

BOILERS, FURNACES, BOILER EQUIPMENT

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This paper is a review of the work done on steam raising in Natal and Zululand Sugar Factories during the past eleven years. This vital question was taken up by a Committee of our Association in 1925. Practically no reliable data or figures had been obtained in this country at that time and to lay the foundations of the whole matter a paper was presented to the Congress of the South African Sugar Association in April 1926. In that paper the Technologists' Committee discussed boiler settings and set forth fundamental calculations governing combustion, excess air and furnace temperatures. It was shown that from theoretical calculations it should be possible to attain a temperature of 2,300° F. in the furnace using bagasse as fuel. Such a temperature was far above that reached in the furnaces then in use, 1,500° F to 1,700° being the figures attained. However, in later years, with furnaces of different design this high temperature has become usual thus confirming the theoretical work.

In 1926 the grates in common use were either of the flat grate or step-grate type and the furnace volumes which originally were large enough became too small for the demands placed upon the boiler plant due to increased crushing rates, and hence of increased burning rates.

About 1928 attention was drawn to the Cook furnace. This furnace was patented in the U.S.A. in 1886 and in the United Kingdom in 1889. In this furnace the bagasse is burned on a flat hearth and air admitted through the side walls, no air passing through the fuel as is the case in both the step-grate and the flat grate. Such a construct-

ion should lead to the better admixture of the air with the products of combustion. Bagasse, as everyone knows, having a moisture content of about 50 per cent., has to be dried in the furnace before the distillation or gas production will start, and combustion will not occur unless the proper ignition temperature is produced. The products of combustion should therefore not be cooled before the reaction is completed. In the Cook the bagasse falls upon the floor and forms a cone and for this reason the floor is given a horse-shoe shape. The walls around and above the horse-shoe become exceedingly hot and radiate heat upon the cone thus assisting the drying and the initial combustion. The combustion is not completed in the furnace proper and secondary air is admitted to the combustion space through further tuyeres at the back of the bridge to insure complete combustion.

In 1929 in conjunction with Messrs. Armstrong & Pearce of the Zululand Sugar Millers' & Planters' Ltd., Mr. P. Murray with Messrs. Duncan Stewart of Glasgow designed furnaces of this type for two B. & W. boilers each of 7,322 sq. ft., heating surface. The results were excellent. These furnaces went into commission without any trouble and without forcing these boilers gave 5 lbs. of steam per sq. ft. of heating surface which was a great advance on any other boilers then in use in South Africa.

Later further Cook furnaces were installed, Felixton and Doornkop being the factories. A sectional elevation of the construction is shown in figure 1.

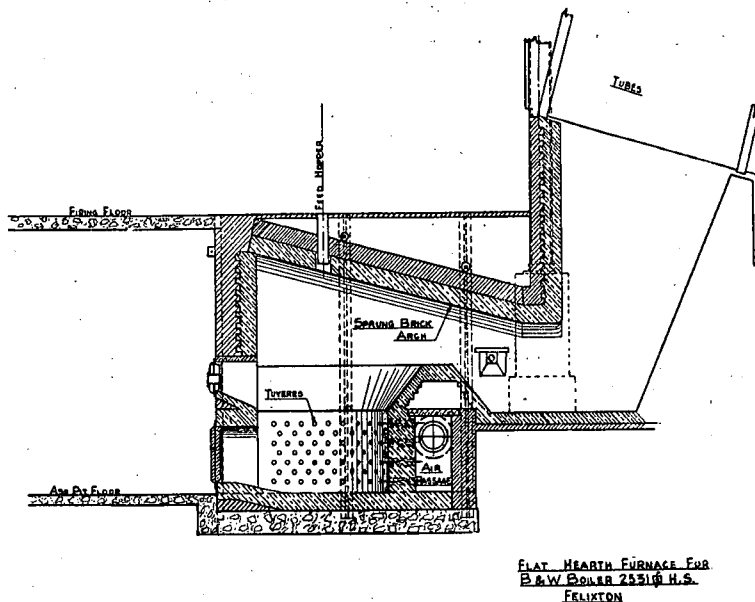


Figure 1.

