SOME DEDUCTIONS ON THE EXTENT AND CHARACTERISTICS OF THE STEAM DEMAND OF VACUUM PANS

By G. A. DUNN and W. F. NELSON.

General Considerations.

We have no less authority than the recently issued report by the Board of Trade on the South African Sugar Industry, that **"pan boiling is regarded as a somewhat mysterious art, and is undoubtedly an operation requiring great care and skill,"** and it is to be expected that this must be particularly so when, as happens in many instances, the pressure of the heating steam varies inversely to the rate at which it is required, between the limits of 10 lbs .and zero on the gauge.

Pan boiling procedure varies somewhat in different factories, but in Fig. 1 an endeavour has been made to depict the fundamentals of this process as followed in the raw sugar boiling house analysed later in this paper.

The **seed** is boiled from virgin syrup in a single pan.

An **"A" massecuite** is made by reboiling half the seed strike with virgin syrup from the evaporator and "wash" returned from the second centrifuging of a previous "A" massecuite.

A **"B" massecuite** is made by reboiling the other half of the seed strike, this time combined with the molasses spun off from the first centrifuging of an "A" massecuite, and wash returned from the second centrifuging of a previous "B" massecuite.

A **"C" massecuite** is made in the same manner as a "B" except that it is boiled a stage later in the process, and the sucrose remaining in the molasses spun from the first centrifuging of a "C" massecuite is finally extracted in the **jelly** boiling, and as the sugar thus obtained is lower in purity than that from the previous boilings, it is remelted and passed into the pans again with the virgin syrup.

It may be mentioned that in practice it is usual to transfer or "cut" only half the seed formed in the first boiling and to boil one of the succeeding massecuites in the seed pan, whereas on the flow sheet, and for the purpose of clarity, the seed and each succeeding massecuite is shown as boiled in a separate pan.

When a boiling-house is working to capacity, each pan, while boiled independently on the batch system, will take up an allotted place in the complete boiling sequence, and when the seed is being cut to form part of two succeeding boilings, there will be a period when three pans do not take steam.

Then when these pans are charged and ready for boiling, this period of quiescence will be succeeded by one when they all start drawing steam again at about the same time. Thus, even should the pans take steam at a uniform rate during the boiling process, the steam demand would rise and fall in unison with the number of pans in operation.

A second and equally disturbing factor is that in the early stages of a boiling, pans can and do take steam at a much higher rate than towards the end.

At the start the charge is relatively fluid and cool and the rate at which a pan can draw is mainly dependent on the area of the heating surface; but as water is boiled off and the contents become more viscous, the reduced rate of circulation acts as a brake, and finally cuts down steam flow to a mere fraction of the initial rate.

The following figures are taken from a curve by Webre,[2] to demonstrate the change in the velocity of circulation which takes place in the course of boiling a "C" massecuite :—

Maximum at start ...	1.8 feet per second.
Average first hour ...	1.45 feet per second.
Average second hour ...	0.6 feet per second.
Average third hour ...	0.15 feet per second.
Average fourth hour onwards	practically static.

As is to be expected, the curve of the rate at which a pan can draw steam is rather similar to that of the velocity of circulation, and when three pans start together the resulting draw may, for the purpose of this general explanation, be visualized as a threefold replica of that for a single pan, so that the curve of total steam to pans will tend to take the form of a series of recurring peaks, each, at their inception, rising steeply to the maximum and then diminshiing at a progressively lessening rate.

Thus while the steam required by a raw boiling-house averages at approximately 28 per cent. of the total used for all purposes, in two South African factories, each having a total boiler output in the region of 125,000 lbs./hr., there are times when the steam accumulators with which they are equipped discharge at the rate of between 60,000 and 70,000 lbs./hr., and thus aid the boilers to the extent of 50 per cent. of their normal output.

In one of these factories, one large pan of 3,500 sq. ft. heating surface, when boiled with a full charge of virgin juice, drew accumulated steam at the rate of 75,000 lbs./hr. over the first 15 minutes after starting, which is equivalent to a consumption of 22 lbs. per sq. ft. heating surface, and this is an interesting instance of a case where one pan can draw steam at a rate exceeding half the total boiler output

Notwithstanding these instances of the rate at which pans are capable of drawing on an unrestricted steam supply, it is not so very long ago that the steam system of a factory was considered to be in balance when heating, evaporation and pan boiling were done by exhaust steam from mill engines, pumps and generating sets only, and although provision was made to by-pass a restricted quantity of live steam for process work, engineers were, by virtue of boiler limitations, reluctant to admit that the process required, or was given, live steam to any appreciable extent.

The pans were the "Cinderella" of the process system, and when one started it was not unusual for the L.P. steam pressure to fall to zero and remain there for a considerable time, and this condition still prevails to-day in some factories.

Although the five largest factories and refineries in this country can give ample proof of the advantages derived by providing pans with an unrestricted supply of steam at steady pressure, the question is sometimes raised if this necessarily applies in all cases, particularly where pans with relatively small heating surfaces are used, and/or where a policy of stepping the boilings to some extent, is adopted in the interests of reducing the severity of the peaks.

Standard books of reference on sugar practice give little guidance on this subject, and in the following the procedure adopted when analysing the boiling-house steam demand for a combined sugar factory and refinery is described stage by stage, in the hope that it will serve as **a reliable method for determining, by calculation, the extent and characteristics of the steam demand of any conventional boiling system** to a degree of accuracy sufficient for all ordinary purposes, and also, whereby the effect on the steam conditions of any proposed change in an existing boiling system can be predicted.

It is desired to emphasise that it is intended that the methods by which these deductions are arrived at should take precedence over the resulting values. In the absence of records of steam conditions prevailing at the factory analysed, many assumptions have been made, but as these enlarge the extent to which calculation can be applied, this is more an advantage than otherwise for the present purpose.

Wherever possible, the methods used are described by means of diagrams, and the various tables serve, primarily, to collate basic data and calculated values, in a manner convenient for quick reference by those wishing to study the subject in detail.

Brief Description of the Factory Investigated.

In this factory, all sugar produced by the raw side is melted and reboiled, and the final product is first grade refined sugar, plus a small quantity of golden syrup.

Steam is provided by three B. & W. bagasse-fired boilers, each 4,780 sq. ft., two bagasse-fired multitubulars each 2,000 sq. ft., and two coal-fired B. & W. boilers each 4,780 sq. ft. and equipped with chain-grate stokers, and the coal-fired boilers are essentially for meeting the needs of the refining side.

The five water tube boilers operate at a normal pressure of 160 lbs., have balanced draught and the gases pass to an economiser. The two multitubulars operate at 100 lbs. and with natural draught.

Normally, all power is obtained from back-pressure generating sets, supplied from the 160 lbs. range. The mill itself is steam-driven and operates at 100 lbs. pressure, and conditions in the raw boiling-house are, in general, similar to those prevailing in other Natal mills producing raw sugar, with the exception that the pans and other processes which operate on L.P. steam get the benefit of the additional quantity of exhaust resulting from the extra power produced for the refining side.

The refining pans are supplied with steam at 40 lbs. by-passed direct from the 100 lbs. range.

The raw sugar is boiled in four pans numbered 3 to 6, with heating surfaces as follows :—

No. 3	1,000 sq. ft.
No. 4	1,250 sq. ft.
No. 5	400 sq. ft.
No. 6	1,600 sq. ft.

The refined sugar is boiled in two coil pans, each 1,000 sq. ft. heating surface.

The investigation was made between seasons and the only available record of the steam conditions prevailing was provided by charts from pressure recorders on the 160 lbs. boiler range and the 40 lbs. system supplying the refining pans.

No records of the quantity of steam produced or consumed were available, as the factory is not equipped with flow meters.

Circumstances which led up to the investigation and determined the course it should follow.

The factory was being seriously handicapped by the inability of the boilers to meet the demand for steam for power and process work, with the result that the boiler pressure dropped at frequent intervals to a stage at which efficient working was no longer possible.

The Boiler Pressure Chart shown in Fig. 2 is representative of average day-to-day conditions. In contrast, the 40 lbs. supply to the refining pans was remarkably steady, indicating that this service had first call on the steam available.

The boiler pressure tends to recover between the periodic drops and there are periods when the safety valves lift. Consequently, it was considered probable that the inability of the boilers to cope with the situation was principally due to the varying rate at which steam is required for process work, rather than to their inability to meet the *average* of total factory steam requirements, when permitted to work steadily at a rating comparable with their normal capacity, as would apply if, as in similar circumstances elsewhere, the demand of the pans was stabilised by a steam accumulator.

As the refining pans draw direct from the high pressure steam range, whereas the raw pans are reputed to operate on exhaust steam only, it seemed rational to assume that the refining pans were primarily responsible for the unstable high pressure steam conditions, and therefore that, if this service were stabilised, the boilers would be able to cope with any out-of-balance conditions then remaining.

On the other hand, and from the knowledge that raw pans, reputed to operate on exhaust steam only, do in fact frequently both require and get a fair quantity of reduced live steam, it was decided to get a better understanding of the steam requirements of each boiling-house in the following manner:

Firstly, calculate the curve of unrestricted steam flow for each boiling-house, by a common method, permitting direct comparison and so determine the extent to which they were individually and collectively out of balance.

Secondly, relate in time the curves thus found, with a chart of the high pressure steam pressure, and so determine the relationship between the peaks of each curve and the periods of low pressure, and therefore the extent to which each boiling-house could be expected to be responsible for these low periods.

Basic calculations and conditions pertaining to the working period to which they were applied.

The two boiling-houses use steam of differing heat values, and as their curves of steam flow have to be resolved to a common denominator for direct comparison, the heat values of the steam used were deduced from knowledge of their source, in the manner explained in Appendix I, and the values thus found are stated in subsections (6) for refining pans and (11) for raw pans.

From these steam values and the quantities, densities and temperatures normally applying to the various boilings, as given in Table 1 and on the flow sheet shown in Fig. 1, the total quantity of steam required to make each quality of massecuite was calculated in the manner shown in Appendix 2 for raw pans and Appendix 3 for refining pans.

These quantities were obtained by determining the heat required, firstly, to raise the incoming charge and make up to the slightly elevated surface boiling temperatures applying to sugar solutions, and, secondly, to boil off the water taken in with the charge and make up, in excess of that remaining at final density, and, in accordance with general practice, it was assumed that all pans are boiled at 25-inch vacuum.

