been plotted on a Webre B.P.E. Chart[2] (Fig. 10) and refractometer Bx's were read before seeding several pans. Manual judgment of the seeding point by the pan boiler coincide closely with the values which he gives. This is of the order of 78.5 Bx. i.e. at about 1.15 super-saturation which is in the middle of the metastable zone and the correct point for seeding.

General

To give some idea of the extent to which pan control is used overseas a summary of a survey conducted in Hawaii by W. S. Haines in 1963 is given below.[5] Of a total of 116 pans, 94 have vacuum automatically controlled by varying water to condenser and 6 are automatically controlled by Air Bleed. 46 use B.P.E. or Massecuite consistency (circulator or probe motor load) to control syrup, molasses or remelt feed. 54 receive feed with density automatically controlled at evaporators. Conductivity of massecuite is not used as a basis of control in Hawaii.

As a general background to pan performance and an estimate of condenser water requirements the steam consumption of the pan was noted for some controlled boilings.

The following tests remain to be carried out in the coming season:

1. An A.C. milli-ammeter is at present being constructed by the S.M.R.I. workshop in order to calibrate the conductivity charts into electrical units.
2. Checks of syrup purity, mother liquor purity and crystal content throughout some boilings including a complete strike.
3. An assessment of consistent improvement in sugar quality once pan boiling control is used as a routine procedure.
4. Correlation of conductivity control with B.P.E. from temperature measurement.

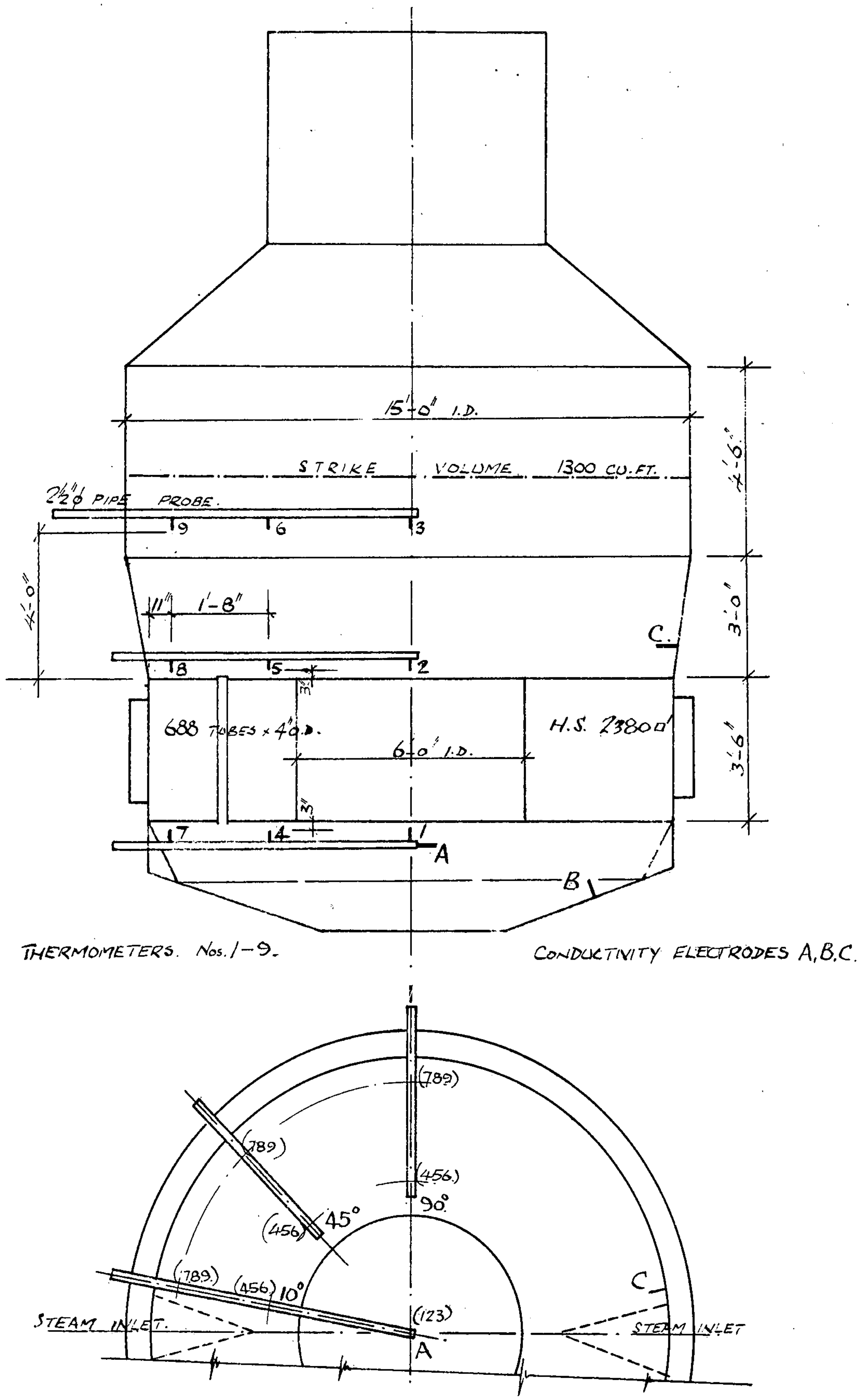
Acknowledgements

Appreciation is expressed to the Management, Engineering and Process Staff at Gledhow for their co-operation and assistance during the past season and also to Messrs. Negretti & Zambra for providing the control equipment with which we have carried out this work. Thanks are due to Messrs. Hulett's Refineries Ltd. for the loan of the Syrup Control Valve.

