RESULTS OBTAINED FROM THERMAL STORAGE APPLIED TO A SUGAR REFINERY

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The PRESIDENT: Stated that Mr. Wilson's paper had already been presented to the Natal Institute of Engineers, and had won the prize of that Institute for the best paper of the year. The Council of the Institute had kindly consented to it being read again.

Introduction.

In the average industrial plant, probably the greatest source of waste, both of time and material, is the inability of the boiler plant to cope with the fluctuations in the demand for steam. If the maximum production is to be maintained, it is imperative that adequate supplies of steam at the correct pressure be instantly available in order that the operations may not be delayed. The present day industrial boiler house, despite all its improvements is not economically capable of meeting the enormous variations in the demand for steam. It has no flywheel to tide it over the alternating heavy and light periods.

The Lancashire boiler with its large water volume has been extensively used in the past in factories where a fluctuating load has to be met, since it is claimed that such a boiler has a comparatively large steam reserve. In almost every case, however this reserve can only be drawn upon at the expense of either quality or quantity of the factory output on account of the very considerable drop in boiler pressure required to liberate an appreciable amount of steam. It should be noted that in this connection a standard 8ft. x 30ft. Lancashire boiler would have to suffer a drop in pressure from, say 100 to 70lbs. per sq. in. to give off an additional 1,000lbs. of steam above the amount generated from the fuel burned in the grates. The resultant fluctuations in boiler pressure in meeting peak loads is not only detrimental to the quality of process work, but seriously retards the rate of output. Moreover, too low a working pressure often involves an increased steam consumption with an aggravation of the boiler house troubles.

The proper solution of the elimination of this source of waste and restricted output is to be found in the system of Steam or Thermal Storage first put forward in a thoroughly practical way by Dr. Johannes Ruths, an eminent Swedish engineer, and which system has been adopted in most countries with ever increasing rapidity.

In 1924 the author, during a trip to Great Britain, United States and the Continent, investigated the possibilities of Thermal Storage for Sugar Refinery work, reported favourably on its uses, and recommended that a system of this type should be installed in conjunction with Turbo Alternator Sets which were then being considered in connection with the Extensions to increase Refinery output from 150 tons to 500 tons melt per day. Owing to certain financial reasons the Thermal Storage scheme was left in abeyance until the year 1935, when after a thorough investigation of the steam load conditions obtaining in the Refinery at that date, a Thermal Storage system was considered to be the most suitable for Refinery load conditions.

Before proceeding further it is perhaps advisable to briefly outline the difficulties under which the Refinery was operating at that time, and the benefits which it was anticipated would result from a Thermal Storage system.

In common with other industries which are subject to large and sudden fluctuations in the demand for process steam the boiler plant at the Refinery was quite unable to follow the demand. The process consumers were working under conditions of serious steam starvation with all its resulting disadvantages.

Thermal Storage was installed with two main objects. Firstly, to ensure that an adequate supply of steam for process work at the correct pressure and temperature would be always available even at periods of peak demand, thus giving the conditions necessary for the economic production of a high grade and uniform product. Secondly, to relieve the boiler plant of all fluctuations in output resulting from variations in the rate of demand for both H.P. and L.P. steam, thus enabling them to operate under steady firing conditions over long periods with a consequent gain in both efficiency of steam production and available output.

A Ruths variable pressure Thermal Storage system was duly ordered and put into commission on September 1st, 1935. It was an immediate success and fulfilled all expectations.

General Description of Steam Plant at the Refinery and the Steam Control and Distribution System.

The general layout of the steam plant and system of steam control and distribution is shewn diagrammatically on Fig. 1, which also gives the postion of the several steam meters from which the charts, which will be referred to later, were obtained.

The boiler plant consists of:—

Six Babcock & Wilcox Boilers fitted with chain grate stokers, and working in conjunction with a Greens economiser and induced draught fan. Four boilers have a heating surface of 2,852 sq. ft. and two of 2,882 sq. ft. H.S. All are fitted with superheaters.

One Stirling Boiler, Tri-drum, heating surface 7,250 sq. ft. fitted with super-heater, B. & W. compartment type chain grate stokers, balanced draught, and Howden Ljungstrom air heater.

One Thompson Boiler, 7,560 sq. ft. H.S. with super-heater and intergral economiser, compartment type chain grate stokers and balanced draught.

The boiler working pressure is 200 lbs. per sq. with 150° Fah. superheat.

The Thompson and Stirling Boilers work alternately in conjuction with the B. & W. boilers.

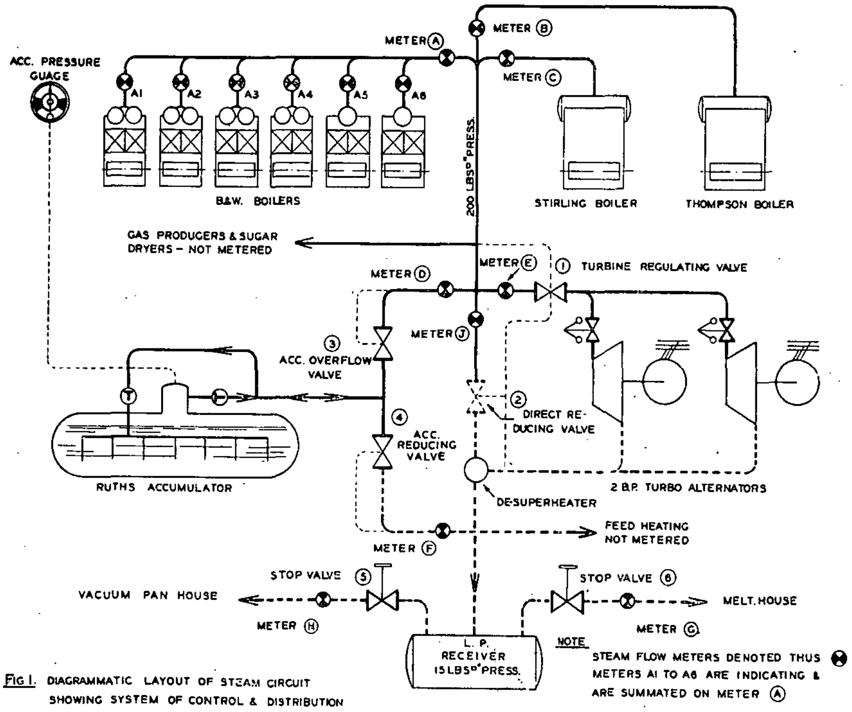


FIG I. DIAGRAMMATIC LAYOUT OF STEAM CIRCUIT SHOWING SYSTEM OF CONTROL & DISTRIBUTION

The Turbine plant consits of two 1,200 K.V.A. back-pressure Turbo-Alternators working in parallel with each other. They take steam at about 187 lbs. pressure and 150° Fah. Superheat and exhaust into a steam receiver at a pressure of about 15 lbs. per sq. in., and 50° superheat, from which the steam to the process is distributed by two pipelines, one 20 in, and the other 16in. diameter.

A list of the process consumers served by these two pipelines is appended.

The Turbo-Alternators work in parallel with the Municipal supply, so that when the electrical output is in excess of the factory requirements, the surplus passes into the Municipal mains. This is the normal condition. On occasions when the output falls below the factory requirements, the additional power required is obtained from the Corporation. The Turbines are set to run slightly off the speed governor, and the steam supply is controlled by an "Arca" relay operated regulating valve (1). This valve is operated by compound impulses, one of the overflow type from the H.P. steam range, and the other of the reducing type from the L.P. receiver.

A drop in pressure in the L.P. receiver resulting from an increase in the demand causes the reducing impulse to open the regulating valve to pass more steam quantity through the turbines to meet this demand. When the steam quantity passing through the turbines tends to exceed the boiler output the resulting drop in the steam range pressure acts on the overflow impulse to close in the regulating valve, and thus limit the quantity passing through the machines to that which is available from the boilers.