This furnace gave very good results and in the 1934 Proceedings (1) the figures of two tests are recorded. These refer to Doornkop, where it will be seen that the evaporation "from and at 212°F." averages 3.69, flue temperature 630° F, and furnace temperature 2,178° as an average. As a matter of fact in one furnace we got 2,300°F, not only at one particular time but the year following as well. There was, however, rather much slagging in the furnace due to the high temperature. This formation of clinker has been overcome by putting in a grate, and it is now the practice to put a flat grate in the Cook's furnaces. Since the first test by the Boiler Committee in 1933, Doornkop, has installed superheaters in all its boilers, and an Usco air pre-heater and the tests shown in our 1936 Proceedings (2) show the increased efficiency due to each piece of plant.

A modification of the principles of the Cook furnace consisting of a combination of the flat grate and flat hearth was designed by Messrs. Duncan Stewart of Glasgow and is known as the Stewart Turbulent Furnace. This furnace has been installed at Chaka's Kraal and at Sezela under Multitubular boilers. Figure 2 shows a sectional elevation of the furnace and combustion chamber.

Prior to 1932 Sezela had two ranges of step-grate furnaces on Multitubular boilers, in the one range the combustion space was 256 cubic feet, and in the other the combustion space was 464 cubic feet. The Boiler Committee carried out tests

in 1932 on these two settings and published the results in our Proceedings (3). There it will be seen that the evaporation from and at 212°F. is 2.47 lbs. and 3.11 lbs. per sq. ft. of heating surface. The larger setting is shown in figure 3.

After the Turbulent Furnace had been installed, another test was conducted and this showed (4) that the evaporation was over 5 lbs. per sq. ft. of heating surface from and at 212°F. The results of a similar test carried out at Chaka's Kraal (5) gave a result of 4.55 lbs. from and at 212°. The flue temperatures, of course, are rather higher than they were with the old step-grate. Formerly they showed between 500° and 580°F, now they range at 640°F. to 666°F.

In general it may be stated that with the Cook's type of furnace, owing to the better combustion of the fuel, the flue temperatures have all gone up to well over 600°F. This excessive heat is economically utilised by passing the flue gases through the air pre-heater and will be discussed later.

Another interesting alteration is shown by comparing figures 4 and 5. Figure 5 shows a step-grate furnace at Maidstone on a Stirling Boiler, and is reported in our Proceedings (6). It was found that the evaporation from and at 212°F. was 3.12 and 2.66 lbs. per sq. ft., but with the Turbulent Furnace the evaporation is over 5½ lbs. per sq. ft. heating surface, and the gross thermal efficiency has been raised from 35% to 57.9%.

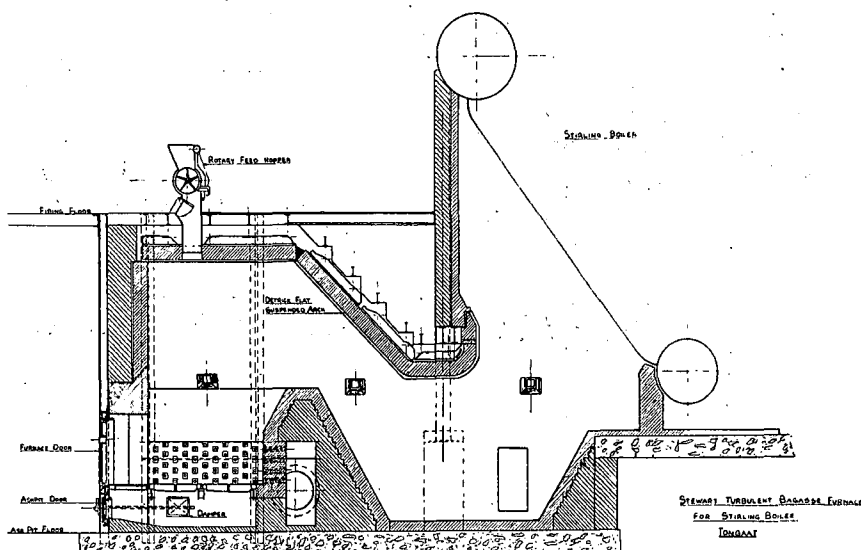


Figure 4.