NOTE.—The density of the charge for the succeeding refining side massecuites is somewhat higher than that for the first one, but, for simplicity, the steam quantity given in Appendix 3 is taken to apply in all cases, and the resulting error is not sufficient to materially affect the final results.

The weight per cubic foot of solutions of differing sucrose values was taken from a chart by Tromp,[1] and to simplify calculations the specific heat of sucrose was taken at the round figure of 0.3.

The basic steam quantities given in Appendices 2 and 3 apply to straight boilings, and no account has been taken of—

(1) additional water which may be added in the course of a boiling for washing out false grain or similar purposes;

(2) heat loss by radiation; and

(3) the steam used in steaming out pans between boilings.

In the present instance the steam equivalent of the heat lost by radiation would seem to average at about .05 of the steam used by the pans, and over the working period analysed the quantity of steam used for steaming out is roughly estimated to average at 850 lbs./hr. and 1,150 lbs./hr. for the raw and refining boiling houses respectively.

Having obtained the basic steam quantities required for each boiling, the next stage was to relate these to the actual boiling cycles applying on a representative working day, and the period 6 a.m., 13th September, 1946, to 6 a.m. on the following day, was selected by the factory as one in mid-season, when both boiling-houses were working at practically full capacity; the cane crushed was predominantly of the varieties considered to give bagasse of good burning properties; moisture in bagasse normal; stoppages normal and none of long duration; the reserve of bagasse on the firing floor sufficient to prevent the boilers being starved of fuel during stoppages, and fluctuations in high pressure steam range pressure about the average experienced.

Extracts from the log books for raw and refining pans for this day are given in Table 2, and the high pressure steam range pressure chart is reproduced in Fig. 2.

Other conditions pertaining to this day are as follows:—

Average crushing rate		56.4 tons/hr.
Cane varieties crushed:	Co.301 ...	27.22 %
	Co.281 ...	65.31 %
	P.O.J. ...	6.39 %
	Co.290 ...	1.08 %
Maceration on cane		40.59 %
Raw juice on cane at 15.11° brix ...		105.00 %
Bagasse on cane		34.61 %
Moisture in bagasse		48.46 %
Additional raws from outside melted in refinery		Nil

Continuing with the calculations, the average values for steam used and water evaporated per boiling were obtained by relating the calculated totals to the actual boiling times, and as pans do not take steam and therefore boil at a uniform rate, the maxima applying at the start of each boiling had to be determined.

It was intended to base these values on curves instanced by that well-known authority on sugar technology, L. A. Tromp, for the rates of evaporation applying to individual boilings, so that while the values for each quality boiled would differ, they would be uniform for each boiling of the same quality.

However, difficulties were experienced in relating the values so derived with the varying averages as determined by the differing times obtained from the log sheets for similar boilings, and consequently the compromise of fixing the maximum rates of evaporation, and therefore steam consumption, at twice the average, was finally adopted; and as it is desired to emphasise the methods used in this investigation rather than the resulting values, it is thought that the simplicity of this procedure will compensate for any inherent errors.

The following is a comparison of the rates of evaporation per square foot heating surface so derived, with those instanced by Tromp[1] as obtained under test, when using exhaust steam at about 5 lbs. pressure.

	Calculated average × 2.	Tromp.	No. of pans boiled in period analysed.
Seed...	14.0	17.0	4.5
"A" massecuites ...	17.4	14.5	2.5
"B" massecuites ...	9.9	9.5	4.0
"C" massecuites ...	11.1	7.5	2.5
Average of boilings	13.1	12.1	—

The information required for constructing the curves of pans' steam demand is now complete, and Table 3 summarises the pan sequences and boiling times applying on the day analysed and the total, average and maximum steam and evaporation values applying to each pan boiled, as determined in the manner reviewed in the foregoing.

Construction and Comparison of Curves of Pans, Steam Demand.

Figure 3 shows the calculated curves of steam consumption of each raw pan set out on a time base corresponding to the pan log for the period analysed, and summed to obtain the curve of total steam to the raw boiling-house in terms of an unrestricted supply at 5 lbs. pressure and 93 per cent. dry.

Bearing in mind that the boiling times are nett and do not include the periods occupied in steaming out, emptying and filling, the individual curves show the regularity of the boiling cycle, and that the pans were being worked to almost full capacity; as one seed pan comes down another starts boiling, and when the seed is cut, two pans immediately start boiling the succeeding massecuites, and it would seem that the only way to appreciably improve the present capacity of the boiling-house would be to cut down the actual boiling times by providing conditions whereby the pans could draw more heavily on the steam supply when the rate of circulation prevailing would enable this to be used effectively.

The curve of total steam to the raw boiling-house averages at 25,000 lbs./hr. and peaks at between 60,000 and 65,000 lbs./hr. and the peaks are surprisingly uniform and regularly spaced.

The steam values are given for the areas of the peaks and valleys above and below the average, and from these **the extent to which the curve is out of balance is assessed at 56,000 lbs.**

This out-of-balance quantity can be considered as the theoretical capacity of a steam accumulator plant capable of taking steam at the average rate, and discharging it at the varying rates which go to make up the curve of supply. This capacity is obtained by summing algebraically in series the steam values of the peaks and valleys, starting from zero, and then adding, irrespective of sign, the greatest positive value in the series of additions to the greatest negative value in the series, disregarding signs.

It may be mentioned that because of the heavy conditions present on this day the figure of 25,500 lbs./hr. for the average of the steam demand is not a fair measure of the steam required in terms of the quantity of cane crushed, and an average of 22,500 lbs./hr. was obtained from an analysis, on similar lines, of a more normal day in the boiling-house.

Fig. 4 shows the calculated curves of steam consumption for each refining pan, related in time to the log of pan boilings, and summed to obtain the curve of total steam to the refining boiling-house, in terms of an unrestricted supply at 40 lbs. dry saturated.

The curve of total steam to the refining boiling-house averages at 15,000 lbs./hr. and peaks at between 30,000 to 40,000 lbs./hr., and the system was found to be out of balance to the extent of 23,500 lbs.

Conditions prevailing during the period analysed may be taken as representative of a good average day in the refinery, and as these pans draw on a steady supply it can be assumed that, contrary to conditions prevailing in the raw side, they get all the steam they require.

Fig. 5 shows the curves of the steam demand of each boiling-house in Figs. 3 and 4 replotted in terms of high-pressure steam, and the resulting sum curve of total steam to both boiling-houses, all aligned on a common time base with the curve of high-pressure steam range pressure shown in Fig. 2.

The curve of total steam to both boiling-houses averages at 37,300 lbs./hr. and the peaks at 87,000 lbs./hr., and this curve is out of balance to the extent of 59,000 lbs. in terms of high pressure steam.

As is to be expected under the circumstances, the peaks and valleys, in the three curves of steam flow, do not always fall exactly in line with those of the boiler pressure, but their relationship is sufficiently close to indicate that, in the absence of other explanation, and contrary to expectations, **the peaks of the draws by the raw pans lower the steam pressure, to practically the same extent as those for the refining pans,** and it will be noted that the raw pans would seem to be entirely responsible for the pressure drops which coincide with the inner two of the four main peaks.

CONCLUSIONS.

From the relationship established between these curves of steam supply and steam pressure, it is considered that in all probability the raw pans draw on the live steam range to a considerable extent, and that to ensure complete stabilisation of the steam supply and demand in this factory the demand of both boiling-houses should be balanced by a common system of steam storage.

Moreover, this system should be arranged to give preference to the refining pans, in consequence of the fact that they draw direct on the live steam range, and because, in the interests of the quality of the final product, it is necessary that they operate on a steady supply.

It should perhaps be mentioned that in practice it is not necessary to provide a steam storage system with a capacity equivalent to the total out-of-balance quantity, determined by the foregoing methods, and that this capacity is usually based on a compromise between the theoretical figure and the extent to which experience has shown the boilers to be capable of assisting, without appreciable reduction in their optimum efficiencies and outputs.

The fluctuations in the steam supply to the power plant and to other processes, such as juice heating and evaporating, are comparatively steady, compared with that for the pans and, under normal circumstances, disturbances resulting from these services can be neglected in problems referring to steam balance.

These conclusions stand or fall on the premise that the short-period steam requirements of a boiling-house bear little relation to the quantity of exhaust steam on which they can draw, and that, unless the supply of exhaust steam is so ample that it is blown to waste when the demand is low, it must, **for conditions of adequate supply,** be augmented by live steam to a considerable extent when the demand is high, with the result that the peaks of the demand are thrown directly back on the boilers.

This is not always accepted as being the case and thus, although it is here intended to describe the method of analysis, rather than to stress the conclusions thereby resulting, the two following examples of the extent to which pans actually can and do draw live steam may be of interest.

Case 1, applying to a Natal factory producing refined sugar by the double-carbonation process, prior to stabilising steam conditions.

In the interests of uniformity of the final product, the supply of exhaust steam to the pans in this factory was augmented by a considerable quantity of reduced live steam by-passed direct from the 100 lbs. boiler range, and a set of charts showing the conditions of flow and pressure in these two systems is shown in Fig. 6.

In this instance there is no doubt regarding the need to use live steam, or that the peaks of the demand are thrown directly back on the 100 lb. boilers, and, from the extent to which the pressure fluctuates, it is evident that the boilers acted as a one-way system of steam storage; which is to say that, while under falling pressure they flashed off additional steam to that generated by the heat in the furnace, they were unable to absorb any surplus when the demand was low, and so store this to meet the peaks.

Notwithstanding the large amount of live steam used by the boiling-house in this factory, the flat tops of the peaks in the flow charts and the excessive drops in pressure, in both live and exhaust steam ranges, give ample evidence that the pans' demand was not being fully met.

Conditions of steam supply and demand at this factory have now been stabilised and the pans now draw on a single supply, which, under all normal conditions, remains steady at a pressure of 10 lbs.

Case 2, applying to a typical Natal factory producing raw sugar only, under stabilised steam conditions.

Fig. 7 shows a typical chart of the quantity of live steam, by-passed to the exhaust range via a steam accumulator, to augment the supply from the mill engines, power plant, etc., and as required to maintain a steady pressure of 8 lbs. or thereabouts in this range.