Previous to installing Thermal Storage, the steam supply to the process via the turbines was augmented at periods of heavy process demand by an "Arca" relay operating reducing valve (2) placed between the H.P. and L.P. steam ranges. This reducing valve discharged into a desuperheater which could be brought into service when it was necessary to reduce the bye-passed H.P. steam down to a temperature suitable for process work. As normally the greater volume of steam to process was passed through the turbines, it was only necessary to use the desuperheater when one or both turbines were out of action. Since Thermal Storage has been installed the reducing valve (2) is only used during starting up and shutting down operations at the week-end.

The Thermal Storage system consists of a Ruths Steam Accumulator, a relay operated overflow, or surplus valve (3) controlled by an impulse connected to the H.P. steam range, and a similar valve (4) of the reducing type controlled by an impulse connected to the L.P. steam receiver. As will be observed from diagram I, the thermal storage system replaces in the steam circuit the reducing valve (2) referred to in the foregoing paragraph.

The Accumulator has a storage capacity of approximately 40,000 lbs. when operated between the pressure limits of 200 and 15 lbs.

It consits of a cylindrical steel shell with hemispherical ends. It is 11ft. 3ins. in diameter by 58ft. long, and weighs apprximately 52 tons. It was shipped to this country in one piece. Special arrangements had to be made with the S.A. Railways for its transport from the dock-side to the Refinery at Rossburgh—a distance of approximately seven miles—and the new Esplanade Railway was specially opened for the occasion. By shipping the shell in one piece it was possible to complete all riveting and caulking in the shops where it was manufactured, and also give it the necessary hydraulic tests (which were done under the supervision of Lloyds Surveyor) before despatch.

The increased freightage costs due to shipping the shell in one piece were more than offset by the reduction of erection costs at the site. Notwithstanding the rough usage to which a shell of the dimensions mentioned must be subjected to in transport, it is pleasing to state that after erection in its final position, and the hydraulic and steam tests applied, the shell was found to be perfectly tight and has remained so.

The Accumulator is internally fitted with special charging nozzles and diffusing sleeves, so arranged that the kinetic energy in the incoming steam is utilised to keep the large volume of storage water in circulation, thus maintaining an even temperature throughout the vessel. A special nozzle is fitted at the outlet pipe in the steam dome in order that the safe maximum rate of discharge will not be exceeded in the event of a breakdown in the pipe system. Non-return valves are fitted to both inlet and outlet pipes of the Accumulator, in order to obtain the correct direction of steam flow.

The other fittings include spring-loaded safety valves, air valve, blow-off cock, pressure guage and thermometer. A long water level guage is fitted to be used in conjunction with two cocks for periodically adjusting the water level in the accumulator. The accumulator is charged with steam having a greater heat content than the outgoing steam so that, to maintain the heat balance, more steam must be given off in the accumulator than is condensed. This tendency of the water level to fall is partially counter-balanced by the accumulation of water due to the slight radiation loss. For every pressure in the accumulator there is a definite water level, and as the water guage is graduated in lbs. per sq. in. the level is easily checked once or twice per week. If the water be low, opening the cock will allow feed water to be pumped in. The other cock allows water to be drawn from the accumulator to the feed tank, or to other parts of the factory where hot water may be required in connection with the process work.

There is also a definite relationship between the pressure in the Accumulator and the steam quantity stored, and the operating staff in the boiler house can, therefore, ascertain at any time how much reserve steam is available by reading the large dial accumulator pressure guage installed in the boiler house for this purpose. Incidentally, this constitutes the only guide to the rate at which the boilers should be fired as the boiler pressure is maintained constant except when the Accumulator becomes fully charged or empty. This should not happen except in exceptional circumstances.

The satisfactory storing and discharging of large quantities of steam calls for very sensitive and reliable control valves, and the Ruths Automatic Overflow and Reducing valves (3) and (4) referred to previously, have been specially designed for this service. They are operated by oil under pressure which is supplied by a motor-driven rotary oil pump. The valves are controlled by very sensitive steam pressure operated oil relays. These valves have now been in service for approrimately two years and after slight adjustments when they were first put into commision they have proved perfectly reliable and have required little or no attention.

The general operating principle of the variable pressure steam storage system is now generally known and it is not therefore considered necessary to refer to this in detail.

With this system the boilers are fired at a rate equivalent to the **average** of the total refinery steam demand.

When this demand exceeds the boiler output the additional steam quantity required is constantly provided by the accumulator.

When the boiler output is in excess of the demand the surplus is stored in the accumulator until such time as it is required to augment the boiler output.

With the Thermal Storage system as installed at the Refinery, the method of controlling the steam to the turbines, as previously described, remains unchanged and the Thermal Storage control valves (3) and (4) operate in conjunction with the turbine regulator (1) in, briefly, the following manner:—

If the maximum flow through the turbine via regulating valve (1) is not capable of meeting the process demand, the process pressure tends to drop, thus causing the reducing valve (4) to come into action and make up the deficit from the accumulator. If at periods of light demand for process steam the quantity of steam passing to the turbine is less than the output of the boilers the resulting tendency for the H.P. steam range pressure to rise causes the overflow valve (3) to come into action and pass the surplus to the accumulator, consequently, under conditions of both heavy and light demand for process steam, both the H.P. and L,P. pressures are maintained stable except for the very slight variation required to bring the regulators into operation. It should perhaps be mentioned here that the turbines take priority of steam flow to the process and it is only when this results in a tendency to reduce the boiler pressure that the accumulator comes into action to augment the supply.

Steam Flow Metering Equipment.

The position of the steam meters in the diagram system is indicated digramatically on Fig. 1. The four meters (D), (F), (G) and (H). are of the "electroflo" indicating recording and integrating type. The recording is done by means of a strip chart which greatly facilitates rapid analysis of the steam conditions at any moment.

Meter (D) measures the H.P. steam flow to the Steam Storage system.

Meter (F) measures the L.P. steam flow from the Steam Storage system.

Meters (G) and (H) measure the steam flow from the L.P. receiver to the process through the 16in. and 20in. mains respectively.

Meter (E) measures the quantity of H.P. steam supplied to the turbo-alternators.

Prior to the installation of Thermal Storage, the Thompson Boiler was the only boiler equipped with a steam flow meter. Six months after the installation, all boilers were equipped with steam flow meters, also Lea Coal meters. This was done in order to get reliable data re steam output from boilers and amount of coal consumed in producing the steam.

The meters, both steam and coal, are of great benefit to the Technical and Operating staffs of the Refinery. At a glance, the operating staff can see immediately how steam conditions are at any time of the day or night, and they can plan their work accordingly. The Technical staff, from the figures obtained from the meters, can check up results from day to day, and thus spot where leakage and waste is taking place, and have this rectified with as little delay as possible.

In addition to the foregoing permanent equipment a temporary steam flow meter (J) of the recording type was installed in the direct bye-pass system via valve (2) to obtain some idea of the process steam requirements when the conditions under which the Thermal Storage plant would operate were being investigated.

Operation of the Thermal Storage System as determined from analysis of the Steam Flow Meter and Pressure Charts.

In Figs. 2 to 12 are given a set of steam flow and pressure charts taken over a twelve hour period before and after installing Thermal Storage. These charts have been chosen as representative of the two conditions of working and it is hoped that they will be of service in explaining how the Thermal Storage system acts as a thermal fly-wheel to balance the steam load and to augment the boiler output at periods of peak demand.

Figs. 2, 3 and 4 refer to conditions prior to installing Thermal Storage. Fig. 2 shows the total H.P. steam passing to the process via the turbines and the reducing valve (2) through meters (E) and (J) respectively. Figs. 3 and 4 show respectively the pressure conditions in the H.P. and process steam systems over the same period.

The flows shewn on Fig. 2 are only approximate as they have not been corrected for the fluctuations in the quality of the H.P. steam, consequently the actual flow to the turbines will be rather less than that shewn.

The principal feature demonstrated by these three charts is that the boilers were quite unable to follow the process steam demand and that, in consequence, there was a continual shortage of both H.P. and process steam.

To avoid the boiler pressure being pulled down to a dangerous extent the flow to the process was frequently restricted by partially closing in the stop valves (5) and (6) shewn at the receiver outlets on Fig. 1.