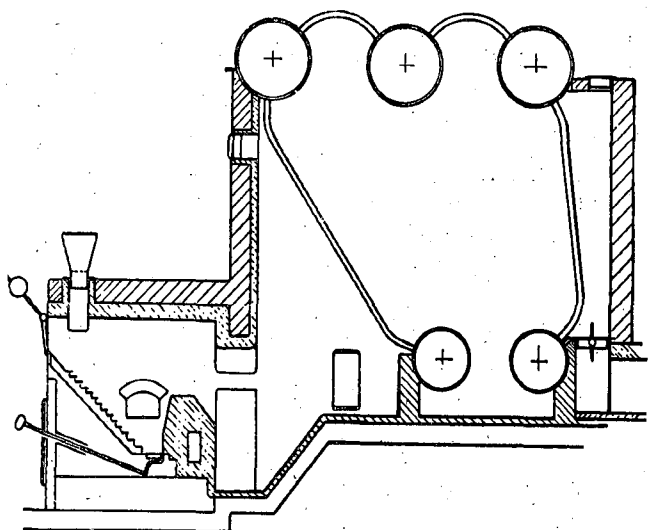


Figure 5.

This furnace has a modern suspended arch of the Detrick type which has given excellent wear. It has also fitted to it a rotary feed Hopper which prevents an inrush of air with the fuel.

We now come to the largest boiler unit in the Sugar Industry in the British Empire. This was installed at Darnall factory in 1934 and was a tremendous undertaking. It was designed by Vincent & Pullar. Some idea of the foundations necessary can be deduced when we realise 3,500 cubic yards had to be excavated. This was done by washing away by means of hoses the clay formation which overlaid the rock foundation. The concrete foundations, 550 cubic yards were then poured into the shuttering in pig sty formation. The boiler is built on the banks of the Nonoti. It is a Babcock & Willcox w.i.f. type; a four drum boiler, each four feet in diameter, and one flush drum; 200 lbs. steam pressure; and 150°F. of super-heat. It has a B. & W. tubular air pre-heater of 22,000 sq. ft. H.S. with motor-driven forced and induced draught fans, with diamond soot blowers; with Liptak suspended double flat arch, and with four Cook furnaces of Vincent & Pullar's design. The heating surface is 11,080 sq. ft. and the total furnace volume is 6,600 cubic feet.

The boiler work is controlled by means of a complete panel of instruments carrying meters for air draught in and out; the flue gas draught in and out; the temperature of the gas in and out; the temperature of the air in and out. The feed water is regulated by a Cope's regulator.

The boiler has a novel feature, in that it is furnished with a Bailey Contactor and instrument reading direct temperatures, the element of which is fitted into the arch. It is fitted further with a

red light indicator which warns the fireman of low temperature conditions in the combustion space. When the temperature is above 1,800°F. a white light is shown.

Figures 6 and 7 show the longitudinal elevation and plan of the boiler. Figure 8 shows Front elevation.

The boiler and hearths were designed to give as a normal evaporation 6 lbs. per sq. ft. of heating surface, but in actual practice 8 lbs. per sq. ft. were realised.

After three seasons' work the Liptak Arch is without blemish and has had no renewals.

Superheaters.

One of the important points soon established by our boiler tests was the enormous amount of moisture which the steam carried. This varied between 12.5 per cent and 18 per cent thus showing the need for superheating the steam. There was nevertheless, a good deal of controversy about the advisability of installing superheaters. However, in the end one factory had the courage to try them and the benefit was at once evident. The superheated steam was used in their Beliss & Morcam engines, for their crane, and in other ways. Before the superheat was installed the engineers took daily two gallons of water off the oil, in the Beliss, the following season not a drop of water was drawn off. Further, this use of the superheated steam more than halved the oil used. At the beginning of the season 70 gallons were put into the crank chamber and three drums had to be used as replacements, after installing the superheaters the original filling of oil, without any addition, was used for the whole crop.

Moreover, by using superheated steam in this way a better exhaust steam results because the steam is still dry.

It has now become the usual practice to instal superheaters on all new boilers and many old ranges have had superheaters put in. In the Boiler Committee's Report in the 1936 Proceedings (7) it is shown that the use of superheaters raised the boiler efficiency 12 to 13 per cent.

The superheat given the steam should be high enough to ensure that the exhaust is still dry after expansion in the mill engines, etc., and that the superheat used is between 60° and 100°F.