Messrs. Bruijn and Bowes of the S.M.R.I. designed and built the electric measuring devices used in these tests.

References

1. Ahari, D., Genotelle, J., Hodent, Michel, R. Validity of Electrical Conductivity for Control and Automatic Boiling in Beet Sugar Factory. British Sugar Corporation Ltd. 18th Technical Conference, 1966.
2. Fischer and Porter Publication No. 11353. B.P.E. Tables.
3. Wright, P. G. Control of High Grade Boilings. 28th Congress Q.S.S.C.T. 1961.
4. Diago, R. E. Refractometric Determinations to Assist Graining by Seeding. Sugar Y Azucar. Oct. 1965.
5. Haines, W. S. Pan Control Survey. Hawaii Sugar Technologists Congress, November, 1963.
6. Lyle, O. Sugar Technology for Refinery Workers.



LAYOUT OF THERMOMETERS + ELECTRODES.

FIGURE 1

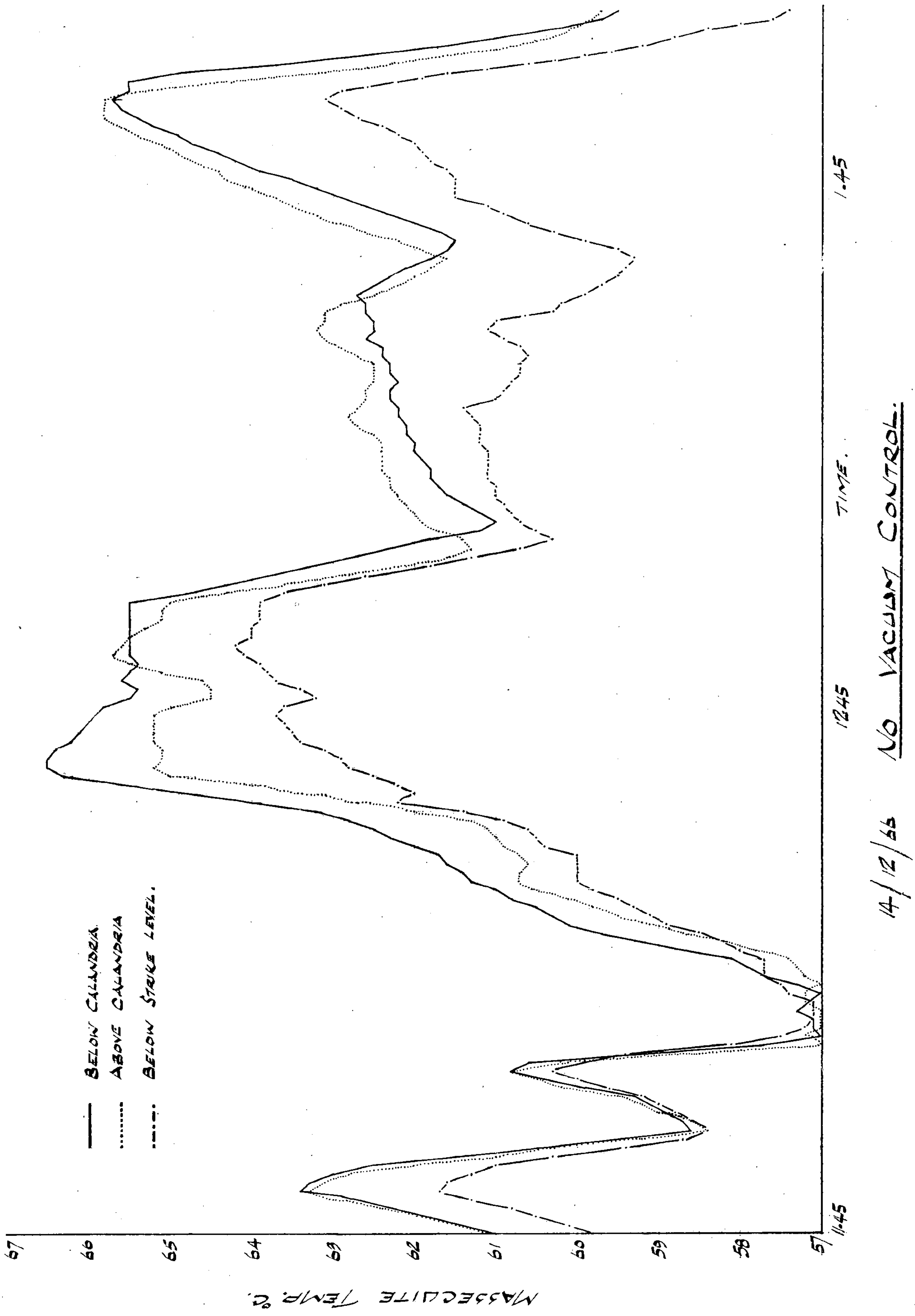
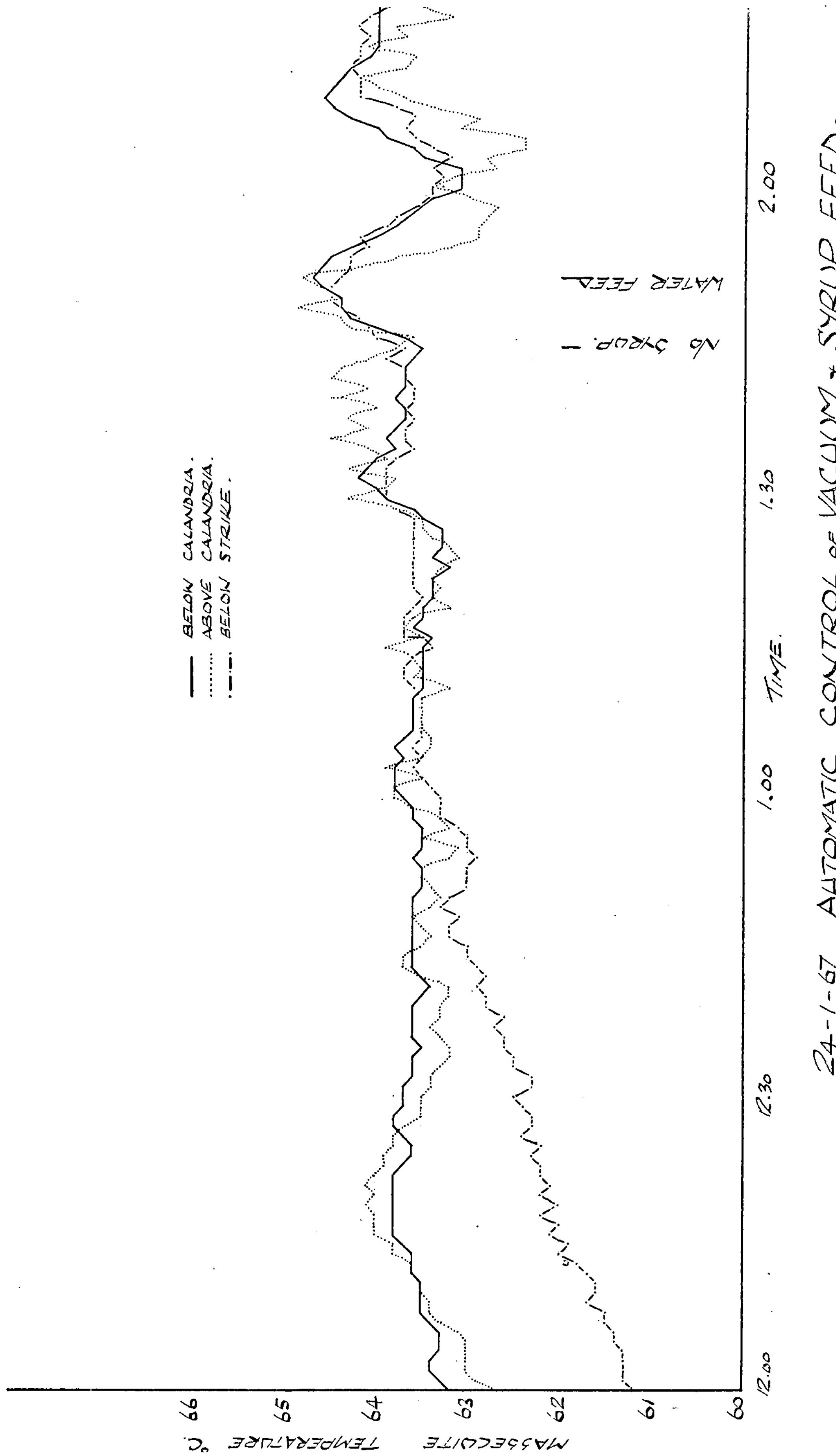

Below Calandria
Above Calandria
Below Strike level.
Massecuite Temp. °C.
57
58
59
60
61
62
63
64
65
66
67
11.45
12.45
1.45
Time.
14/12/66
No Vacuum Control.