Figs. 5 to 12 refer to the conditions obtaining after installing Thermal Storage, and when comparing these charts with those shewn on Figs. 2, 3 and 4 it should be noted that without Thermal Storage the full complement of six Babcock boilers were in service, whereas subsequent to installing Thermal Storage only five of these boilers were normally required and in each case the Thompson boiler was also in operation and the Stirling boiler was shut down.

Fig. 5 shews the total steam output of the boiler plant. A high and steady rate of output is maintained over long periods and the comparatively slight periodic drops in the flow are due to cleaning fires, these, it will be observed, are more pronounced in the case of the Babcock boilers, where the fire doors have to be opened for this operation. The larger drop in output from the Thompson boiler, which occurred between 9 and 10 p.m., is due to soot blowing.

Fig. 6 shews the pressure in the H.P. steam range. The rise at 8 p.m. is the result of the load on the turbines being dropped for the time signal at a period when the accumulator was full and therefore not capable of absorbing the surplus steam. See curve of accumulator pressure Fig. 12.

Fig. 7 shews the total H.P. steam available for process via the turbines and the Thermal Storage overflow valve (3) through meters (E) and (D) respectively. This chart illustrates the ability of the accumulator to absorb surplus H.P. steam when the load on the machine is dropped at periods of low process demand and it therefore explains the steady rate of boiler output shewn on Fig. 5. On comparing this chart with Fig. 2 it will be observed that in consequence of this sustained boiler output the steam quantity available for process has been increased considerably notwithstanding the reduction in boiler power.

As will be shewn later, more steam is being by-passed direct to the process via the Thermal Storage system than is required to maintain the Accumulator in a state of balance, and it will be appreciated that the excess could, with advantage, be passed through the turbines to generate power, but these machines are already running at full output, and the overload nozzles are open during the greater part of the time.

Fig. 8 shews the temperature of the steam output from the Thomson boiler, this is reasonably steady and need not be commented upon, except perhaps to mention that the drop at 9 p.m. should in all probability coincide with the drop in output shewn in Fig. 5 between 9 and 10 p.m. during the soot blowing operations.

Fig. 9 shews the total process steam demand as summed from meters (G) and (H) plus the estimated quantity required for feed heating, which is not metered.

Fig. 10 shews the process steam pressure over the corresponding period.

The periodic rises are caused by the automatic control of the steam to the turbines being partially in-operative when the hand operated overload nozzles are open.

It is apparent from these two charts that as the process pressure has not fallen below the normal all demands for steam by the process have been adequately met practically as quickly as they developed, notwithstanding that the peak of the demands is about 30,000 lbs. (equivalent to the output of two Babcock boilers) in excess of the average quantity passing to the process from the boilers (Fig. 7). This does not fully extend the Accumulator which when it is fully charged can pass to process approximately 40,000 lbs. for one hour to supplement the boiler supply, and over a half hour period it is capable of discharging twice this quantity. A comparison of these two charts with those shewn on Figs. 2 and 4 will illustrate the improvement in the process steam conditions which took place after installing Thermal Storage.

Fig. 11 shews in a convenient manner the relationship between the rate of steam supplied by the boilers to the process and that of the process demand at any instant, the heavy line represents the supply from the boilers as given on Fig. 7, but converted on a total steam basis to terms of L.P. steam, the light line represents the total process demand as given on Fig. 9. By super-imposing these two flows one on the other and comparing them with the chart of the accumulator pressure for the same period as shewn in Fig. 12, a useful pictorial representation of the performance of the Thermal Storage is obtained.

These two charts shew that the Accumulator not only meets the fluctuations in the process demand but also compensates for any fluctuations which may occur in the output from the boilers. The charts also shew that, not only can the plant balance out what may be termed as short period fluctuations in both these demands, but that, at the same time, it is capable of appreciably augmenting a deficit in the average of the supply from the boilers over a considerable period, or, alternatively, of absorbing an excess in this average.

The charts have several other interesting features, for instance, the rate of charge to and discharge from the Accumulator over any period can be obtained from the slope of the pressure line on Fig. 12, and for comparison the maximum output of the plant under these two conditions has been indicated in this manner.

The total quantity of steam passing to and from the Accumulator during any period can be obtained by summing the areas between the curves of supply and demand, and the magnitude of individual quantities stored or discharged can be obtained in a similar manner or, alternatively, by reading the pressure difference in the Accumulator at the beginning and end of the period. For instance, during the 12 hours covered by the charts the total steam absorbed by the Accumulator and given up to the process was 74,500 lbs., which is equivalent to an average of approximately 6.000 lbs. per hour, thus of the average steam quantity of 14,500 lbs. passing to the Thermal Storage system via meter (D) Fig. 7, an average of 8,500 lbs. per hour passes direct to the process through valves (3) and (4) without entering the Accumulator and this explains the earlier statement that more steam was passing to the Thermal Storage system than was required to balance the load.

The largest individual peak carried by accumulated steam is approximately 15.000 lbs. and the sum of the two peaks which follow closely on each other between 11.30 p.m. and 1.30 a.m. is 26,000 lbs., these two peaks are so close to each other that as far as they effect the conditions in the Accumulator they can be considered as one.

The largest individual quantity stored amounts to 17.500 lbs. This took place between 5 and 6 a.m. and it will be observed that coincident with the fall in the process demand at that time, there was an increase in the quantity of steam coming over from the boilers; hence the comparatively rapid charging of the Accumulator.

A survey of the Boiler Plant, Power Plant and Process Steam distribution over the period covered by the charts given on Figs. 5 to 12 is appended.

Benefit obtained from Thermal Storage.

The benefits which have been obtained from the Thermal Storage plant at the Refinery can be stated as follows:—

1. **Improvement in the quality of the finished product.** The unstable condition of the process steam pressure prior to installing Thermal Storage caused corresponding variations in the temperature of this steam, and since the temperature difference producing heat transfer in the vacuum pans is, in any case, relatively low, the wide variations in the steam conditions therefore materially affected the process of refining, and this was especially the case during graining. This is a matter of common experience in refineries and raw sugar factories, where steam pressure fluctuations considerably influence the size and quality of the grain.

The uniform process steam pressure and temperature obtained with Thermal Storage has resulted in a marked improvement in the quality and uniformity of the finished product.

2. **Increased production.** The conditions of process steam starvation which existed prior to installing Thermal Storage increased the time necessary to carry out process operations, and in addition, inevitable delays occurred due to the formation of false grain, and the consequent necessity to remelt or wash out as termed by the pan boiler.

Thermal Storage by supplying steam at the desired pressure and temperature throughout the refinery at a time rate governed by the requirements of the consuming units, has enabled process operations to be carried out at maximum efficiency. As a direct result of this, the output of sugar increased by 200 tons the first week the accumulator was put into service. The output increased steadily week by week until a peak of 580 tons of extra sugar was melted per week. The normal weekly sugar melt prior to installing Thermal Storage was 3.300 tons. The peak tonnage melted per week after installing the Accumulator amounted to 3,880 tons.

During the present season the average weekly melt has approximated 3,560 tons. The reduced melt is due to a policy of slowing up the work on the vacuum pans and centrifugals with a view to obtaining a higher class of refined sugar than had been aimed at in previous years, and the results obtained, due to constant process steam pressuure and temperature, have so far been very successful.

3. **Reduced Steam Consumption per unit of Output.** Under this heading comes the maintenance of a steady steam pressure and temperature, and the speeding up of output. The steam consumption per ton of output in the Refinery has been decreased, particularly due to reduction in radiation loss. This is an important factor in a sugar refinery on account of the large size of the manufacturing units, and the relatively large surfaces exposed to the atmosphere, although every precaution of these losses is guarded against by efficient lagging of the various vessels and steam mains used in connection with process work.

4. **Improved Boiler House operating conditions.** Prior to installing Thermal Storage the boiler pressure gauge constituted the only reliable indication of a change in the rate of the steam demand. Consequently, this change had actually to take place before the boiler attendant was aware of it. This resulted in periods of forced firing in an endeavour to meet up with the demand followed by periods of rapidly reducing firing in an endeavour to prevent the boilers blowing off.

It will be appreciated that irrespective of the maximum output of which the boilers in service are capable, the rate of steam production at any moment is limited to that of the demand. Consequently, as a peak usually develops after a period of light demand, the boilers were seldom in a condition which enabled their full output to be attained in time to meet the peak.