Although the steam is dried by superheating it does not follow that the superheated steam is clean. The writer has in fact, seen that quite the opposite is the case in more than one instance. It was found, for example, that the copper connecting pipes from either side of the orifice plate of a Bailey

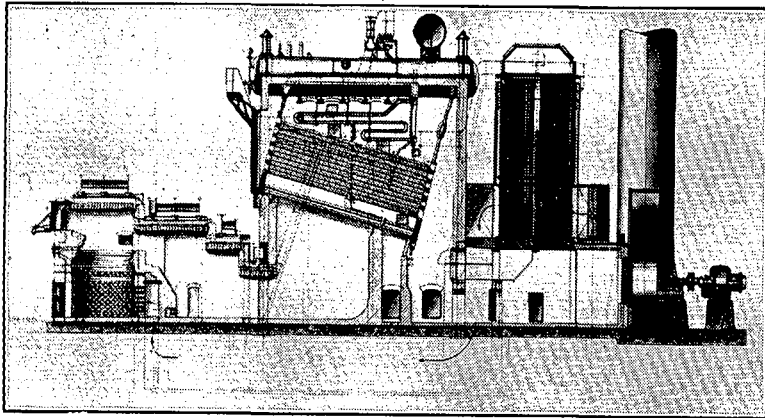


Figure 6.

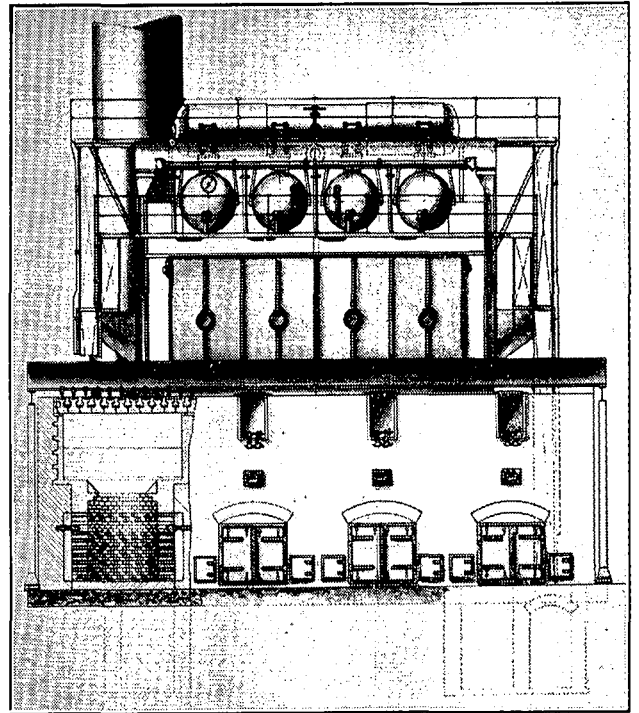


Figure 8.

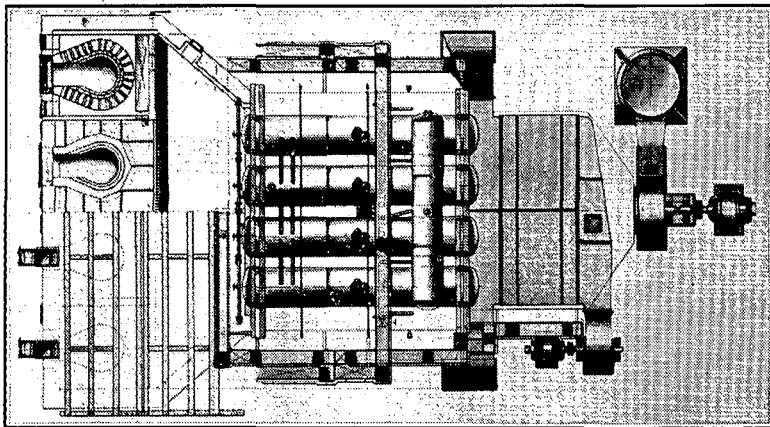


Figure 7.

Meter became clogged up with dirt and had to be blown down frequently.

It was found also that the blades in a steam turbine had quite a considerable deposit on them at the end of a season's work.

The Tracy Purifier.

To overcome such difficulties quite a number of factories have installed the Tracy steam purifiers which have proved very satisfactory. This re-

moval of the grit suspended in the dry steam will ensure a pure gas passing to the moving parts and keep governors clean and avoid wear and tear on cylinders. The result of some tests on the Tracy Purifier are to be found in our Proceedings (8).

Solids in the Water in the Boiler.

In connection with dirty steam the following analyses of boiler water taken from the guage glass in each instance will surprise many.

Factory	Boiler Feed	From the Guage Glass.			Condensed Steam
	Total solids	Total solids	Filtered solids	Solids in Solution	
A	2.15	241.4	168.5	72.9	1.0
B	3.00	895.7	861.6	34.1	0.6
C	51.60	821.5	531.8	89.7	1.3
D	9.35	243.7	89.8	153.9	0.3
E	—	866.0	576.8	289.2	—
F	—	80.8	3.5	77.3	—

All figures in parts per 100,000 of water.