FIGURE 2



24-1-67 AUTOMATIC CONTROL OF VACUUM + SYRUP FEED.
BELOW CALANDRIA.
ABOVE CALANDRIA.
BELOW STRIKE.
NO SYRUP.
WATER FEED
TIME.
12.00
12.30
1.00
1.30
2.00
MASSECUITE TEMPERATURE °C.
60
61
62
63
64
65
66

FIGURE 3

FIGURE 4: Control Panel showing Vacuum, Steam and Syrup Feed Controllers together with ancillary gauges

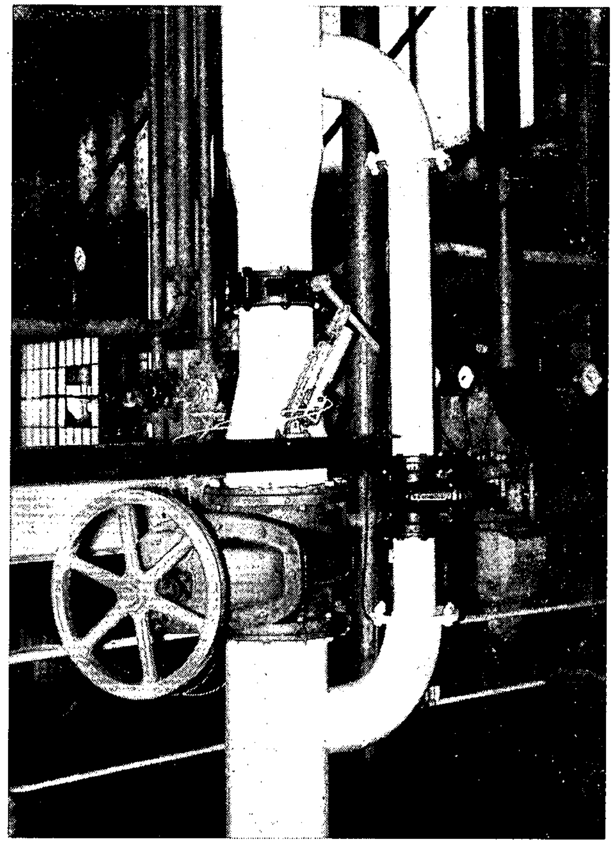


FIGURE 5: Injection water main showing Hagan Power Positioner operating 10″ diameter butterfly valve