With the Thermal Storage the boilers are only called upon to meet the average of the demand and the Accumulator pressure guage gives ample warning of any change required in the rate of firing. The boilers can, consequently, be steamed steadily for long periods at their most efficient rating.

Under these circumstances the efficiency of the boiler plant has been considerably improved, and peak firing and safety valve losses have been eliminated. Notwithstanding the increased sugar output obtained, one of the Babcock boilers was taken out of service the first week the Thermal Storage plant was placed in operation.

This improvement in boiler house conditions, together with the reduction in the process steam consumption per ton of sugar, has resulted in important coal savings, plus a reduction in labour and maintenance charges. A table giving the coal savings which have been obtained is appended.

5. **Increased electrical output from process steam.** The wide variations in the pressure and temperature of the steam supply to the turbines which obtained before Thermal Storage was installed, naturally had an adverse effect on the electrical output of these machines.

Since installing Thermal Storage a steady pressure of from 185 to 187 lbs. can be maintained at the turbine stop valves, and this, together with the increased output obtained from the boiler when operating under steady firing conditions, has resulted in a considerable increase in the electrical output of the turbo-alternators which, of course, benefits the Refinery and the Durban Corporation, the power plant being run by both parties on a 50—50 cost basis.

Figures shewing the average weekly output in units generated before and after the Accumulator installation are appended. The results obtained have exceeded all expectations and, in consequence, the installation of a 2,000 K.W. Turbo-Alternator to replace one of the existing 1,000 K.W. machines, is now under consideration, and, in all probability, the machine will be installed during the 1938-39 season.

6. **General.** The introduction of Thermal Storage at the Refinery has effectively suppressed all steam pressure variations, and has made possible better co-operation between the various Refinery departments, and the dissatisfaction which existed previously amongst those members of the staff concerned with production insofar as related to the quality of the steam supplied, created a certain amount of friction which, no doubt, adversely affected to some extent, the smooth running of the plant as a whole.

The elimination of anxiety, and this internal friction, is therefore an important point, and one which should not be overlooked by managements of industrial concerns using steam for process work, should they consider at any time the installation of Thermal Storage equipment.

Summarised advantages obtained at Refinery by introduction of Thermal Storage.

Boiler Capacity Increased. As boilers can be operated continuously at full economic rating.

Reduced Number of Boilers. As the boilers are only required to meet the average of steam demand.
Fuel Saving. Due to better steaming conditions.
Reduced Maintenance Costs. As alternate forcing and damping of boiler plant is eliminated.

Increased Production. Due to steam supply being instantly available at constant steam pressures and temperatures.

Automatic Thermal Balance. By storing surplus steam to meet subsequent peak loads.

Improved quality of product. On account of the constant steam pressures and temperatures.

Smooth Operation throughout the Works. As the boiler house, power plant and process departments are independent of each other.

Cheap Power. Due to operating back-pressure Turbo-Alternators without loss of exhaust steam and to maintenance of constant pressure and superheat.

Simplified Week-end operation. As small continuous heating operations can be effected by Accumulator and heavy loads met on starting up with cool juice after the week-end shut down.

APPENDIX.

Tonnage of Sugar Melted per Week.

	Average Sugar Melted per week	Percentage Increase in Sugar Melted
Six consecutive weeks before Accumulator installation	3,184 tons	
Six consecutive weeks after Accumulator installation	3,568 „	12.0
Season 1937-38 to date (excluding start-up week)	3,387 „	6.4
Seven consecutive weeks recording highest output of electrical units 1937-38	3,475 „	9.1

Relation of Coal Consumed to Sugar Melted.

	Lbs. coal per ton sugar melted	Percentage saving in coal
Average for 2½ years before Accumulator installation	612	
Average for 2 years after Accumulator installation	570	6.87

(Last year accumulator working for first full season).

Weekly Output in K.W's. from Turbo-Alternators.

	Average output of machine	Increase of units per week	Percentage increase in units
Six consecutive weeks before Accumulator installation	297,746		
Six consecutive weeks after Accumulator installation	323,793	26,047	8.75
Season 1937-38 to date (including start-up week)	341,828	44,082	12.8
Output for seven consecutive weeks (1937-38)	351,921	54,175	18.1

Operating Period.

Season	Melting Days	Tons Sugar Melted	Average Melt per day
1933-34	160	95,176	594.4
1934-35	179	116,121	649
1935-36	153	98,658	645
1936-37	197	136,638	693
1937-38 to date (approximately 4 months).		57,427	—

(The steam accumulator was put in commission on 1st September, 1935, and has been in continuous service since that date).

If we take the 1933-34 season daily melting rate as a basis of comparisons, the melting days would have resulted as follows:—

Season 1934-35 would have taken 195.5 days .. .. = 16.5 extra days.
Season 1935-36 would have taken 166 days .. .. = 13 extra days.
Season 1936-37 would have taken 230 days .. .. = 33 extra days.
Saving in melting time 1936-37 (at 5 melting days per week) .. .. = 6½ weeks.

Boiler House and Power House Reports.

Sugar Melted season 1936-37 = 136,638 tons.
Coal used = 38,976 tons giving 570 lbs. coal, per ton sugar melted, i.e. a saving on previous season of 23 lbs. coal per ton sugar for season = £1,392/0/0.
Average cost of coal—17.72/- per ton = (17/8.6).
Cost of coal for season = £34,539/9/8.
Cost of coal per ton sugar (boilers) = 5.0502s. (5.0502/-).

On a capital investment of £10,000 this saving of £1,392/0/0 for season shews a return of 13.9%.

Power Generated — Season 1936-37.

The total steam supplied to Turbo-Generators during the season amounted to 458,324,000 lbs.—an increase of 122,178,00 lbs. compared with previous season. The toal units generated amounted to 12,729,720 Units (or K.W.H.)—an increase of 3,508,720 Units compared with previous season. The ratio of lbs. of steam per Kilo-Watt-Hour = 36 lbs., i.e., 0.34 lbs. less than previous season.

The Units used by Refinery during the running period = 5,814,300 Units = 45.675% of total generated; the balance 6,915,420 Units were supplied to Durban Corporation = 54.325% of total generated. ,The Power Account Statement for Refinery for season is as follows:—

Refinery Costs.

Units consumed during running period .. .. = 5.814,300 Units (or K.W.H's.).
Cost of above .. .. = £1,710/2/1.
Cost per Unit .. .. = .0706d.
Cost per Unit (1935-36) .. .. = .0828d.
Units consumed (during week-ends and shut-down periods).. = 358,300 Units.
Cost of above at .3d. (Corporation charge) .. .. = £447/17/6.

Total Units consumed during the season (one year) including Units used during week-ends and shut-down period = 6,172,600 Units.

Cost of above, including rebate of £30 per month from Corporation plus special rebate (fuel allowance) .. .. = £1,738/12/2.
Cost per Unit .. .. = .067 per Unit.
Cost per Unit (1935-36) .. .. = .098 per Unit.

1936-37 Costs work out at .031 pence per Unit less than previous season.

If 6% of total fuel cost is added, the cost to Refinery per Unit on 5,814,300 Units = .067 plus .085 = .152d.

If taken on the total generated (12,729,720 Units), the cost per Unit works out at .067d. plus .039d. = .106d.

General Analysis of Steam Distribution over period 6 p.m. 23/8/37 to 6 a.m. 24/8/37.

The following analysis of the steam distribution in the Refinery has been determined from the averages of the flows given on the accompanying diagrams. It should be noted that these diagrams are primarily intended to illustrate the relationship which exists between the characteristics of the steam supply and those of the steam demand, and as the unmetered flows to the gas producers and feed heating were arrived at by deduction and were assumed to be constant it is not possible to obtain a complete analysis from these diagrams.

Further, during the period under consideration, the H.P. supply to the process was augmented by about 4,000 lbs. of stored steam from the Accumulator. In the interests of simplicity this has been neglected as the corresponding hourly average is comparatively small.

Average Steam Conditions.

H.P. Steam in range 187 lbs. guage 522°F. or 140°F. Superheat.