It is no wonder that at times solids are torn away with the steam from the boiler water. The last factory, F, is the refinery and the engineer there makes a point of keeping the solids in his boiler water below 200 parts per 100,000.

Heat Recovery from the Flue Gases.

The introduction of the new furnaces, as has been said already, put up the flue gas temperature thus increasing the loss in sensible heat.

This loss can be calculated from Siegert's formula:—

$$h = c \frac{t_1 - t_2}{k} \qquad \frac{300 + 80}{2} = 190^\circ\text{F.}$$

h = chimney loss (sensible heat) in per cent., the lower calorific value.

t₁ = temperature of flue gas after the boiler.

t₂ = temperature of the surrounding air.

k = carbonic acid content of the flue gas.

c = constant.

The formula is based on the fact that the carbonic acid content is in inverse proportion to the amount of the gases, the greater the excess air, the lower the carbonic acid content, and that at the temperatures ruling in the furnaces the specific heat of the flue gases is fairly constant.

For coal, this constant is about 0.65. For flue gases from bagasse we cannot assume a fixed value for c owing to the high percentage of water-vapour, for c would vary according to the excess air and the moisture content. With a 13 per cent CO₂ and a 50 per cent moisture this constant would have a value of 1.05. The sensible chimney loss with bagasse is therefore 1.6 times greater than it is for coal. No further argument is necessary consequently to see the additional value over coal in recovering this lost heat.

In considering how this heat recovery is to be affected two plants come before our notice, economisers and air pre-heaters. Economisers recover the heat by heating up the feed water, and the air pre-heater heats the combustion air. The economiser is well known and is installed in some of our factories where it is giving satisfaction.

The air preheater is coming at last to be recognised as a very useful addition to the boiler plant. The air heaters originally installed in South Africa failed though excessive corrosion due to the high moisture in bagasse which was condensed on the air heater elements. The smuts in the bagasse too

settled on the elements and becoming damp provided all the requirements for corrosion due to differential aeration. Robey & Harlow (9) discuss this problem, stating "It was recognised that in order to maintain the plates of an air heater or any other cold surface free from moisture, it is necessary to keep the temperature of the surface at or above the dew point temperature of the gases. If the temperature of the wall of an air heater element is the mean of the temperatures of the air and gas on either side, then with the plant in question the minimum temperature would be well above the theoretical dew point temperature. For example, with gas leaving at 300°F. and air entering at 80°F., the minimum plate temperature would be

The dew point as calculated from hygrometric tables would be about 100°F. (for coal with 10% moisture, 4% H₂ and 13% CO₂ in the flue gases). Nevertheless the condensation on these air heaters was so rapid that the elements were simply dissolving away.

"A closer examination of the problem showed that this accepted theory of the temperature wall was fallacious because it presupposed equal rates of transfer from the gases to the metal and from the metal to the air, which in practice do not occur throughout the element."

"The foregoing considerations, combined with their experience in this matter, led the authors to conclude that the only practical way to ensure that the lowest temperature of the heater elements was above the dew point temperature of the gases was to **maintain the temperature of the air entering the heater at, or closely approaching, this temperature.** In general the results obtained by the application of this principle have greatly exceeded expectations, as by this means it is possible not only to prevent any deterioration whatsoever of the elements, but there is a considerable increase in heat transfer and definitely no falling off whatever of the heat efficiency, even after long service."

I have given these quotations in full because they set forth the case so completely and concisely.

Later on in the discussion Harlow tells us that one might expect the recirculated air which is introduced at a higher temperature than previously to reduce the thermal efficiency of the air heater. In practice this is not the case, the efficiency is not diminished at all. This is a very interesting state of affairs.

In South Africa we have three types of air pre-heaters in use, the Ljungström rotary pre-heater of which three are installed, the Usco plate type of which half a dozen are in use, and the tubular air pre-heater, three being in our factories at present, and five or more are being erected this year.

In our Proceedings (10) we gave the results of a test on the Usco heater which showed that it increased the efficiency of the boiler by 16.2 per cent. Mr. W. Mackesy carried out a test some time ago on the Ljungström heater and showed that it increased the efficiency of his plant by 14.7 per cent. (Private communication). However, in his test he was not able to get his flue temperatures from the air heater below 139°F. in the twelve hours during which he ran the test and consequently his figure is rather on the low side.