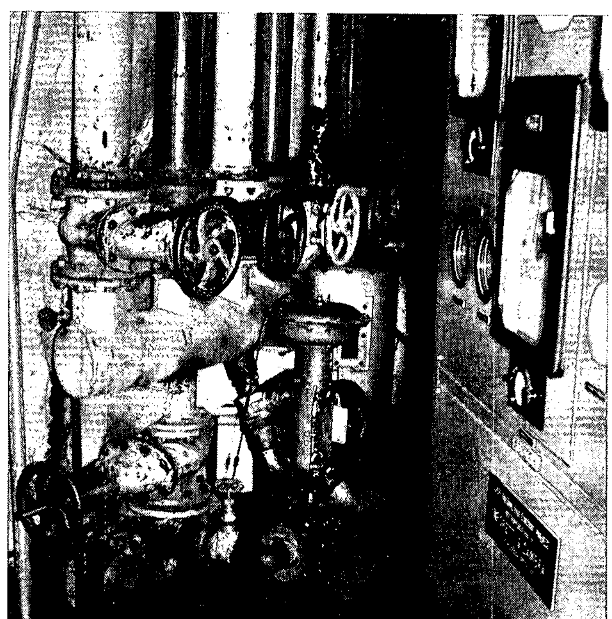


FIGURE 6: Syrup Control Valve with Main Control Panel on the right

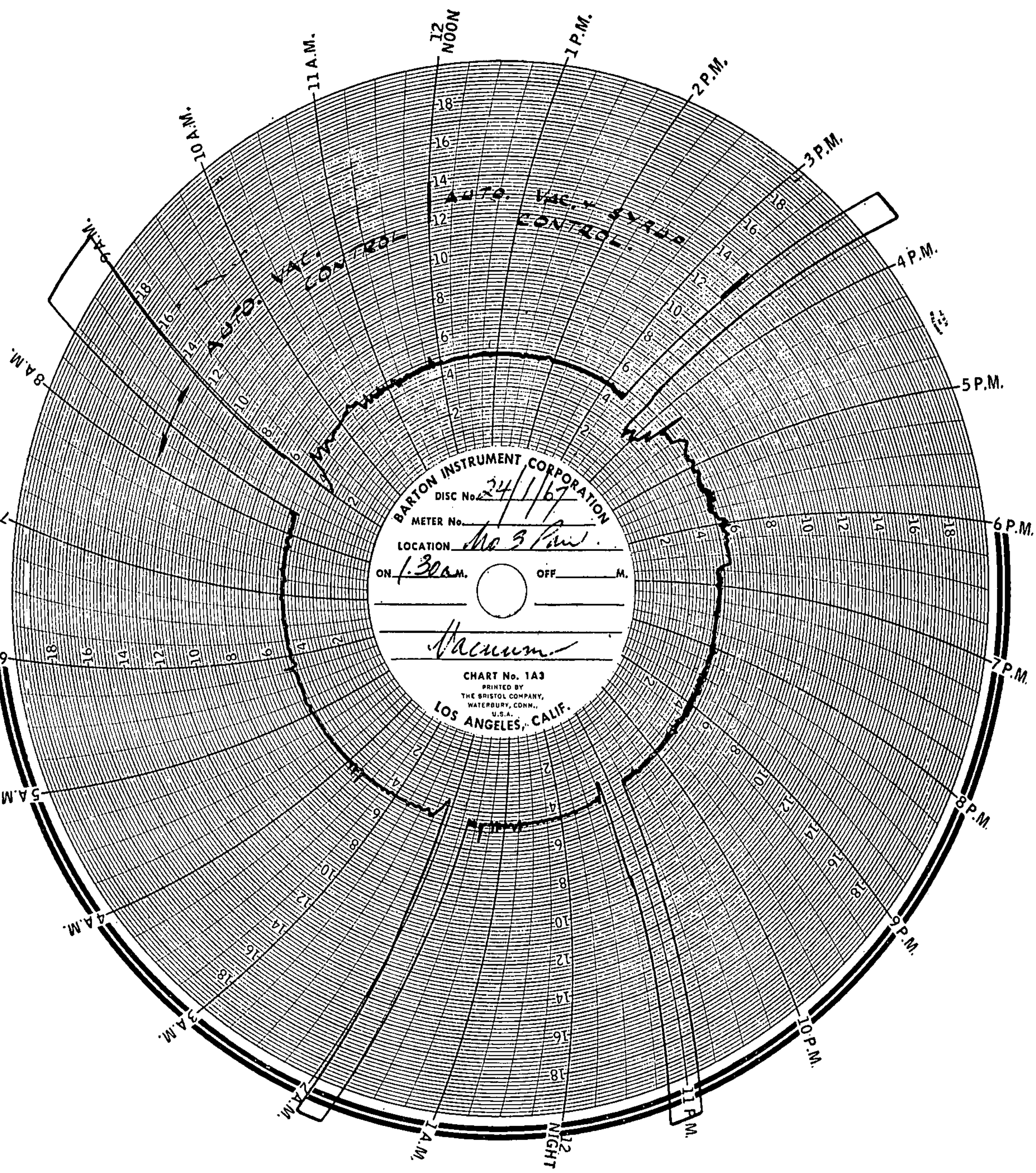

12 NOON
1 P.M.
2 P.M.
3 P.M.
4 P.M.
5 P.M.
6 P.M.
7 P.M.
8 P.M.
9 P.M.
10 P.M.
11 P.M.
12 NIGHT
1 A.M.
2 A.M.
3 A.M.
4 A.M.
5 A.M.
6 A.M.
7 A.M.
8 A.M.
9 A.M.
10 A.M.
11 A.M.
AUTO. VAC. CONTROL
AUTO. VAC. + SYRUP CONTROL
BARTON INSTRUMENT CORPORATION
DISC No. 24/1/67
METER No.
LOCATION
ON 1.30 A.M.
OFF M.
Vacuum
CHART No. 1A3
PRINTED BY THE BRISTOL COMPANY, WATERBURY, CONN., U.S.A.
LOS ANGELES, CALIF.