L.P. Steam in range 17 lbs. guage 300°F. or 46°F. Superheat.

Average Boiler Output.

Stirling Boiler and one Babcock Boiler not in service.

Babcock Boilers	74,000	Meter A.
Thompson Boiler	51,000	Meter B.
Total	125,000	lbs./hr.

Average H.P. Steam Distribution.

To Process via turbines	101,500	Meter E.
To Process via Thermal Storage	14,500	Meter D.
To Gas Producers and Dryers	9,000	(by deduction).
Total	125,000	lbs./hr.

Average H.P. Steam to Process.

Via Turbines	101,500	Meter E.
Via Thermal Storage	14,500	Meter D.
Total	116,000	lbs./hr.

Average L.P. Steam to Process.

Via Turbines	101,500	(as above).
Via Thermal Storage	16,000	(meter D. increased in proportion to difference in total heat).
Total	117,500	lbs./hr.

Average L.P. Steam Distribution.

Pan House	73,000	Meter H.
Melt House	37,000	Meter G.
Feed Heating	7,500	(by deduction).
Total	117,500	lbs./hr.

The following comparison of the steam quantities given up by the boilers before and after installing Thermal Storage illustrates how the output of boiler plant can be increased by continuous operation at steady output.

Heating Surface of Boiler Plant in Service.

Before installing Thermal Storage.

4 Babcock Boilers each 2,852 sq. ft. H.S. = 11,408 sq. ft. H.S.
2 Babcock Boilers each 2.882 sq. ft. H.S. = 5,764 sq. ft. H.S.
1 Thompson Boiler = 7,560 sq. ft. H.S.

Total heating surface = 24,732 sq. ft. H.S.

After installing Thermal Storage.

4 Babcock Boilers each 2,852 sq. ft. H.S. = 11,408 sq. ft. H.S.
1 Babcock Boiler = 2,882 sq. ft. H.S.
1 Thompson Boiler = 7,560 sq. ft. H.S.

Total heating surface = 21.850 sq. ft. H.S.

Average H.P. Steam Available for Power Generation and Process.

Before installing Thermal Storage	101,350 lbs./hr.*
After installing Thermal Storage	116,000 lbs./hr.

*The metered steam flow to the process via the Turbines and direct bye-pass before installing Thermal Storage has not been corrected for the large variations in the quality of H.P. steam then present, and in consequence the actual average flow will be rather less than the figure given

Average Steam Produced per Sq. Ft. Boiler H.S. after installing Thermal Storage.

Babcock Boilers (Feed temp. leaving Economiser 360°F.)	5.2 lbs./hr.
Thompson Boiler (Feed Temp. leaving Heater 234°F.)	6.75 lbs./hr.

Note: When considering the performance of the boiler plant it should be appreciated that the neglected blow-down losses are relatively large. On the average 3 inches of water is blown down from each boiler every three hours.

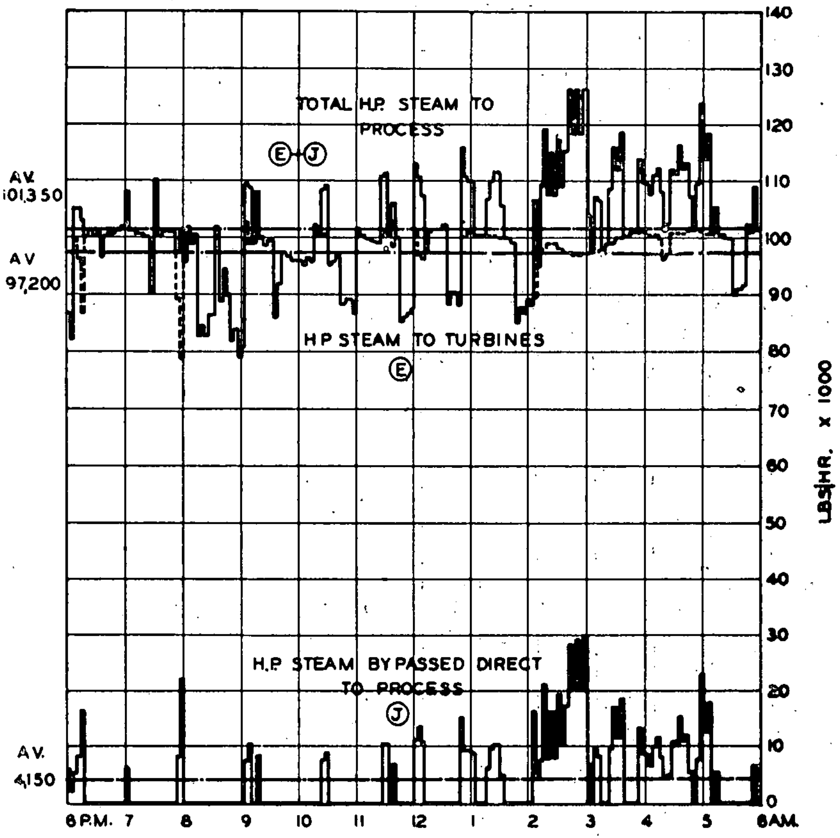
Principal Process Steam Consumers.

Vacuum Pan House.

1 Calandria Pan	2,400 sq. ft. H.S.
3 Calandria Pans each with	1,426 sq. ft. H.S.
1 Coil Pan	1,000 sq. ft. H.S.
1 Coil Pan	480 sq. ft. H.S.

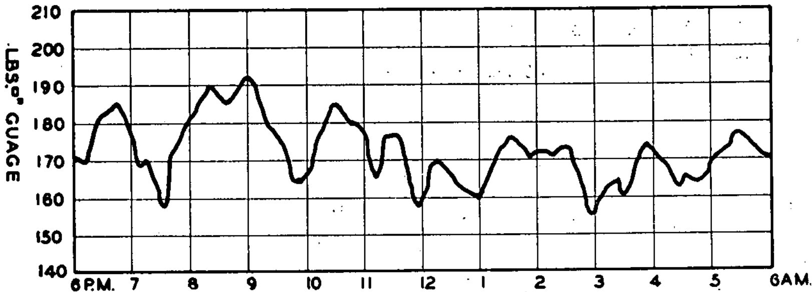
Melting House.

2 Calandria Pans each with 1,426 sq. ft. H.S.
1 Triple Effect Evaporator 3,700 sq. ft. H.S.
6 Blow-up Tanks (Coil Heating).
6 Valley Filter Liquor Tanks (direct Heating).
2 Continuous Melters (direct Heating).
6 Blow-up Tanks (Coil Heating).
2 Re-melt wash and Syrup Heating Tanks Calandria each with 150 sq. ft. H.S.
Water Heaters Closed and Direct Heating, etc.