We have not been able to get a test on the tubular air heater as yet but it has given every satisfaction to the factory where it was installed as a separate unit. This year this factory crushed 20 per cent of new variety canes, with an average fibre content of 14.4 per cent., and with a moisture content of 50.98 per cent in their bagasse, and never was short of bagasse and fuel. That is they did not find it necessary to use coal or wood, as so many of our factories have had to do, in fact they were able to make surplus bagasse. It may, therefore, be deduced that the tubular heater is also an efficient auxiliary installation, in fact it is expected that its efficiency will be similar to that found for all the others.

An interesting and important point is that, thanks to pre-heated air, a somewhat smaller excess of air will suffice for perfect combustion. The draughts, of course, used with their air pre-heaters are higher than they were when burning bagasse on step-grates, both induced and forced draughts now being in use. Our records give the figures showing the temperature of gas leaving the furnaces, the air entering through the tuyeres, and the draughts in use.

It must be clear now to all interested in the use of the air pre-heater that the closed system of air control which its operation and construction requires, has made it possible to control satisfactorily the excess air supplied to the furnaces. The want of such control was the greatest fault, from the point of view of good combustion, in the old grates. Moreover, with the hot air forced draught, grates and combustion chambers have been re-proportioned, which has given a control of CO₂ production not previously possible.

A few years ago sugar engineers were satisfied if they raised 1,500 lbs. of steam from 2,000 lbs. of cane. It has now been shown that 2,000 lbs. of steam may be raised in a modern furnace from 2,000 lbs. of cane.

Feed Water Regulation.

The manner in which the boiler is fed with water leaves much to be desired. The usual practice is to have a boy whose sole job is to keep up the water level in the boilers. The routine adopted consists in opening the feed valve on a range and filling in water up to a mark on the gauge. This operation takes about five minutes, and having completed it the valve is closed and the next boiler in the circuit is attended to. What such a practice actually meant was seen when boilers-meters were installed. The meter might be reading, let us say, 20,000 lbs. of steam per hour. When the water feed valve was opened the indicator very soon began to fall and fell to 2,000 or 3,000 lbs. per hour. On closing off the feed it took nearly 10 minutes for the steam output to reach its original level. This loss of time has to be multiplied by the number of boilers on the range. In one factory it amounted to over 2 hours loss of full steaming time for every round the boy made, which means an astonishing loss of boiler power in a week's work.

Some factories have overcome such a position by the installation of Cope's Boiler Feed Regulators. These regulators provide a continuous feed to the boiler with a variable water level, but one which is controlled and stabilised between fixed limits. This variable water level operates under an increase in load by allowing the level to fall and therefore the stored up thermal capacity in the boiler itself takes care of such an increase. When the load is decreased the water level rises and stores up the heat for the next demand. These fluctuating demands on pumping capacity are controlled by the regulator. Where these have been installed the writer has never seen the boiler attendant touch the water feed from week-end to week-end, beyond operating the control valve by hand once or twice a day to keep it free from scale.

The Conservation of Heat.

This is a subject which warrants a paper to itself for it is of vital importance to our factories. In almost every possible way, in one factory or another one sees quite a lot of heat lost. With the advent of the new variety canes the conservation of the heat derived from the bagasse becomes increasingly urgent. Take one way in which heat can be conserved, namely in the feed water. The feed to the boilers is made up in most factories from the condensate from the 1st body of the Quadruple effect, from the juice heaters, and from the pans. This water is delivered at about 210°F. but by running it about the factory in pipes which are not lagged and storing finally in an open well this water falls in temperature to any figure, say 170°F. What this loss means can be seen from an actual instance:—

From the Quadruple 20,000 lbs. water per hour at 210°F.
 From the Juice Heaters 15,000 " " " " " "
 From the Pans 15,000 " " " " " "

Total condensate 45,500 lbs. water at 210°F.

$$40 \times 45,500 = 1,820,000 \text{ B.T.U.}$$

$$\frac{1,820,000}{970} = 1,876 \text{ lbs. steam from and at } 212^\circ\text{F.}$$

This equals about 45,000 lbs. of steam in 24 hours or the output of a B. & W. of 2,531 sq. ft. H.S. working at 5 lbs. per sq. ft. for 3.8 hours. It has been said that in reply to this criticism that it is not possible to pump water at a higher temperature than 180°F. through the feed water heaters into the boiler, but to-day it is possible to get pumps which will handle water well above 212°F. and against considerable pressure. Such have been installed in at least two factories in the sugar belt.