FIGURE 7

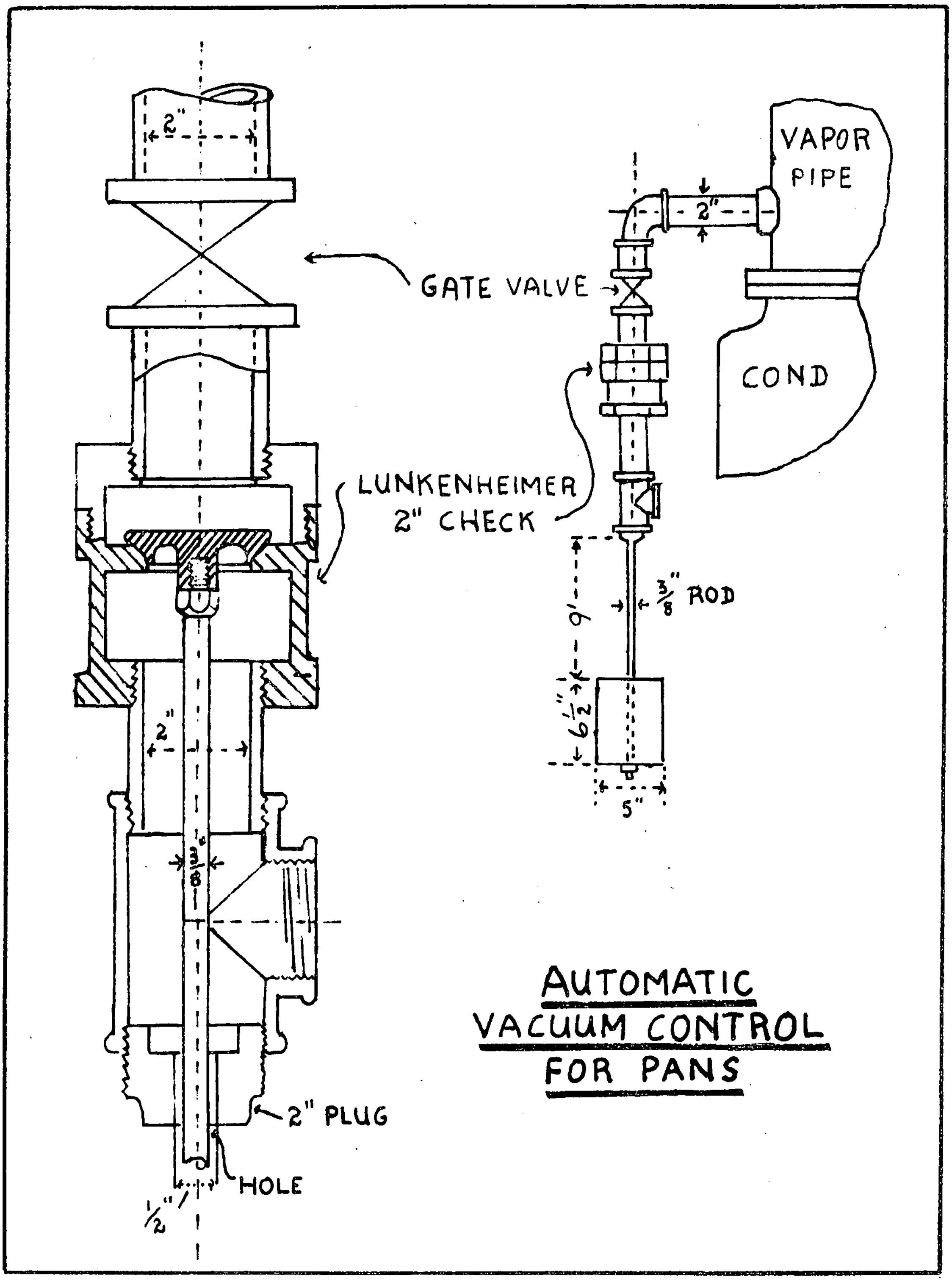

2"
GATE VALVE
VAPOR PIPE
2"
COND
LUNKENHEIMER 2" CHECK
9'
3/8" ROD
6 1/2"
5"
2"
3/8"
AUTOMATIC VACUUM CONTROL FOR PANS
2" PLUG
HOLE
1/2"