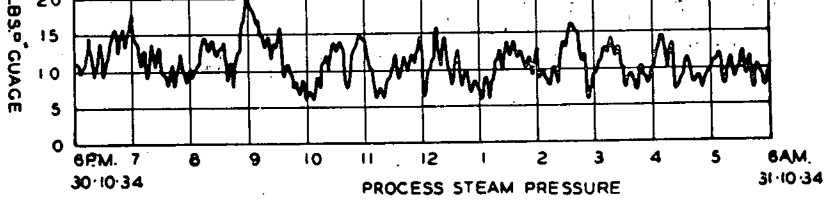
METERED H.P STEAM DISTRIBUTION
PRIOR TO ACCUMULATOR INSTALLATION

FIG 2



H.P. STEAM PRESSURE
PRIOR TO ACCUMULATOR INSTALLATION

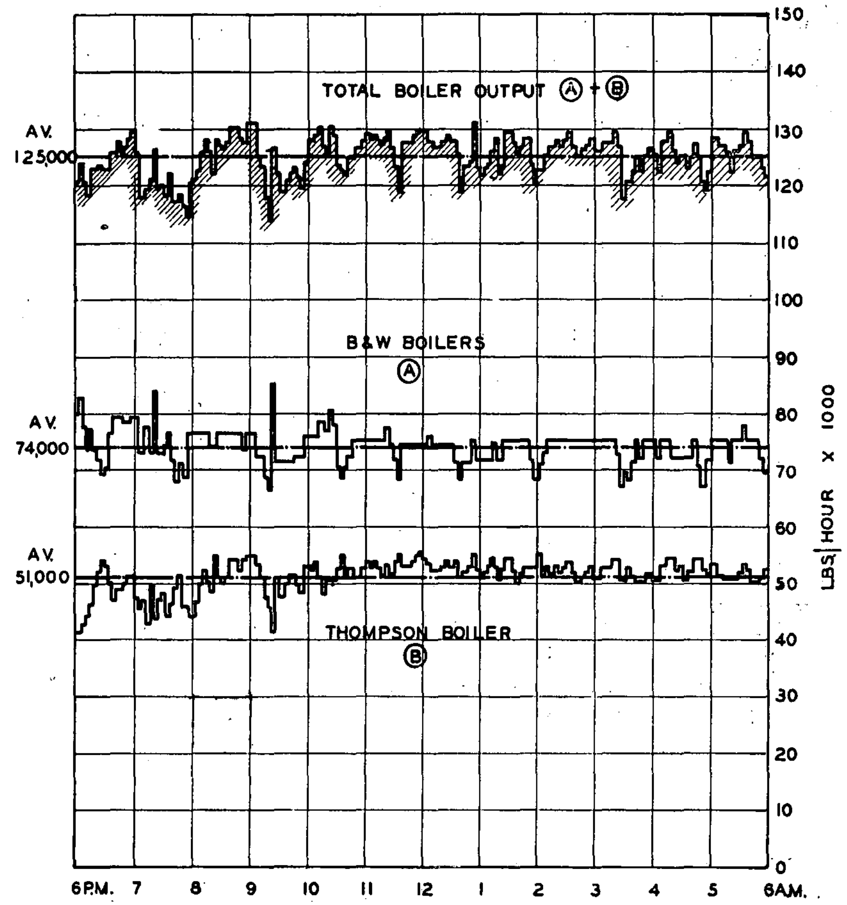
FIG 3



PROCESS STEAM PRESSURE

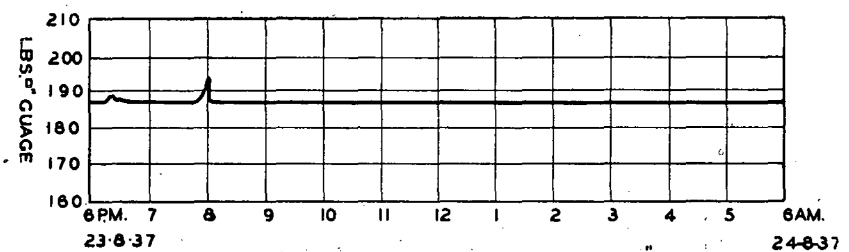
PRIOR TO ACCUMULATOR INSTALLATION

FIG 4



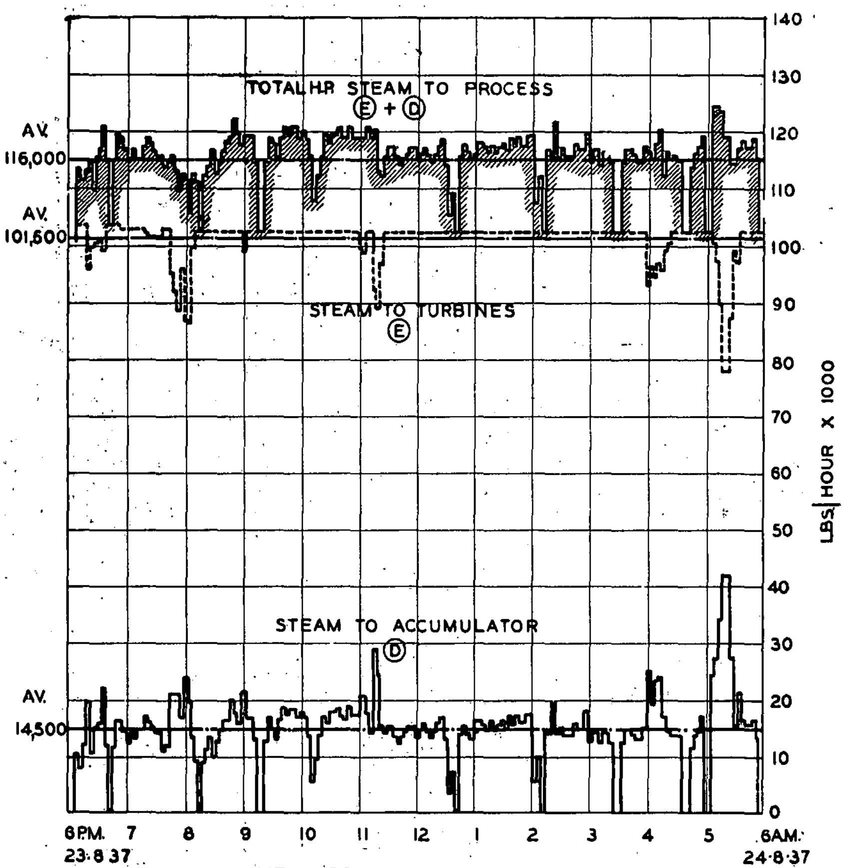
TOTAL STEAM FROM BOILERS

FIG. 5



H.P STEAM RANGE PRESSURE LBS□"