In this instance the process draws live steam at the average rate of about 30,000 lbs./hr., and between the limits of zero and 65,000 lbs./hr.

Thus, while the output of the boilers can be assumed reasonably steady at about 140,000 lbs./hr., there are periods when the quantity of steam both necessary and available adequately to meet the total requirements of this factory for power and process work, rises to approximately 180,000 lbs./hr. in terms of high-pressure steam.

This process system is conventional, and there is little doubt that these variations reflect the changes which take place in the draw by the pans.

That the by-passing of live steam, to the extent illustrated by this chart, does not result in wastage is, if there is need to make the point, substantiated by the fact that, under present-day conditions, and notwithstanding an increase of 20 per cent. in the factory output without alteration to the boiler plant, the surplus of bagasse has reached embarrassing proportions, whereas previously wood had to be burned to compensate for a shortage of bagasse; and despite the use of this extraneous fuel, a condition of almost chronic steam shortage then prevailed.

A feature of this chart is the practically instantaneous manner in which the rate of discharge from the accumulator rises from zero or thereabouts to between 45,000 and 50,000 lbs./hr.

This is a good example of the rate at which pans can draw steam when the supply is unrestricted, and it would seem to indicate that the maximum rates of evaporation considered to apply in the analysis described are reasonably representative of actual conditions.

A discourse such as this would not be complete without referring those who may wish to know more about the practical side of balancing steam conditions in sugar factories and refineries to the under-noted papers on this subject :—

"Results Obtained from Thermal Storage Applied to a Sugar Refinery," by G. C. Wilson, A.M.I.Mech.E., M.I.Cert.E. Proc. Natal Inst. Eng., Nov. 1937.

"The Steam Accumulator at Mount Edgecombe," by W. Mackesy, A.M.I.Cert.E. Journal Inst. Cert. Eng. (S.A.), May 1944.

Finally, it is desired to thank the management of the factory to which this analysis applied, for permission to use their figures and to freely express our personal views on the conditions thereby implied, and also the managements of the Natal Estates Ltd., Mount Edgecombe factory, and Sir J. L. Hulett and Sons Ltd., Darnall factory, for permission to instance their steam flow charts and factory conditions.

References.

[1] Tromp, L. A. (1936) : Machinery and Equipment of the Cane Sugar Factory. Norman Rodger, London. 1936.

[2] Webre, Alfred L. (1934) : Circulation in Vacuum Pans. Proc. American Soc. Mech. Eng., Dec. 1934.

FLOW SHEET FOR RAW PANS

GIVING PARTICULARS OF BOILINGS

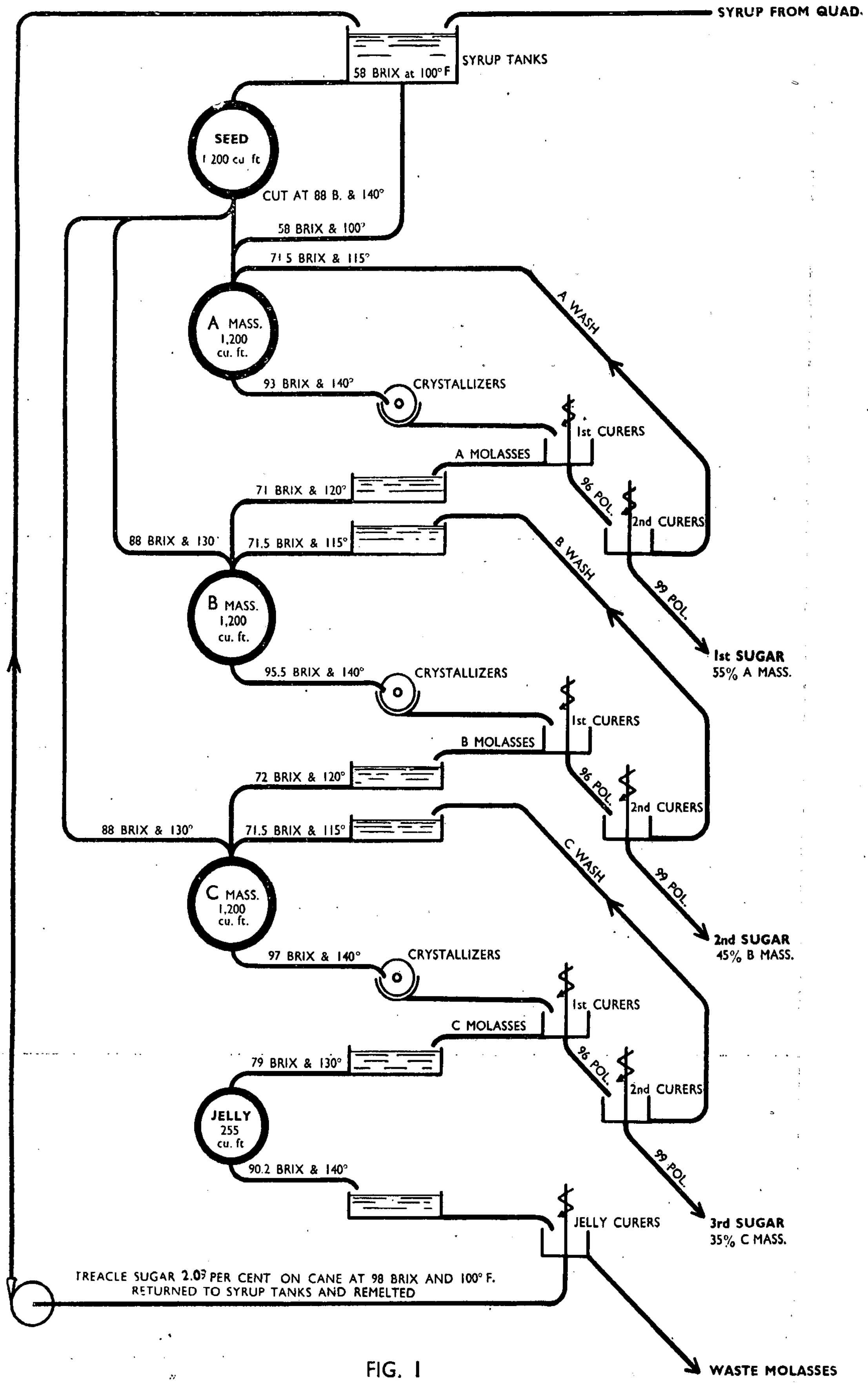

FIG. 1

TABLE 1

PARTICULARS OF PAN BOILINGS.

Raw Pans.

Quality.	Charge.	Make up per cent. total make up by weight.	Strike.	Sugar out (99 pol.) per cent. total strike by weight.	Numbers of pans boiled in period analysed.
Seed	Syrup at 58° brix and 100°F.	——	1,200 cu. ft. at 88° brix and 140°F.	—	Part 6, 6 Complete 4, 6, 4
"A" mass.	600 cu. ft. seed at 88° brix and 130°F.	66% syrup at 58° brix and 100°F. 34% wash at 71.5° brix and 115°F.	1,200 cu. ft. at 93° brix and 140°F.	55%	Part 3. Complete 3, 3
"B" mass.	600 cu. ft. seed at 88° brix and 130°F.	66% "A" molasses at 71° brix and 120°F. 34%"B"wash and 71.5° brix and 115°F.	1,200 cu. ft. at 95.5° brix and 140°F.	45%	Part 3 Complete 6, 3, 6
"C" mass.	600 cu. ft. seed at 88° brix and 130°F.	66% "B" molasses at 72° brix and 120°F. 34% "C" wash at 71.5° brix & 115°F.	1,200 cu. ft. at 97° brix and 140°F.	35%	Part 4, 4 Complete 4
Jelly	"C" molasses at 79° brix and 130°F.	——	225 cu. ft. at 90.2° brix & 140°F.	—	Part 5 Complete 5,5,5,5

Note.—The temperature of the charge for "B" and "C" massecuites given in this table applies when these massecuites are boiled in a separate pan to that in which the seed is made, and when "B" and "C" massecuites are boiled in the seed pan the temperature of the charge should be increased by 10°F., i.e. this temperature becomes 140°F.

Refining Pans.

Quality.	Charge.	Make up per cent. total make up by weight.	Strike.	Sugar out (99.9 pol.) per cent. total strike by weight.	Numbers of pans boiled in period analysed.
1st mass.	1st liquor at 60° brix and 120°F.	——	All massecuites 550 cu. ft. at 89° brix and 140°F.	All massecuites approximately 50 %	2, 2, 2, 2, 2, 2
2nd mass.	2nd liquor at 60° brix and 120°F.	1st wash included in 2nd liquor			1, 1, 1
3rd mass.	3rd liquor at 60° brix and 120°F.	2nd wash included in 3rd liquor			1, 1.
4th mass.	4th liquor at 60° brix and 120°F.	3rd wash included in 4th liquor. 5th wash at 60° brix and 120°F.			1.

Note.—5th liquor returned to raw pans.