FIGURE 8

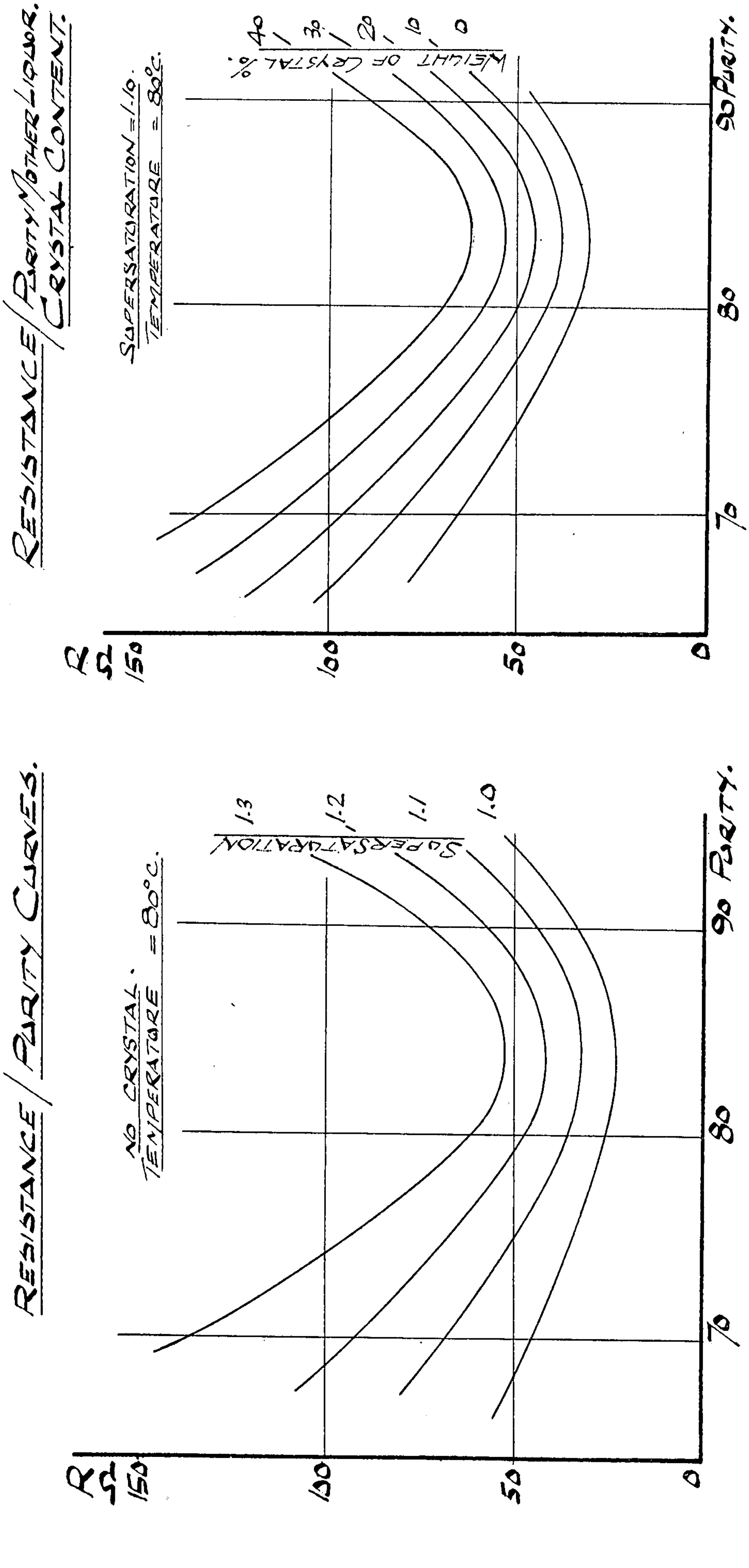

RESISTANCE / PURITY MOTHER LIQUOR. CRYSTAL CONTENT.
SUPERSATURATION = 1.10.
TEMPERATURE = 80°C.
WEIGHT OF CRYSTAL %
40
30
20
10
0
R Ω
150
100
50
0
70
80
90 PURITY.
RESISTANCE / PURITY CURVES.
NO CRYSTAL.
TEMPERATURE = 80°C.
SUPERSATURATION
1.3
1.2
1.1
1.0
R Ω
150
100
50
0
70
80
90 PURITY.