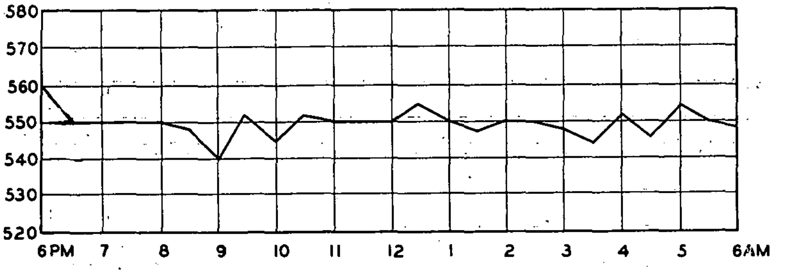
FIG. 6



METERED H.P STEAM DISTRIBUTION

9000 LBS. HR. TO GAS-PRODUCERS & DRYERS NOT METERED

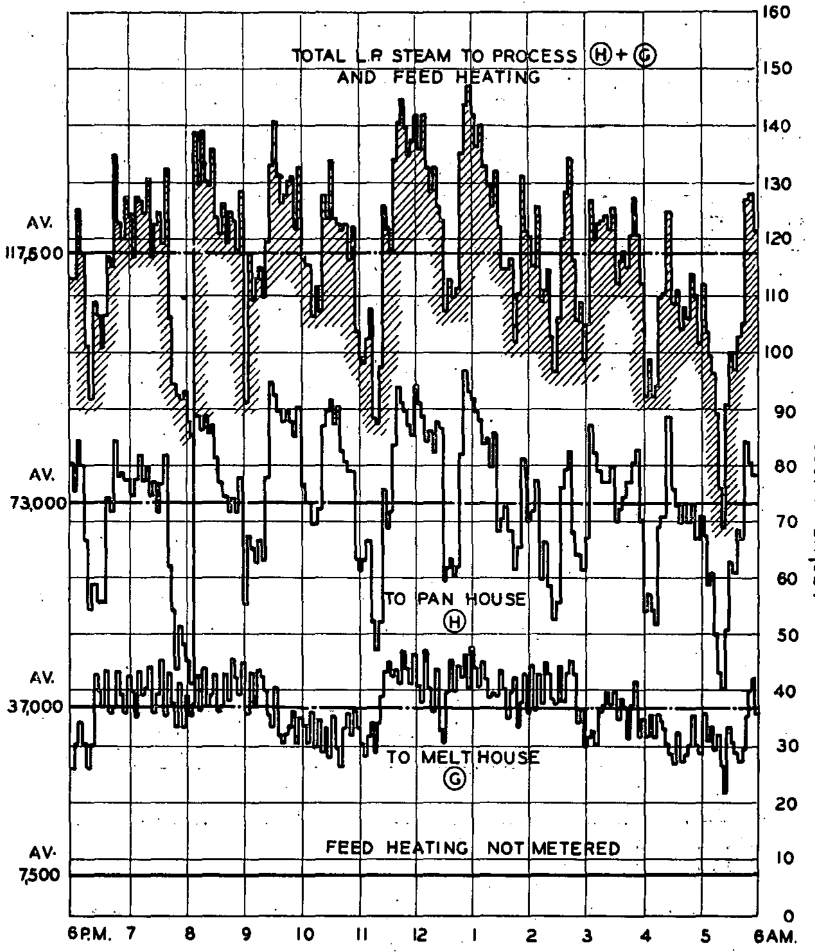
FIG 7



H P STEAM TEMP. – THOMPSON BOILER

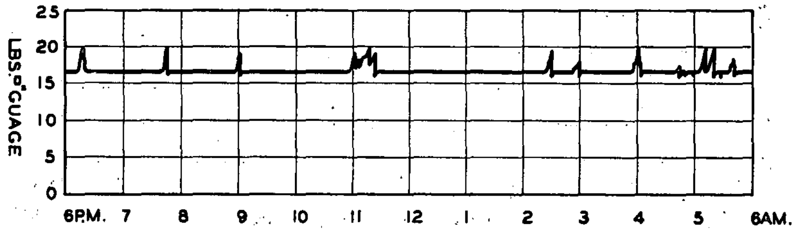
HALF-HOURLY READINGS IN FAH. DEGREES

FIG 8



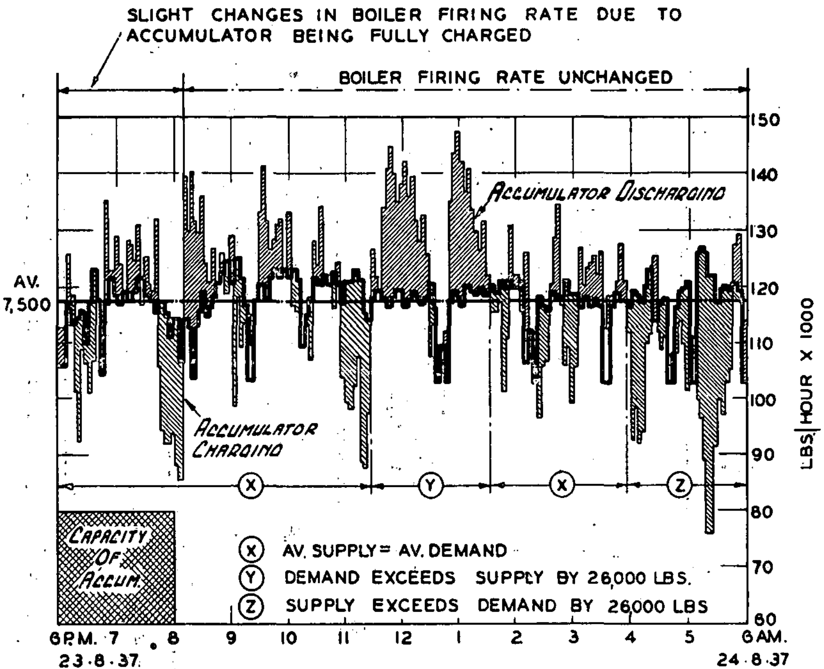
METERED L.P. STEAM DISTRIBUTION + ESTIMATED QUANTITY TO FEED HEATING

FIG 9



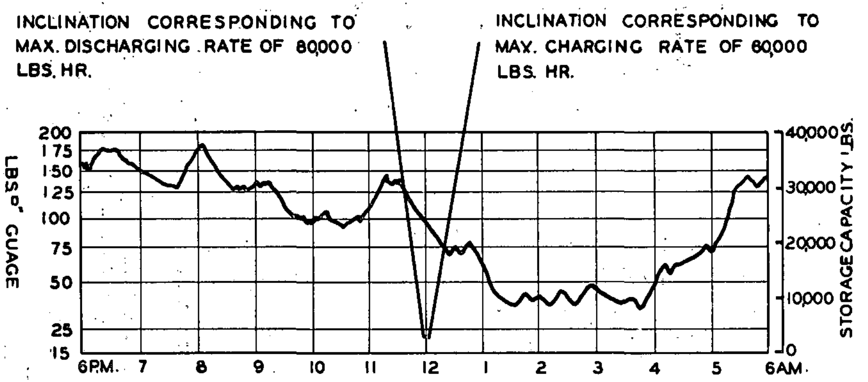
PROCESS PRESSURE

FIG 10



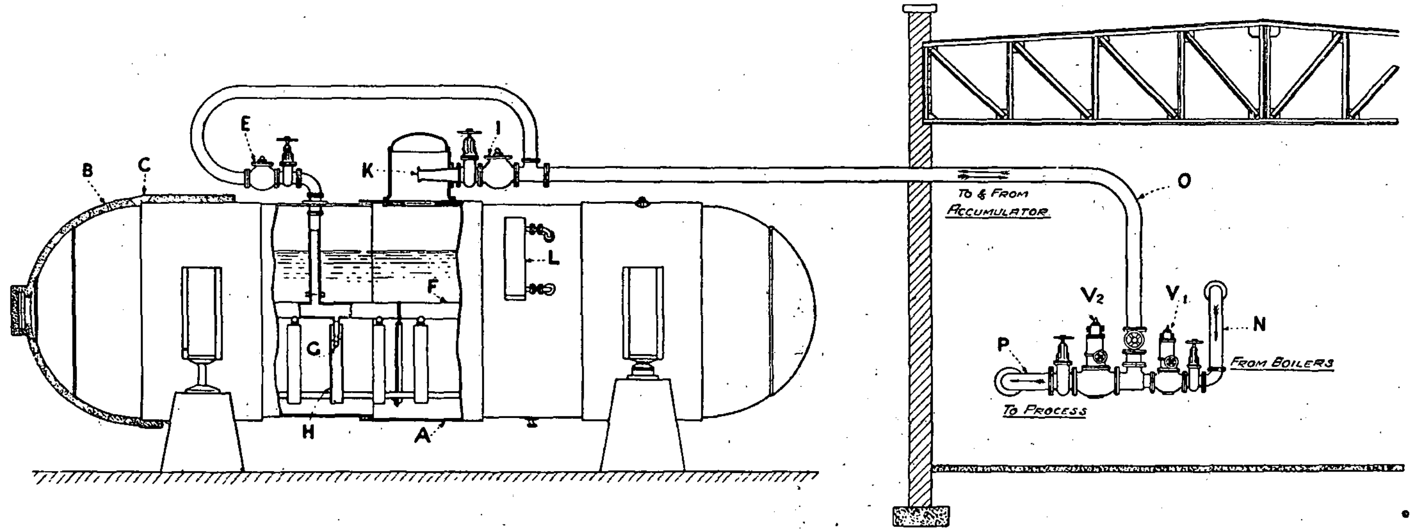
THE RELATIONSHIP BETWEEN STEAM SUPPLIED TO PROCESS AND THE PROCESS DEMAND

FIG 11



ACCUMULATOR PRESSURE & CORRESPONDING STORAGE CAPACITY

FIG 12



LONGITUDINAL SECTION OF RUTHS STEAM ACCUMULATOR SHOWING VALVE SYSTEM

A.—Accumulator Shell with hemispherical ends and of special construction to withstand pressure fluctuations.

B. Heat Insulation; limiting loss by radiation to .16 B.T.U's/sq. ft./hour/°F. difference between temperature of water content and oustide air.

C.—Removable insulation over riveted seams to facilitate inspection.

E.—Inlet non-return valve, controlled with dash-pot.

F.—Steam distribution pipe.

G.—Charging nozzles.

H.—Circulation pipes.

I.—Outlet non-return valve similar to E.

K.—Convergent Divergent nozzle limiting the discharge rate.

L.—Special water level guage.

Mr. JOHNSON: Thanked Mr. Wilson for his paper and gave his own experience of the accumulator in beet factories overseas. He thought the demands on the steam boiler for a factory were greater than those in a refinery. In one instance before the installation of the accumulator he found that the pans pulled the boilers down from a steam pressure of 80 to about 45. This resulted in disabling the routine of the factory. After the accumulator was installed the steam pressure hardly varied. He appreciated having the facts set down in this paper, and wondered why the accumulator had not been installed in more of our factories. The initial costs would be more than overcome by the resultant increase in efficiency.