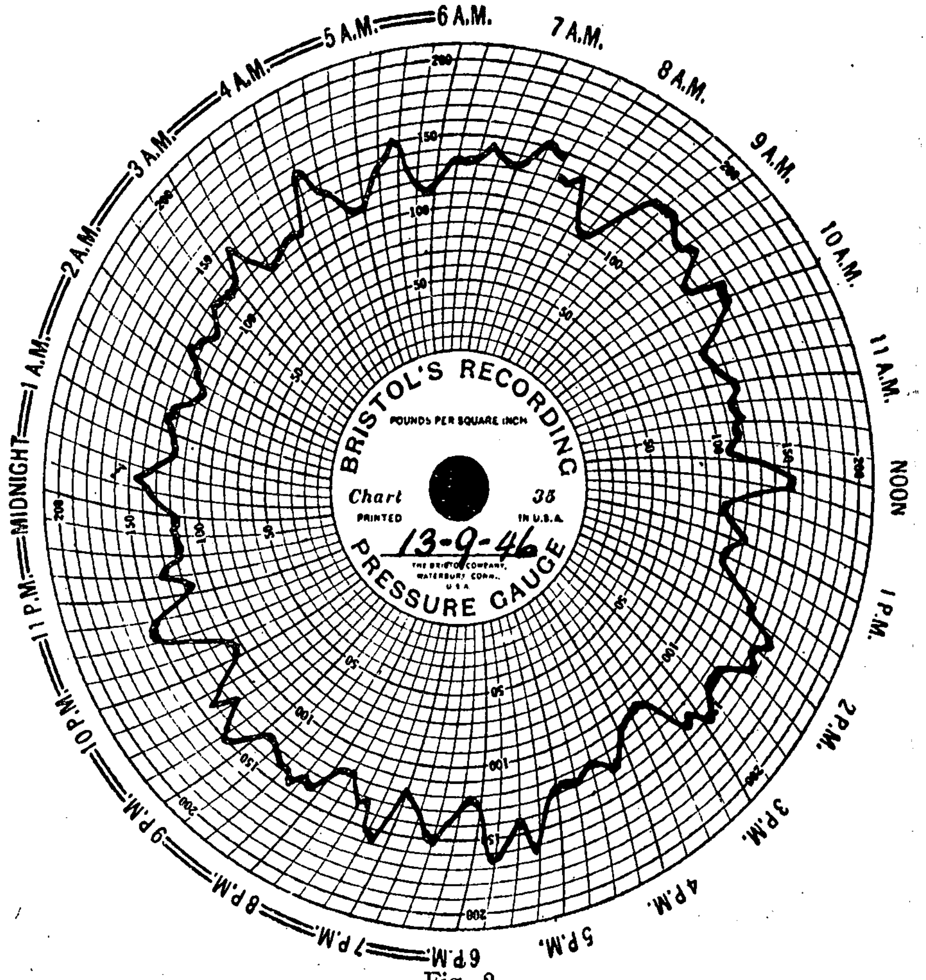
6 A.M.
7 A.M.
8 A.M.
9 A.M.
10 A.M.
11 A.M.
NOON
1 P.M.
2 P.M.
3 P.M.
4 P.M.
5 P.M.
6 P.M.
7 P.M.
8 P.M.
9 P.M.
10 P.M.
11 P.M.
MIDNIGHT
1 A.M.
2 A.M.
3 A.M.
4 A.M.
5 A.M.
BRISTOL'S RECORDING
POUNDS PER SQUARE INCH
Chart 35
PRINTED IN U.S.A.
13-9-46
PRESSURE GAUGE

Fig. 2

TABLE 2.

EXTRACT FROM RAW AND REFINING PAN BOOKS FOR CROP DAY NO. 102.

Period 6 a.m., 13th September, 1946, to 6 a.m. on following day.

Raw Pans.

Strike.	Pan No.	Start.	Finish.	Nett boiling time.	Quality.	Remarks.
—	6	3.30 a.m.	10.00 a.m.	5 hr. 45 m.	Seed	Cut to 3.
303	5	4.45 ,,	7.00 ,,	1 hr. 55 m.	Jelly	
605	3	4.45 ,,	8.15 ,,	3 hr. 15 m.	"A" massecuite	
606	4	4.45 ,,	8.45 ,,	3 hr. 45 m.	"C" massecuite	
304	5	9.15 ,,	11.15 ,,	1 hr. 40 m.	Jelly	
—	4	9.15 ,,	3.30 p.m.	5 hr. 30 m.	Seed	Cut to 3.
607	3	10.00 ,,	3.00 ,,	4 hr. 45 m.	"A" massecuite	
608	6	10.00 ,,	2.30 ,,	4 hr. 15 m.	"B" massecuite	
305	5	11.45 ,,	1.45 ,,	1 hr. 40 m.	Jelly	
—	6	3.00 p.m.	8.45 ,,	5 hr. —	Seed	Cut to 3.
609	3	3.30 ,,	8.00 ,,	4 hr. 15 m.	"B" massecuite	
610	4	3.30 ,,	7.30 ,,	3 hr. 45 m.	"C" massecuite	
306	5	3.00 ,,	5.00 ,,	1 hr. 40 m.	Jelly	
—	4	8.00 ,,	1.15 a.m.	4 hr. 30 m.	Seed	Cut to 3.
307	5	8.00 ,,	10.15 p.m.	1 hr. 55 m.	Jelly	
611	3	8.45 ,,	12.45 a.m.	3 hr. 45 m.	"A" massecuite	
612	6	8.45 ,,	1.00 ,,	4 hr. —	"B" massecuite	
613	4	1.15 ,,	6.30 ,,	5 hr. —	"C" massecuite	
614	3	1.15 ,,	6.45 ,,	5 hr. 15 m.	"B" massecuite	
—	6	1.30 ,,	9.00 ,,	6 hr. 45 m.	Seed	Cut to 3.

Refining Pans.

Strike.	Pan No.	Start.	Finish.	Nett boiling time.	Quality.	Remarks.
839	1	6.00 a.m.	8.30 a.m.	2 hr. 15 m.	3rd massecuite	—
840	2	7.30 ,,	10.15 ,,	2 hr. 30 m.	1st massecuite	—
841	1	10.00 ,,	12.15 ,,	2 hr. —	2nd massecuite	—
842	1	12.30 p.m.	2.30 p.m.	1 hr. 45 m.	4th massecuite	—
843	2	1.30 ,,	4.30 ,,	2 hr. 45 m.	1st massecuite	—
844	2	4.45 p.m.	7.00 ,,	2 hr. —	1st massecuite	Concentrated in No. 1 pan.
845	1	6.30 ,,	8.30 ,,	1 hr. 45 m.	2nd massecuite	—
846	2	7.45 ,,	10.30 ,,	2 hr. 30 m.	1st massecuite	—
847	1	10.00 ,,	12.15 a.m.	2 hr. —	3rd massecuite	—
848	2	11.45 ,,	2.30 ,,	2 hr. 30 m.	1st massecuite	—
849	1	2.00 a.m.	4.00 ,,	1 hr. 45 m.	2nd massecuite	—
850	2	3.15 ,,	6.00 ,,	2 hr. 30 m.	1st massecuite	—

Special Process Pan.

Strike.	Start.	Finish.	Nett boiling time.	Quality.	Remarks.
Stage 1	10.00 a.m.	12 noon	2 hr. —	—	—
,, 2	12 noon	1.35 p.m.	1 hr. 35 m.	—	—
,, 3	1.35 p.m.	3.00 ,,	1 hr. 25 m.	—	No steam used.
,, 4	3.00 ,,	5.00 ,,	2 hr. —	—	—
,, 1	2.00 a.m.	4.00 a.m.	2 hr. —	—	—
,, 2	4.00 ,,	5.35 p.m.	1 hr. 35 m.	—	—

TABLE 3.

SUMMARY OF CALCULATED EVAPORATION IN RAW PANS AND THE QUANTITY OF STEAM REQUIRED FOR BOILING.

Strike No.	Quality.	Pan No.	Boiling time.	Heating surface. sq. ft.	Total water evaporated. Lbs.	Total steam to boil pan. Lbs.	Water evaporated per lb. steam. Lbs.	Average evaporation. Lbs./hr.	Average steam. Lbs./hr.	Estimated maximum evaporation. Lbs./hr.	Resulting maximum evaporation per sq. ft. Lbs./hr.	Resulting maximum steam. Lbs./hr.
—	Seed	6	5 hr. 45 m.	1,600	56,200	68,000	.8275	9,780	11,820	19,000	11.8	23,000
303	Jelly	5	1 hr. 55 m.	400	2,850	3,500	.8150	1,490	1,825	—	3.75	—
605	"A" massecuite ...	3	3 hr. 15 m.	1,000	31,800	38,200	.8325	9,800	11,780	19,500	19.5	23,500
606	"C" massecuite ...	4	3 hr. 45 m.	1,250	27,350	32,000	.8550	7,325	8,525	14,500	13.6	17,000
304	Jelly	5	1 hr. 40 m.	400	2,850	3,500	.8150	1,715	2,105	—	4.3	—
—	Seed	4	5 hr. 30 m.	1,250	56,200	68,000	.8275	10,200	12,350	19,000	15.2	23,000
607	"A" massecuite ...	3	4 hr. 45 m.	1,000	31,800	38,200	.8325	6,700	8,050	13,300	16.0	16,000
608	"B" massecuite ...	6	4 hr. 15 m.	1,600	25,900	30,400	.8525	6,100	7,150	12,000	8.75	14,000
305	Jelly	5	1 hr. 40 m.	400	2,850	3,500	.8150	1,715	2,105	—	4.3	—
—	Seed	6	5 hr. —	1,600	56,200	68,000	.8275	11,220	13,600	22,300	14.0	27,000
609	"B" massecuite ...	3	4 hr. 15 m.	1,000	25,900	30,600	.8450	6,100	7,200	12,600	12.6	15,000
610	"C" massecuite ...	4	3 hr. 45 m.	1,250	27,350	32,000	.8550	7,300	8,550	14,500	11.6	17,000
306	Jelly	5	1 hr. 40 m.	400	2,850	3,500	.8150	1,715	2,105	—	4.3	—
—	Seed	4	4 hr. 30 m.	1,250	56,200	68,000	.8275	12,500	15,100	23,200	18.5	28,000
307	Jelly	5	1 hr. 55 m.	400	2,850	3,500	.8150	1,490	1,825	—	3.76	—
611	"A" massecuite ...	3	3 hr. 45 m.	1,000	31,800	38,200	.8325	8,475	10,200	16,700	16.7	20,000
612	"B" massecuite ...	6	4 hr. —	1,600	25,900	30,400	.8525	6,475	7,600	12,800	8.0	15,000
613	"C" massecuite ...	4	5 hr. —	1,250	27,350	32,000	.8550	5,475	6,400	10,250	8.2	12,000
614	"B" massecuite ...	3	5 hr. 15 m.	1,000	25,900	30,600	.8450	4,935	5,825	10,150	10.2	12,000
—	Seed	6	6 hr. 45 m.	1,600	56,200	68,000	.8275	8,325	10,050	16,550	10.4	20,000

TABLE 4.

SUMMARY OF CALCULATED EVAPORATION IN REFINING PANS AND QUANTITY OF STEAM REQUIRED FOR BOILING.