Another terrific source of heat loss is that resulting from the radiation of the settling tanks. Juice is left to settle in these at 212°F. initially and in two hours it is drawn off to the quadruple effect when its temperature has fallen to at least 190°F.

Another instance taken from our experience will illustrate the heat lost.

Crushing 50 tons of cane per hour the Mixed Juice resulting will be

$$\frac{50 \times 85}{100} = 42.5 \text{ tons}$$

or 850,000 lbs. per hour, or 2,040,000 in 24 hours.

$$2,040,000 \times 22 = 44,880,000 \text{ B.T.U.}$$

$$\frac{44,880,000}{970} = 46,268 \text{ lbs. steam from and at,}$$

or the output of a B. & W. of 2,531 sq. ft. working at 5 lbs. per sq. ft. H.S. for 3.9 hours.

The usual feed of fuel per minute to such a boiler is 85 lbs. of bagasse, or 10 tons for 3.9 hrs., and taking 150 days as a conservative estimate of the length of a crop we get that 1,491 tons of bagasse have to be used to replace the heat lost by the juices through radiation. This weight of bagasse is equivalent to 373 tons of coal which is valued at about £373. Surely such a sum should be worth saving and it could be saved by lagging the tanks with really good lagging.

The whole of the radiation loss would not be stopped by lagging the sides and bottom of the tanks, for there would still be the loss from the surface of the settling juice but the calculation has considered only the weight of the Mixed Juice resulting from crushing 50 tons of cane whereas in actual fact owing to the addition of dilution water to the

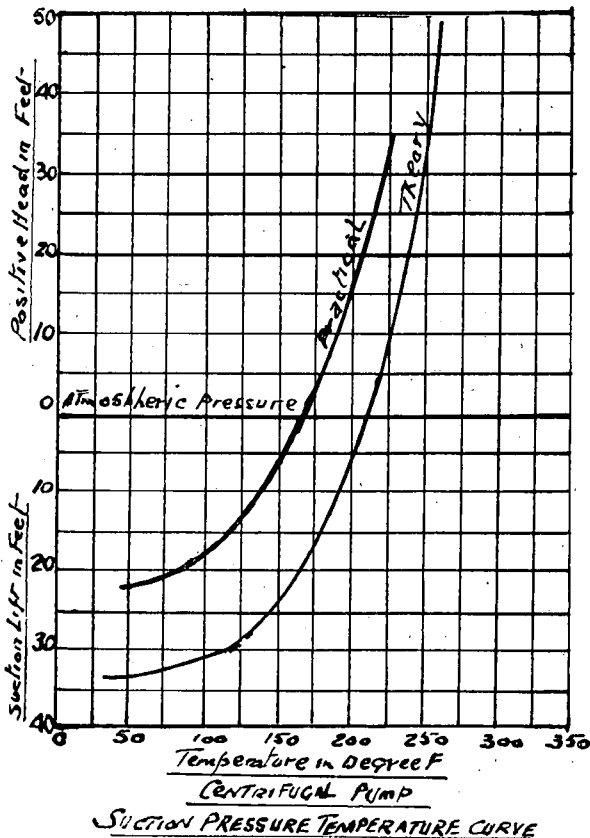


Figure 9.

Figure 9 shews the head required to pump water of different temperatures.

scums the amount of clarified juice is increased considerably. The heating of this extra juice is an offset to the radiation loss from the surface.

There is another way in which lagging settling tanks would pay and that is in the quicker settling of the juice. As the juice tanks stand in draughts and moving currents of air there always are convection currents set up inside the tanks which of necessity carry up the settling colloids etc. If no convection currents could be set up settling would be quicker and better.

Again, since the loss in heat in the feed water was very similar to that lost in settling, it follows that a similar sum of money is lost in restoring the heat to the feed water and therefore the £373 lost in this way could be saved by installing a good closed system of feeding the boilers and thereby conserving the heat.

From these instances it should be clear that lagging pipes and everywhere where heat can be lost in the factory is well worth the money spent on this department. One more instance should suffice to clinch the question. At one of the factories which installed superheaters they found one

day after putting this plant in that the old lagging on the steam pipes went on fire due to the heat in the superheated steam. All this heat had been lost previously by not using superheated steam and the lagging on the pipes cannot have been a very good insulator in any case, in fact the lagging used was the well-known Colonial mixture—cow-dung and straw.

Calorific Values of Bagasse.