Mr. J. MURRAY: Said that there was no doubt that if the makers could modify the design of the accumulator to suit cane sugar factories, it would be widely adopted. Mr. Murray went on to say that in a cane sugar factory steam has to perform two duties (1) To drive the prime movers, (2) To heat the juices, and the exhaust steam from (1) is usually sufficient for the latter. The supply of steam to both was fairly constant. The prime movers used approximately 20% of the heat in the live steam, which when not used was conserved in the boilers. But once the exhaust steam, representing 80% of the total heat in the steam, left the prime movers, it had to be used or was wasted in the atmosphere. If it were possible to close down the centrifugals when a pan was striking, then it would balance up the heat supply somewhat. He quoted as an instance a factory crushing 100 tons of cane an hour. The boilers would give 120,000 lbs. of steam per hour, and after driving engines there would be 100,000 lbs. left for heating. The heating of the juice and evaporating it into syrup took about 65% of this steam, and the pan about 20%. With the mills steam-driven and the rest of the factory electrically driven (involving the use of about 700 K.W.), and if 40 lbs. steam per K.W. hours were used, then this amounted to 28,000 lbs. steam. He suggested that factories having a number of Belliss and Morcom high speed sets, and contemplating installing turbines as had been done at Mount Edgecombe, Maidstone and Umfolozi, should have these turbines constructed to work against a back-pressure of say 15 to 20 lbs. and should be made to exhaust into a steam accumulator fitted with safety valves to blow off at 20 lbs. pressure. This exhaust would then be available for the vacuum pans at pressure varying from 5 to 20 lbs. per square inch. This would bridge over the period when the pan was striking. An accumulator to hold about 25,000 lbs. of steam would be a feasible proposition. He was not sure whether the cost of the suggested low pressure steam accumulator would be any cheaper than a high pressure accumulator under the circumstances. In cane sugar factories however the wastage to be considered was exhaust steam.

Mr. W. A. CAMPBELL: Asked Mr. Wilson if he thought it was essential to install accumulators in some of our factories.

Mr. WILSON: Thought accumulators were essential under certain conditions (illustrated his remarks by pointing to steam flow charts on black board). Regarding Mr. Murray's point he said there was no blowing off to atmosphere of exhaust steam in the refinery. In 1913 the refinery had all steam driven units. The back pressure was 10 lbs. and the vacuum pans were supplied through a reducing valve, 40 to 45 lbs. and the exhaust steam used to blow off continuously. Therefore they started electrifying in 1914. The coal used with all steam driven units was about 1,500 lbs. per ton sugar melted. He then illustrated how the installation of the accumulator together with the complete electrification of the power units in the refinery had been a great saving to them.

Mr. DUNN: Said that he had been closely associated with the accumulator plant at Hulett's Refinery since it was first put into operation. He said there was considerable doubt about the relation between boilers and steam accumulators. The accumulator only stored steam. In a factory where the steam demand was variable an accumulator ensured that the heating surface of the boiler was used to the best advantage and also that the heating surface of the process steam consumers, such as pans, evaporators and heaters was also used to the best advantage. Without the accumulators peak demands for process steam must be met by the boilers, whereas with an accumulator, the boilers are only required to meet the steady average of this demand. When the process demand was less than the average the surplus was stored in the accumulator. When the process demand exceeded the average the accumulator made good the defect. If the boiler plant was not capable of meeting the average demand, an accumulator would make good the deficit. It had been said on more than one occasion that while an accumulator was a good thing for sugar factory conditions, the proper time to install it was after all the other steam plant had been brought up to date. As, however, when buying boilers or process steam plant, one bought heating surface, and as this heating surface could not be used to the best advantage without thermal storage, it followed that only after thermal storage was installed could the true output of which the boiler plant and the steam consumers are capable be determined. In many cases additions had been made to the process plants to increase output when the true cause of the restriction was shortage of steam.

The PRESIDENT: Asked Mr. Dunn, in view of bagasse being used for other purposes and our conditions being altered in the factories, whether an accumulator would be of great use.

Mr. DUNN: Replied that an accumulator by raising the efficiency of the boiler plant would reduce the quantity of fuel required for a given output of steam. This applied equally to coal or bagasse. In a sugar factory where there was no storage of steam, the fluctuating nature of the steam demand made it necessary for the rate at which the boilers were fired to be changed at short intervals. This resulted in inefficient combustion and the boiler could only give its highest efficiency when the output was constant. If as Mr. Wilson had demonstrated, the accumulator enabled the boilers to be fired at a steady rate for periods of 12 hours at a time without once changing the rate of firing, the conditions for best efficiency were obtained.

Mr. W. A. CAMPBELL: Asked if Mr. Dunn advocated starting first with an accumulator if a factory was inclined to be short of reserve steam?

Mr. DUNN: Said that generally speaking he did, but the conditions in each factory needed independent investigation, and it was possible that there may not be a case for thermal storage after all. It was sound to give the plant already existing the conditions under which it could work most efficiently, before deciding whether or not additional plant was required.

Mr. PORTEOUS: Congratulated Mr. Wilson on his paper, and said he had demonstrated beyond doubt the need for thermal storage in a sugar factory. He said he had been associated with the first installation of thermal storage in connection with the manufacture of steel. A variable pressure turbine was used which received steam at falling pressure from the accumulator. He asked if Mr. Wilson intended installing a variable pressure turbine in the new plant he was considering putting in the refinery.

Mr. WILSON: Replied that he did not, as the occasion for it did not arise.

Mr. PORTEOUS: Asked why there was a pressure drop in the pipe line from the boiler plant to the turbines. He thought Mr. Wilson had well illustrated that the average consumption of steam in process was considerably greater after the installation of thermal storage. He would like to know something more about that. He further asked what would happen to the supply of steam to process if one of the turbines failed. He asked also if Mr. Wilson had included in his low estimate of cost of power such items as standing charges, interest and depreciation. Lastly he thought the Industry would be very well advised in considering again the proposals of the Electricity Supply Commission, as the proposition was a dividend-paying one.

Mr. WILSON: Replying to Mr. Porteous said that although he stated 200 lbs. in the paper, that was the working pressure on the B. & W. boilers. He had permission to put the Thompson boiler to 210 lbs. and although the Thompson boiler carried 210 lbs., the B. & W. boilers carried only 190 lbs., so the pressure drop was only 3 lbs. There was a certain amount of restriction through the regulating valve before it reached the steam chest on the turbines, but that was only 3 lbs. The reason for the high pressure in the Thompson boiler was the friction in the superheater. Although they had 210 lbs. on the boiler, they had 195 lbs. in the range. The drop was due to friction in the superheater.

Regarding the proposed new turbine, they had steam available, and were running the existing machines on continuous overload.

With regard to the failure of one or more machines that did not concern them. The plant went on automatically and the necessary power was supplied from Corporation mains. The steam supply came through the Ruths valves, and through the accumulator. Even with both out it still came through the accumulator. Naturally it would have to go through the reducing valve and desuperheater which would bring the pressure down to a temperature suitable for the process work. Too high a superheat slowed up the working on the vacuum pans. The superheated steam did not give up its heat so readily as the latent heat in dried saturated steam.

Referring to costs, he said all charges were included.

Mr. CAMDEN SMITH: Said that so far they had been referring to factories which had to pay in cash for their fuel. The sugar factory got its fuel for nothing, hence thermal storage might be regarded by some people rather as a luxury. He thought, however, that thermal storage was essential in a sugar factory. He commended Mr. Wilson on his paper and said that the illustration of the system as being equivalent to that of a flywheed in an ordinary reciprocating engine was most apt. The fluctuating demand for steam in the average sugar factory threw a great strain on the boiler plant, which was not the best thing to do. A boiler had to be given time, as there was always a time lag between the demand and the effectual reply to that demand on the part of the boiler. Such sudden demands tended to upset the work of the factory, and there was no doubt that thermal storage was not a luxury but a real necessity in every well equipped sugar factory.