Strike No.	Quality.	Pan No.	Boiling time.	Heating surface. Sq. ft.	Total water evaporated. Lbs.	Total steam to boil pan. Lbs.	Water evaporated per lb. steam. Lbs.	Average evaporation. Lbs./hr.	Average steam. Lbs./hr.	Estimated maximum evaporation. Lbs./hr.	Resulting maximum evaporation per sq. ft. Lbs./hr.	Resulting maximum steam. Lbs./hr.
839	3rd massecuite ...	1	2 hr. 15 m.	1,000				10,700	11,750			
840	1st massecuite ...	2	2 hr. 30 m.					9,600	10,600			
841	2nd massecuite ...	1	2 hr. —	1,000				12,000	13,250			
842	4th massecuite ...	1	1 hr. 45 m.	1,000	24,000	26,500	.905	13,700	15,150	22	22,000	24,300
843	1st massecuite ...	2	2 hr. 45 m.	1,000				8,750	9,650			
844	1st massecuite ...	2	2 hr. —	1,000	all	all	all	12,000	13,250	all	all	all
845	2nd massecuite ...	1	1 hr. 45 m.	1,000				13,700	15,150			
846	1st massecuite ...	2	2 hr. 30 m.	1,000	pans	pans	pans	9,600	10,600	pans	pans	pans
847	3rd massecuite ...	1	2 hr. —	1,000				12,000	13,250			
848	1st massecuite ...	2	2 hr. 30 m.	1,000				9,600	10,600			
849	2nd massecuite ...	1	1 hr. 45 m.	1,000				13,700	15,150			
850	1st massecuite ...	2	2 hr. 30 m.	1,000				9,600	10,600			

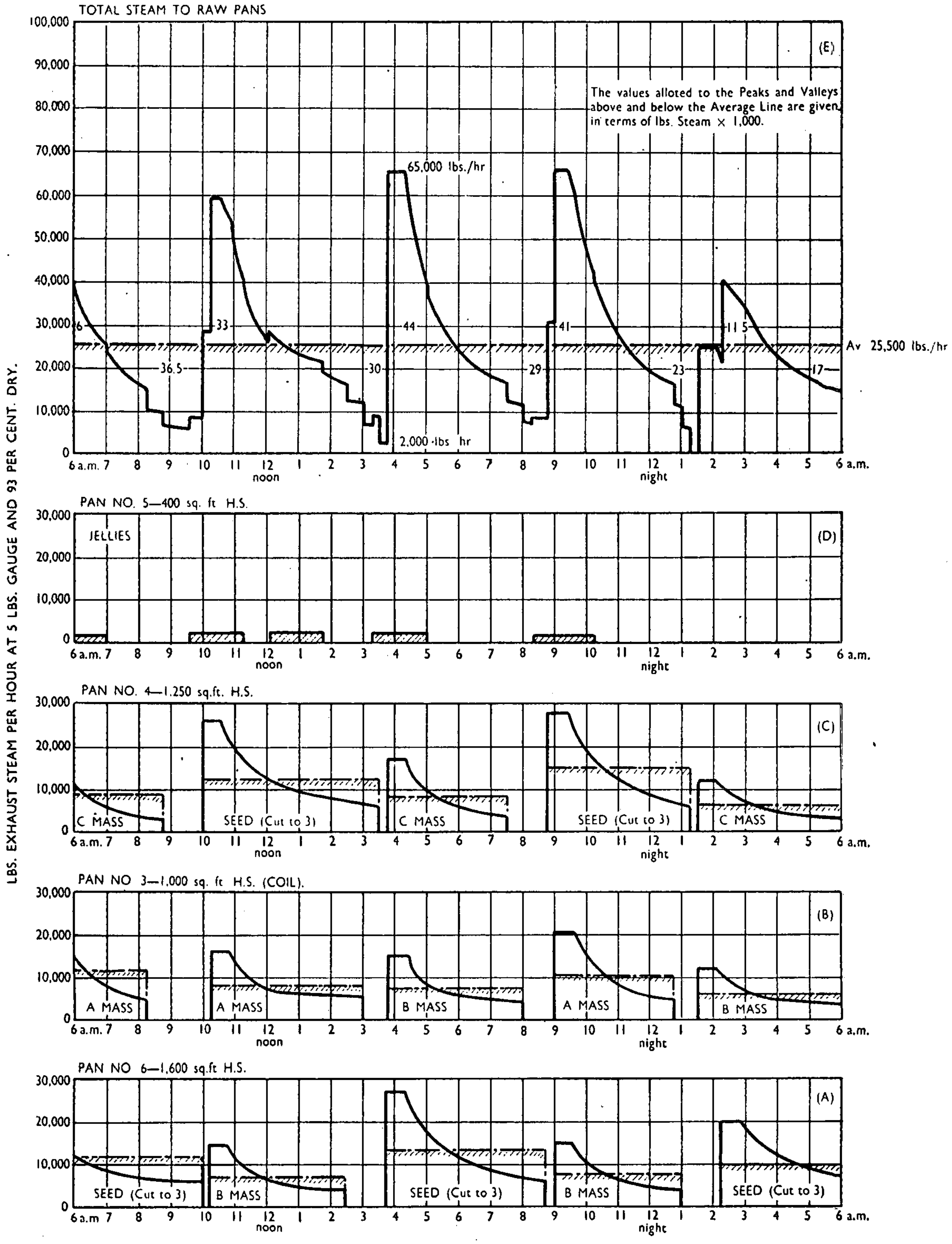
TOTAL STEAM TO RAW PANS
(E)
The values alloted to the Peaks and Valleys above and below the Average Line are given in terms of lbs. Steam × 1,000.
65,000 lbs./hr
2,000 lbs hr
Av 25,500 lbs./hr
PAN NO. 5—400 sq. ft H.S.
JELLIES
(D)
PAN NO. 4—1,250 sq.ft. H.S.
(C)
C MASS
SEED (Cut to 3)
PAN NO 3—1,000 sq. ft H.S. (COIL).
(B)
A MASS
B MASS
PAN NO 6—1,600 sq.ft H.S.
(A)
SEED (Cut to 3)
B MASS
LBS. EXHAUST STEAM PER HOUR AT 5 LBS. GAUGE AND 93 PER CENT. DRY.
6 a.m. 7 8 9 10 11 12 noon 1 2 3 4 5 6 7 8 9 10 11 12 night 1 2 3 4 5 6 a.m.

FIG. 3

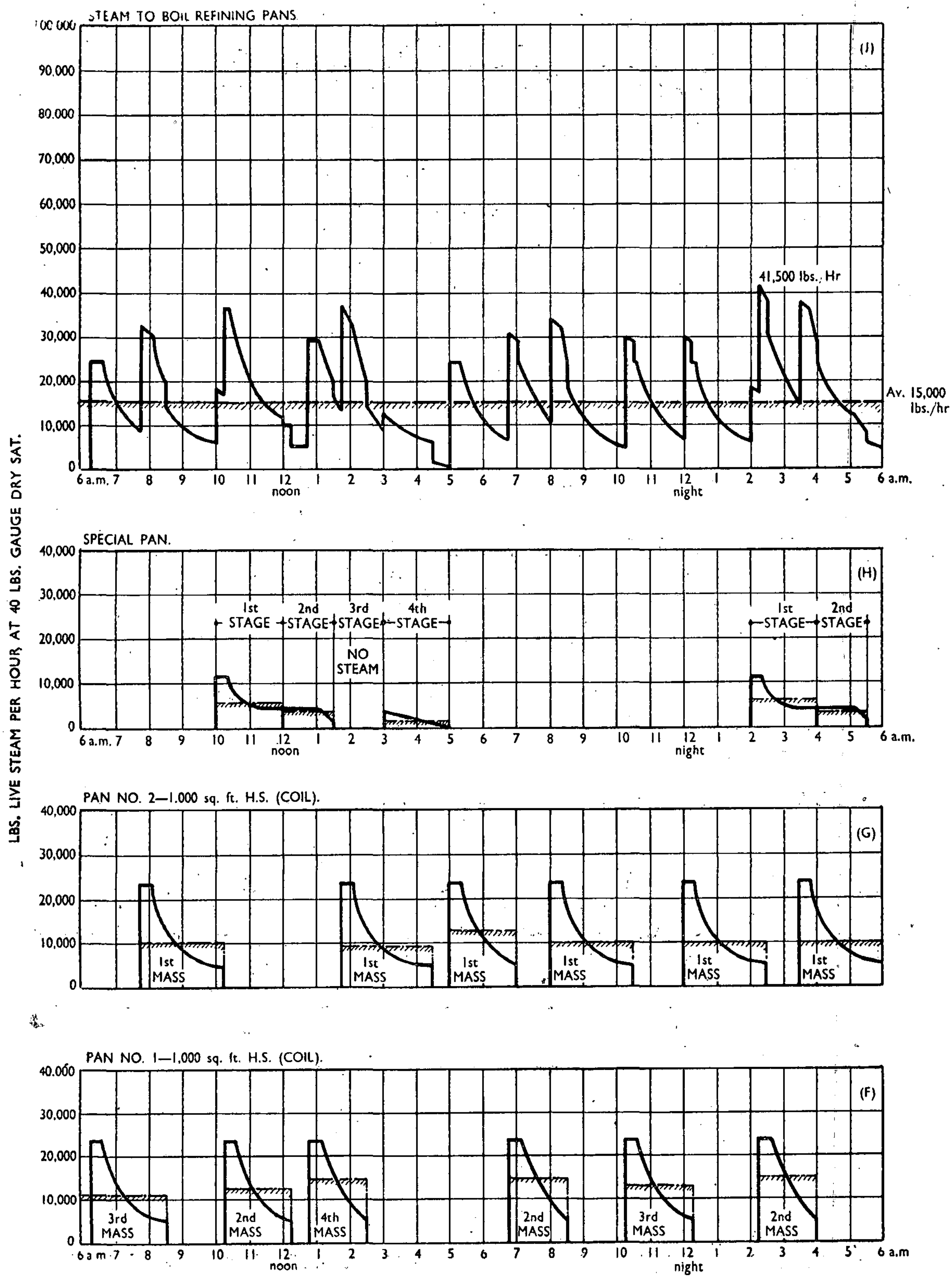
STEAM TO BOIL REFINING PANS
(J)
41,500 lbs./Hr
Av. 15,000 lbs./hr
LBS. LIVE STEAM PER HOUR AT 40 LBS. GAUGE DRY SAT.
SPECIAL PAN.
(H)
1st STAGE
2nd STAGE
3rd STAGE
4th STAGE
NO STEAM
PAN NO. 2—1,000 sq. ft. H.S. (COIL).
(G)
1st MASS
PAN NO. 1—1,000 sq. ft. H.S. (COIL).
(F)
3rd MASS
2nd MASS
4th MASS
6 a.m. 7 8 9 10 11 12 noon 1 2 3 4 5 6 7 8 9 10 11 12 night 1 2 3 4 5 6 a.m.