FIGURE 9

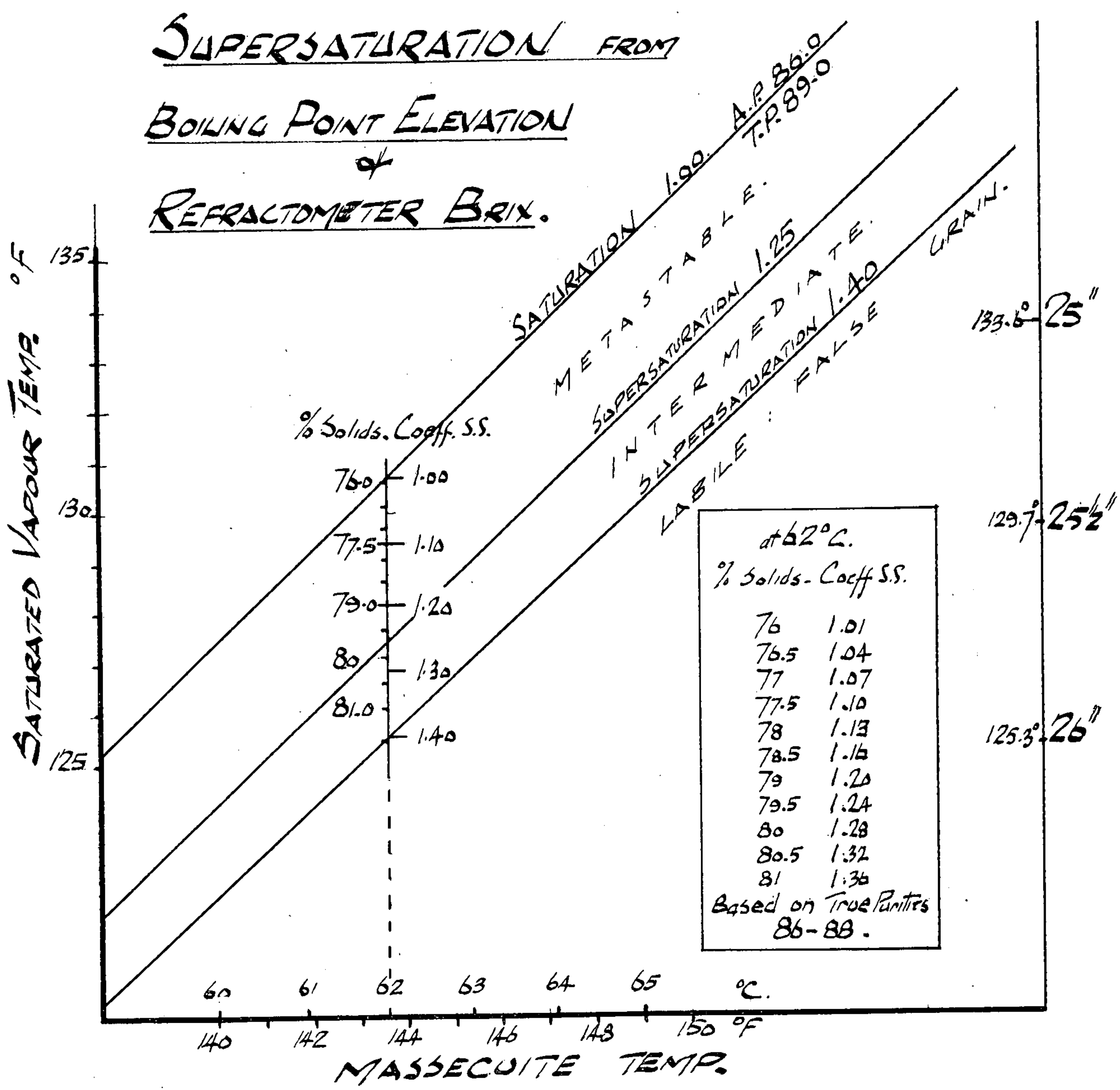


FIGURE 10

Discussion

Mr. Gunn (in the chair): We have had various commodities offered to us by manufacturers to aid pan boiling but in not one instance has a claim made been substantiated, at any rate in this country. Possibly the designs of pans in South Africa are such that they do not require these aids.

At the start of his paper Mr. Allan said they were getting superheated vapour temperature on top of the strike. If this is so it must be very difficult to measure boiling point elevation in the massecuite and I would like to know how it is done.

Mr. Allan: There is a high temperature above the massecuite and normally a pilot pan is built on to the side of the big pan to measure absolute saturation temperature. Noodsberg built a smallish vessel which is coupled into the vacuum system; water is fed into this pan and heated by some device and the pressure in the pilot pan is identical to the big pan. The saturated vapour pressure is obtained from the water in the pilot pan.

Mr. Buchanan: If the saturation temperature in a pan is controlled at a constant level then the boiling elevation can easily be determined.

Mr. Hulett: From the curve given it looks as if it is important to ensure that there is sufficient syrup or molasses to boil the pan uninterruptedly in the syrup feed.

Mr. Allan: If there was a float control on the pan supply tanks it could operate a solenoid valve which could commence to feed water into the pan. As the syrup level drops an electrical signal would switch over air control to the water valve instead of the syrup valve. One need not worry about syrup storage capacity as long as one can get water into the pan to keep circulation going.

Mr. Hulett: With a pan with a mechanical stirrer you switch off the steam and the water, and the condenser water

Mr. Renton: What experience did Mr. Allan have with the automatic vacuum control as pictured in his paper? We have started using one at Darnall and although it obviously works we have had insufficient experience with it as yet.

Mr. Robinson: We do know that it draws a straight temperature chart so we assume it is maintaining good vacuum.

Mr. Allan: This was included in the paper as the equipment is inexpensive and some factories might like to try it.

Mr. Hulett: The air-bleed is expensive on water and on vacuum pump horsepower.

Mr. Warne: There was an acute water shortage at the factory last year when we were carrying out this investigation and by installing Vacuum Control we saved a lot of water, horsepower and steam for the factory.

Dr. Matic: Regarding the type of pans in South Africa, when we started the investigation it was hoped to use a bad pan and show how its performance could be improved. However, the pan we chose proved that it had a very good circulation which was encouraging even though it did not assist our investigation.

Mr. Fourmond: Were any photographs taken of the seeds to give an indication of the regularity of the crystals when using this method?

Mr. Allan: So far we have not worked on the quality of sugar boiled in this way but we intend to do so, as obtaining a regular crystal size and getting good exhaustion is the object of the investigation.

Mr. Lenferna: Was there a difference in dirt accumulation between top and bottom electrodes, and how often were they cleaned?

Mr. Warne: The tests were conducted over short periods and we did not have to clean the electrodes.

Mr. Renton: We have had the electrodes in at Darnall for two seasons and they have not yet been cleaned.

Mr. Hulett: They should remain clean seeing that an alternating current is passing through them.

Mr. Lenferna: We found the electrode in the bottom of the pan difficult to remove for cleaning and the pan had to be entered for that purpose. We also found that the electrodes were erratic shortly after being cleaned.

Mr. Robinson: What type of electrode is being used at Tongaat, and is the current DC or AC?

Mr. Gunn: They are stainless steel with a DC current. We have a very sensitive conductivity meter at Tongaat and possibly a small amount of dirt causes quite a bit of trouble which is why we have to clean our electrodes at least once a week.

Mr. Robinson: We found the resistance between our electrodes on a C- boiling in the region of 500 ohms with a current of 50 milliamps which would indicate that the high sensitivity is not required.

Mr. Hulett: We made our own conductivity probes at Darnall and at first the milliammeter on the conductivity meter flickered a lot. The trouble was due to an air leak in the probe.