FIG. 4

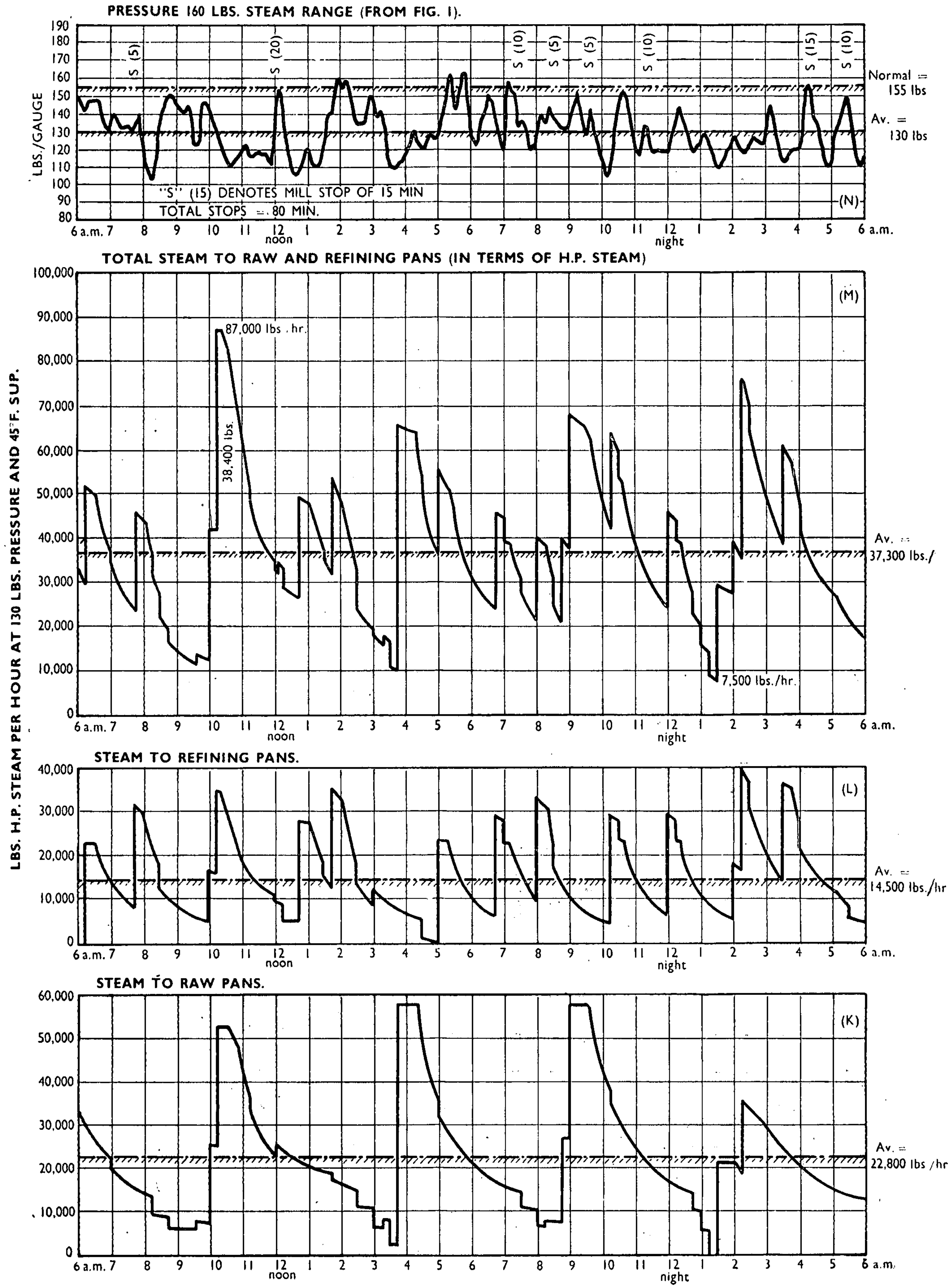
PRESSURE 160 LBS. STEAM RANGE (FROM FIG. 1).
LBS./GAUGE
S (5)
S (20)
S (10)
S (5)
S (5)
S (10)
S (15)
S (10)
Normal = 155 lbs
Av. = 130 lbs
"S" (15) DENOTES MILL STOP OF 15 MIN
TOTAL STOPS = 80 MIN.
(N)
6 a.m. 7 8 9 10 11 12 noon 1 2 3 4 5 6 7 8 9 10 11 12 night 1 2 3 4 5 6 a.m.
TOTAL STEAM TO RAW AND REFINING PANS (IN TERMS OF H.P. STEAM)
(M)
87,000 lbs . hr.
38,400 lbs.
7,500 lbs./hr.
Av. = 37,300 lbs./
LBS. H.P. STEAM PER HOUR AT 130 LBS. PRESSURE AND 45°F. SUP.
STEAM TO REFINING PANS.
(L)
Av. = 14,500 lbs./hr
STEAM TO RAW PANS.
(K)
Av. = 22,800 lbs /hr

FIG. 5

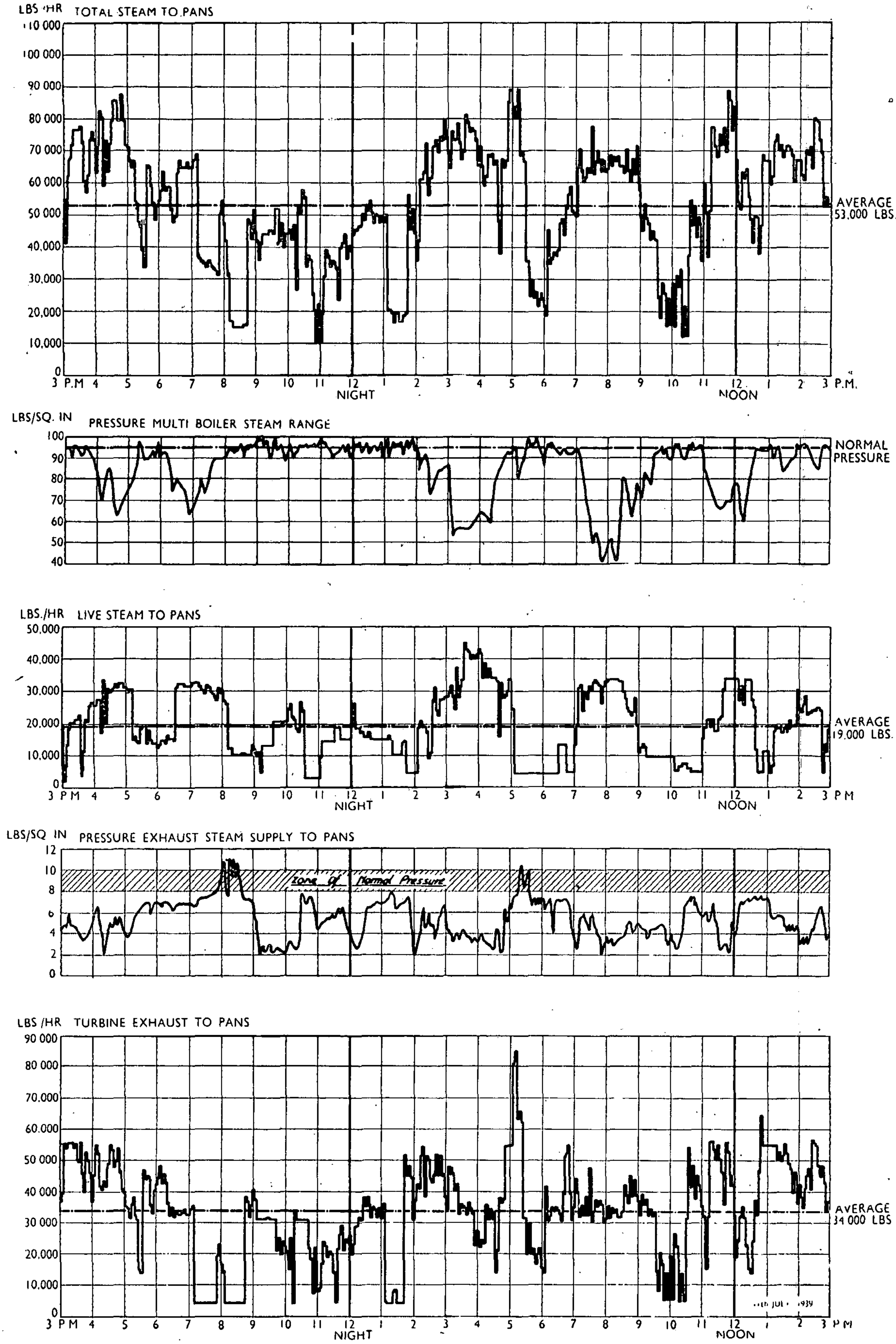

FIG 6 ALIGNMENT OF BOILING HOUSE STEAM FLOW AND PRESSURE CHARTS FOR A NATAL FACTORY

By courtesy of the Natal Estates, Ltd

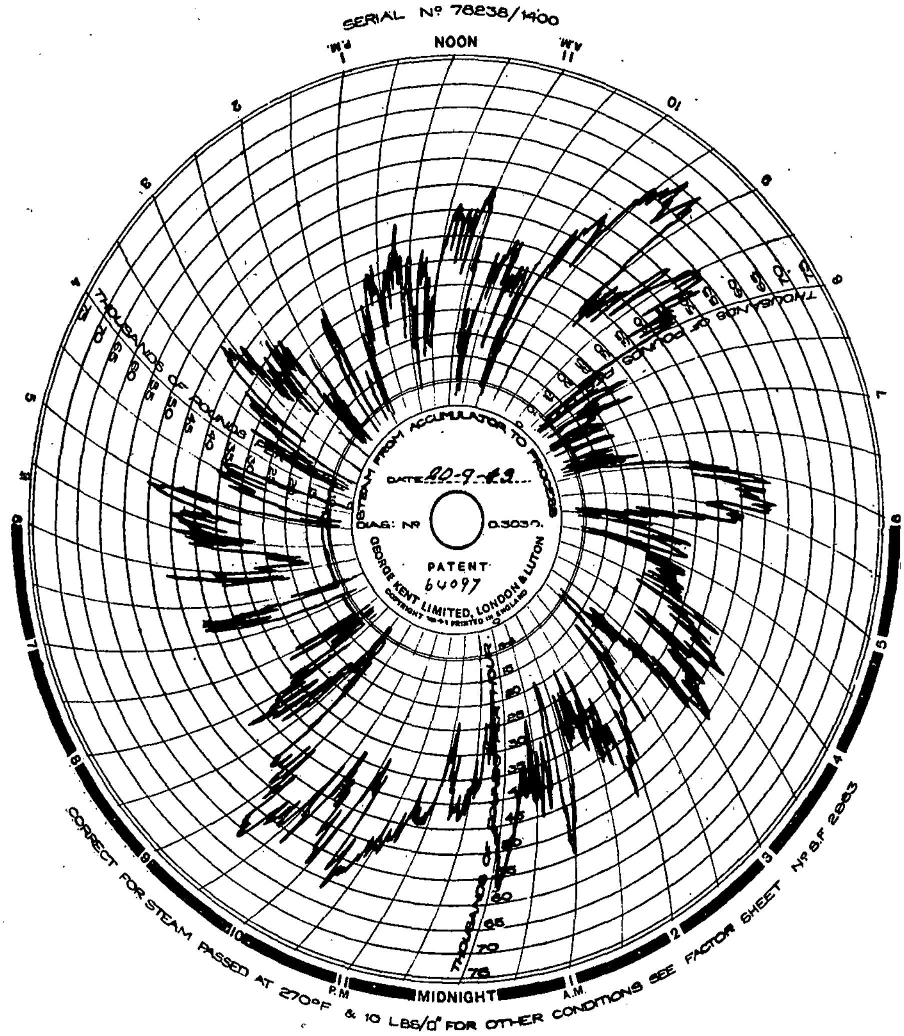

Fig. 7. Live steam by-passed to pans, etc. at a Natal Sugar Factory, to augment exhaust from Mill Engines and Turbines.—*By courtesy of Sir J. L. Hulett & Sons, Ltd.*

APPENDIX I

INFLUENCE OF EXPANSION, HEAT DROP AND LOSS BY RADIATION ON QUALITY OF STEAM AVAILABLE FOR VACUUM PANS.

Average pressure in 160 lb. range =130 lbs. gauge
Estimated average superheat =45° F.
Corresponding total heat of steam leaving boilers =1,220 B.T.U./Lb. (1)

Radiation Loss in 160 lb. Range.

Suppose loss by radiation in this range amounts to $1\frac{1}{4}$ per cent., i.e. each lb. of steam gives up $1\frac{1}{4}$ per cent. of its total heat over the period it remains in the range.

Then the heat in the steam leaving the range is reduced to **1,205 B.T.U./lb.** and its corresponding state at 130 lbs. pressure is **20° superheat** . . . . (2)

Reduction to 100 lbs. Range via Valve.

Taking the average pressure in this range at 85 lbs., the initial state of the steam corresponding to a total heat of 1,205 B.T.U./lb. is **32° F. superheat** . . . . (3)

Radiation Loss in 100 lbs. Range.

Suppose loss by radiation in this range amounts to $1\frac{3}{4}$ per cent. then the heat of the steam leaving this range is reduced to **1,185 B.T.U./lb.** and its corresponding state at 85 lbs. pressure is **dry saturated** . . . . . . (4)

Reduction to 40 lbs. Range via Valve.

This range supplies the refining pans, the pressure is maintained constant at 40 lbs. and the initial state of the steam corresponding to a total heat of 1,185 B.T.U./lb. is **20° superheat** . . . . (5)

Radiation Loss in 40 lbs. Range.

Suppose loss by radiation in this range amounts to $\frac{3}{4}$ per cent. Then the heat of steam leaving the range is reduced to **1,176 B.T.U./lb.** and its corresponding state at 40 lbs. pressure **is dry saturated** . . . . (6)

Reduction to Mean Pressure in Refining Pan Coils via Valve.

Taking the mean pressure in the coils at 12 lbs. gauge, its state corresponding to a total heat of 1,176 B.T.U./lb. is **26° superheat,** and on the basis that only the superheat and latent heat content is utilised in heating a pan, the heat available for this purpose is **965 B.T.U./lb.** . (7)

Reduction from 100 lbs. Range to Common Exhaust Range serving Raw Pans, etc., via Mill and other Engines taking 100 lbs. Steam.

According to (4) the condition of steam leaving the 100 lbs. range is 85 lbs. dry saturated total heat 1,185 B.T.U./lb. Assuming engines exhaust at an average pressure of 5 lbs. and have an efficiency ratio of 60 per cent., then the equivalent useful heat drop is 72 B.T.U./lb. The heat in exhaust is 1,185−72=**1,113 B.T.U./lb.** and the corresponding state of this steam is therefore **95.5 per cent. dry** . . . . (8)

Reduction from 160 lbs. Range to Common Exhaust Range serving Raw Pans, etc., via Generating Sets taking 160 lb. Steam.

According to (2) steam leaving the 160 lbs. range has been assessed at 130 lbs. 20° superheat. Total heat 1,205 B.T.U./lb.

Suppose these engines exhaust at an average pressure of 5 lbs. and have an efficiency ratio of 70 per cent., then the equivalent useful heat drop is 103.5 B.T.U./lb. The heat in the exhaust is **1,101.5 B.T.U./lb.** and the corresponding state of this steam is therefore **94 per cent. dry** . . . . (9)

Mean State of Steam Exhausted by Mill Engines and Generating Sets.

This state will depend on the relative proportions of the steam quantities given up by mill engines, pumps and generators to the common exhaust range, and in the absence of knowledge of these proportions the mean state of the steam in this range is taken as being **95 per cent. dry at 5 lbs. pressure. Total heat 1,108 B.T.U./lb.** . . . . (10)

Radiation Loss in Exhaust Range.

Suppose loss by radiation in this range amounts to $1\frac{1}{2}$ per cent., then heat of steam entering pans is reduced to **1,090 B.T.U./lb.** and its corresponding state at 5 lbs. pressure is **93 per cent. dry** . . . . (11)

Reduction to Mean Pressure in Raw Pan Calandrias.

Taking the mean pressure in the calandrias at $2\frac{1}{2}$ lbs. its state corresponding to a total heat of 1,090 B.T.U./lb. is **93.5 per cent. dry,** and on the basis that only the latent heat of low pressure saturated steam is utilised the heat available for boiling the raw pans is **900 B.T.U./lb.** . . . . (12)

APPENDIX 2

ASSESSMENT OF QUANTITY OF STEAM REQUIRED TO BOIL RAW PANS.

STEAM TO MAKE A SEED MASSECUITE.

Charge.

Syrup, 58° brix and 100°F.

Solids in charge	= 95,500 lbs.
Water in charge	= 69,200 ,,
Weight of charge...	= 164,700 ,,

Strike.

1,200 cu. ft. at 88° brix and 140°F.

Weight = 1,200 × 62.4 × 1.45 ...	= 108,500 lbs.
Solids = 108,500 × .88	= 95,500 ,,
Water	= 13,000 ,,

Water evaporated=69,200−13,000 = **56,200 lbs.**

Temperature rise of charge = 140 −100 ... ... = 40°F.
Sp. heat = (.58 × .3) + .42 ... = .6
Heat to raise temperature
= 164,700 × 40 × .6 = **3,950,000 B.T.U.**
Boiling temperature at surface at 26″ vacuum ... ... = 140°F.
Latent heat of vapour ... ... = 1,020 B.T.U./lb.
Heat to evaporate 56,200 lbs. water = **57,250,000 B.T.U.**
Total heat to boil pan ... ... = **61,200,000 B.T.U.**
Latent heat steam at 2½ lbs. and 93.5 per cent. dry ... ... = 900 B.T.U./lb. Appendix 1 (12)
∴ Steam to boil pan ... ... = **68,000 lbs.** . . (1)

STEAM TO MAKE AN "A" MASSECUITE.

Charge.

Seed, 600 cu. ft. at 88° brix + 130°F. &
Syrup, 58° brix, 100° F., weight = 66 per cent. of molasses +wash.
"A" wash, 71.5° brix, 115°F., weight = 34 per cent. of molasses+wash.

Strike.

1,200 cu. ft. at 93° brix and 140°F.
Weight = 1,200 × 62.4 × 1.48 ... = 110,800 lbs.
Solids = 110,800 × .93 ... ... = 103,000 „
Water ... ... = 7,800 „

Weight seed = 600 × 62.4 × 1.45 = 54,250 lbs.
Solids in seed = 54,250 × .88 ... = 47,750 „
Water in seed ... ... = 6,500 „
Solids in syrup and wash
= 103,000 − 47,750 = 55,250 lbs.
Solids in syrup
$\frac{55,250 \times (66 \times 58)}{(66 \times 58) + (34 \times 71.5)}$ = 33,900 lbs.
Water in syrup = $\frac{33,900 \times 42}{58}$ ... = 24,600 lbs.
Weight syrup added ... ... = 58,500 lbs.
Solids in wash = 55,250 − 33,900 = 21,350 lbs.
Water in wash = $\frac{21,350 \times 28.5}{71.5}$ .. = 8,500 lbs.
Weight wash added ... ... = 29,850 lbs.
Water evaporated
= 6,500 + 24,600 + 8,500 − 7,800 = **31,800 lbs.**
Temperature rise of seed = 140 − 130 = 10°F.
Specific heat = (.88 × .3) + .12 = .384
Heat to raise temperature
54,250 × 10 × .384 = **208,000 B.T.U.**
Temperature rise of syrup
= 140 − 100 = 40°F.
Specific heat = (.58 × .3) + .42 ... = .6
Heat to raise temperature
= 58,500 × 40 × .6 = **1,405,000 B.T.U.**
Temperature rise of wash = 140 − 115 = 25°F.
Specific heat = (.715 × .3) + .285 . = .5
Heat to raise temperature
= 29,850 × 25 × .5 = **373,000 B.T.U.**
Boiling temperature at surface at 26″ vacuum ... ... = 140°F.
Latent heat of vapour ... ... = 1,020 B.T.U./lb.
Heat to evaporate 31,800 lbs. water = **32,400,000 B.T.U.**
Total heat to boil pan ... ... = **34,386,000 B.T.U.**
Latent heat steam at 2½ lbs. and 93.5 per cent. dry ... ... = 900 B.T.U./lb.
∴ Steam to boil pan ... ... = **38,200 lbs.** . . (2)

STEAM TO MAKE A "B" MASSECUITE.

Charge.

Seed, 600 cu. ft. at 88° brix and 130°F.
"A" molasses, 71° brix, 120° F.
weight = 66% of molasses+wash
"B" wash, 71.5°, 115°F.
weight = 34% of molasses+wash

Strike.

1,200 cu. ft. at 95.5° brix and 140°F.
Weight = 1,200 × 62.4 × 1.51 ... = 113,000 lbs.
Solids = 113,000 × .955 ... = 108,000 „
Water ... ... = 5,000 „

Weight seed = 600 × 62.4 × 1.45 . = 54,250 lbs.
Solids in seed = 54,250 × .88 ... = 47,750 „
Water in seed ... ... = 6,500 „
Solids in molasses+wash
= 108,000 − 47,750 = 60,250 lbs.
Solids in molasses
= $\frac{60,250 \times (66 \times 71)}{(66 \times 71) + (34 \times 71.5)}$ = 39,800 lbs.
Water in molasses = $\frac{39,800 \times 29}{71}$ = 16,250 lbs.
Weight molasses added ... ... = 56,050 lbs.
Solids in wash = 60,250 − 39,800 = 20,450 lbs.
Water in wash = $\frac{20,450 \times 28.5}{71.5}$ ... = 8,150 lbs.
Weight wash added ... ... = 28,600 lbs.
Water evaporated
= 6,500 + 16,250 + 8,150 − 5,000 = 25,900 lbs.
Temperature rise of seed = 140 − 130 = 10°F.
Specific heat = (.88 × .3) + .12 ... = .384
Heat to raise temperature
= 54,250 × 10 × .384 = **208,000 B.T.U.**
Temperature rise of molasses
= 140 − 120 = 20°F.
Specific heat = (.71 × .3) + .29 ... = .503
Heat to raise temperature
= 56,050 × 20 × .503 = **562,500 B.T.U.**
Temperature rise of wash = 140 − 115 = 25°F.
Specific heat = (.715 × .3) + .285 = .50
Heat to raise temperature
= 28,600 × 25 × .50 = **357,000 B.T.U.**
Boiling temperature at surface at 26″ vacuum ... ... = 140°F.
Latent heat vapour ... ... = 1,020 B.T.U./lb.
Heat to evaporate 25,800 lbs. water = **26,400,000 B.T.U.**
Total heat to boil pan ... ... = **27,526,500 B.T.U.**
Latent heat steam at 2½ lbs. and 93.5 per cent. dry ... ... = 900 B.T.U./lb.
∴ Steam to boil pan ... ... = **30,600 lbs.** . . (3)

STEAM TO MAKE A "C" MASSECUITE.

Charge.

Seed, 600 cu. ft. at 88° brix and 130°F.
"B" molasses, 72° brix and 120°F.,
weight = 66% Mol.+wash

"C" wash, 71.5° brix and 115°F., weight = 34% Mol.+wash

Strike.

1,200 cu. ft. at 97° brix and 140°F.

Weight = 1,200 × 62.4 × 1.52 ...	= 113,900 lbs.
Solids = 113,900 × .97	= 110,250 lbs.
Water	= 3,650 lbs.
Weight seed = 600 × 62.4 × 1.45	= 54,250 lbs.
Solids in seed = 54,250 × .88 ...	= 47,750 lbs.
Water in seed	= 6,500 lbs.
Solids in molasses + wash = 110,250 − 47,750	= 62,500 lbs.
Solids in molasses, $= \frac{62{,}500 \times (66 \times 72)}{(66 \times 72) + (34 \times 71.5)}$	= 41,300 lbs.
Water in molasses $= \frac{41{,}300 \times 28}{72}$	= 16,050 lbs.
Weight molasses added	= 57,350 lbs.
Solids in wash = 62,500 − 41,300	= 21,200 lbs.
Water in wash $= \frac{21{,}200 \times 28.5}{71.5}$ ...	= 8,450 lbs.
Weight wash added	= 29,650 lbs.
Water evaporated = 6,500 + 16,050 + 8,450 − 3,650	= 27,350 lbs.
Temperature rise of seed = 140 − 130	= 10°F.
Specific heat = (.88 × .3) + .12 ...	= .384
Heat to raise temperature 54,250 × 10 × .384	= **208,000 B.T.U.**
Temperature rise of molasses = 140 − 120	= 20°F.
Specific heat = (.72 × .3) + .28 ...	= .496
Heat to raise temperature = 57,350 × 20 × .496	= **570,000 B.T.U.**
Temperature rise of wash = 140 − 115	= 25°F.
Specific heat = (.715 × .3) + .285	= .50
Heat to raise temperature = 29,650 × 25 × .50	= **370,000 B.T.U.**
Boiling temperature at surface at 26″ vacuum	= 140°F.
Latent heat vapour	= 1,020 B.T.U./lb.
Heat to evaporate 27,350 lbs. water	= **27,900,000 B.T.U.**
Total heat to boil pan	= **29,048,000 B.T.U.**
Latent heat steam at 2½ lbs. and 93.5 per cent. dry	= 900 B.T.U./lb.
∴ Steam to boil pan	= **32,300 lbs.** . . (4

STEAM TO MAKE A JELLY.

Charge.

"C" molasses at 79° brix and 120°F.

Strike.

225 cu. ft. at 90° brix and 140°F.

Weight = 225 × 62.4 × 1.46 ...	= 20,500 lbs.
Solids = 20,500 × .9	= 18,450 lbs.
Water	= 2,050 lbs.
Weight molasses $= \frac{18{,}450}{.79}$ ...	= 23,400 lbs.
Solids	= 18,450 lbs.
Water	= 4,950 lbs.
Water evaporated = 4,950 − 2,050	= **2,900 lbs.**
Temperature rise of charge = 140 − 120	= 20°F.
Specific heat = (.79 × .3) + .21 ...	= .44
Heat to raise temperature = 23,400 × 20 × .44	= **205,000 B.T.U.**
Boiling temperature at surface at 26″ vacuum	= 140°F.
Latent heat of vapour	= 1,020 B.T.U.
Heat to evaporate 2,900 lbs. water	= **2,920,000 B.T.U.**
Total heat to boil pan	= **3,125,000 B.T.U.**
Latent heat steam at 2½ lbs. and 93.5 per cent. dry	= 900 B.T.U./lb.
∴ Steam to boil pan	= **3,470 lbs.** . . (5).

APPENDIX 3

ASSESSMENT OF QUANTITY OF STEAM REQUIRED TO BOIL REFINING PANS.

Charge.

Syrup, 60° brix and 120°F.

Strike.

550 cu. ft. at 89° brix and 140°F.

Weight = 550 × 62.4 × 1.45 ...	= 49,750 lbs.
Solids = 49,750 × .89	= 44,250 lbs.
Water	= 5,500 lbs.
Weight syrup $= \frac{44{,}250}{.6}$	= 73,750 lbs.
Solids	= 44,250 lbs.
Water	= 29,500 lbs.
Water evaporated = 29,500 − 5,500	= **24,000 lbs.**
Temperature rise of charge = 140 − 120	= 20°F.
Specific heat = (.6 × .3) + .4 ...	= .58
Heat to raise temperature = 73,750 × 20 × .58	= **856,000 B.T.U.**
Boiling temperature at surface at 26″ vacuum	= 140°F.
Latent heat of vapour	= 1,026 B.T.U.
Heat to evaporate 24,000 lbs. water	= **24,600,000 B.T.U.**
Total heat to boil pan	= **25,456,000 B.T.U.**

Mean condition of steam in coils = 12 lbs. pressure + 26°F. superheat and corresponding superheat + latent heat available for heating pan = 965 B.T.U./lb.

∴ Steam to boil pan ... ... = **26,500 lbs.**

The PRESIDENT said that this paper showed an ingenious and novel method of investigating steam demands of vacuum pans. The deductions drawn appeared to be very logical.

Dr. HEDLEY said that just before the war he had measured the quantities of steam used at Darnall for making first, second and third massecuites. The results then obtained had never been published, but they confirmed the results obtained in this paper.

The steam accumulator had been very successful, and factories that had to buy fuel prior to its introduction now had surplus bagasse.

Mr. Wilson assured members that the steam accumulator at the refinery, where it was first installed in Natal, had proved very successful. The increased throughput at the refinery had now necessitated the installation of an additional accumulator.

Mr. Royston drew attention to the recent Board of Trade report in which emphasis was laid on better utilization of by-products in the industry. The steam accumulator was not only a means of ensuring a proper steam balance in factory work, but it eventually would make fibre, as a by-product, available for utilization, should economic circumstances warrant it in the future.

Mr. Macbeth said that sufficient steam and a proper steam balance was one of the most essential requirements of a sugar factory. At Mount Edgecombe they had never been so badly off for steam as some other factories, but still it had at times been difficult to get enough steam for the whole factory. Since the installation of a steam accumulator, however, they had no more worries about steam.

Mr. Dunn said that the term balanced steam conditions was often used loosely. He thought that a steady steam pressure was the best indication of balanced steam conditions, for it would show that steam demands and steam supply were in equilibrium. The steam pressure chart need not, of course, be a circle; fluctuations might occur, but these should be so small as not to affect the operation of the factory. Under these conditions, he thought the term balanced steam conditions was justified.

He thought it would be interesting to carry out investigations, similar to those described in the paper, at Natal Estates, for the steam to the pans was actually metered there, and it would be possible to compare conditions now with what they were before.

Mr. Dunn said that the paper described the actual tests that were carried out on one particular day to find the steam demands of the pans in both the pans of raw sugar boiling-house and the refining house. It was found that it was not enough to get balanced steam conditions on the refining side; the steam for the raw sugar pans had to be balanced too. It was really the method described that he thought of importance, rather than the actual figures obtained, for it would provide a tool for engineers to do their own measurements. He would like to see engineers undertaking similar tests so as to be able to confirm or criticise the method described.