With the introduction of non-uba canes there has been a drop in steam production and some people have blamed these new canes for part of this drop. It was considered necessary therefore, to have the B.T.U. value of the various bagasses determined. The calorimeter used was a standard Mahler bomb, which is in regular use for the determination of the calorific value of Natal coals. Some of this work on the bagasse values was published in the 1936 Proceedings (11) and this year a further batch has been examined.

The canes selected were from localities which were far from those selected last year, moreover this year's samples had suffered, to varying extents from locust attacks.

The results were as follows:—

Name of variety.	Sucrose in bagasse.	Moisture in original sample.	Plant or Ratoon.	Age, months	Whether attacked by locusts.	Soil and type.	Ash % bagasse.	B.T.U. ash free.
P.O.J.2725	2.4%	55%	Plant	23	Defoliated..	Heavy loam ..	2.40	8382
P.O.J.2725	1.7%	56%	First ratoon ..	14	Slightly defoliated	Red loam	2.70	8231
Co.281 ..	1.9%	53%	Plant	23	Slightly defoliated	Heavy loam ..	2.08	8399
Co.281 ..	2.4%	54%	Plant flowering 5 weeks	12	Badly eaten Oct., 1936	Sandy loam ..	2.89	8336
Co.290 ..	2.6%	56%	Mixture plant and ratoon	24	Locust-eaten	Ratoons on sandy soil, plant on marshland	2.08	8270
Co.290 ..	2.4%	56%	Plant	22	Repeatedly eaten by locusts	Grey clay	2.44	8321
						Arithmetical average ..		8310

Last year we found an average of 8,394 B.T.U. which does not differ much from this year's figure of 8,310 B.T.U. It may be concluded, therefore, that since last year's figures included Uba cane bagasse, the calorific value of the bagasse is little affected by the variety being crushed or by its history in the field.

Boiler Instruments.

In 1926, at the beginning of this work practically no instruments, beyond the Boiler Gauge, were in use at our factories. Later the Boiler Committee was supplied with its testing instruments and the various factories learned therefrom something of the value of this class of control.

The conducting of the tests referred to in this paper and recorded elsewhere in our Proceedings has helped greatly towards the general understanding of the value of such instruments and the way in which they can be used to determine and to maintain the efficiency of the Boiler Plant. Thus the old way of guessing what was happening has gone for good.

References.

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The PRESIDENT: Gentlemen, I am sure we are all very much indebted to Dr. Hedley for his very interesting and instructive paper, and it proves that the Boiler Committee have not neglected their duty. But before throwing the paper open for discussion, I should like to introduce Mr. Rault, our President-elect. At our Annual General Meeting, yesterday, Mr. Rault was elected President for the ensuing year, and Mr. Pat Murray, Vice-President. I am sure our Association, under the guidance of these two gentlemen, will carry on the good work in the future.

Mr. RAULT: Mr. President and Gentlemen, I must thank you, Mr. President, for the few kind words with which you have introduced me. I must also say that after listening to your valedictory address, I am afraid that you have given us for the ensuing year a very hard task, and put the Technologist's work on a very high standard altogether. Although I am a bit afraid in starting in this new position yet, still I feel very confident after listening to the encouraging words of the Chairman of the South African Sugar Association that our task will be on a whole, a very pleasant one. I take it, gentlemen, that in being elected to this honourable position, it was not only a compliment to the man himself, but mostly to the position I hold as being one of the old servants of one of the leading sugar companies in South Africa. So that in my year of office, whatever will be lacking in competency and in capability, I hope to replace it by goodwill and by keenness, which, with the help of everybody, will make a success of next year's work.

The PRESIDENT: Gentlemen, Dr. Hedley's paper is now open for discussion. There are one or two points I would like to mention. The first is the omission to stress the use of higher boiler pressures. Nothing in the paper has been said about higher boiler pressures. It only requires a very few more heat units to bring the boiler pressure from 200 to 250 lbs. The total heat in the steam at 200 is 1199.2; at 250, 1202.3; at 300, 1204.7. So, for the expenditure of a very little extra fuel, we can get these higher pressures, and these higher pressures, as you all know, can be used in steam turbines, or steam engines, using them for driving generators, which take the place of reducing valves. And then in the process of dropping from the higher to the lower pressure through the turbines or engines, you get electricity in the form of a by-product.

Another point was in connection with boiler efficiency. I have here, a paper which was read before the Institute of Mechanical Engineers, London, by John Johnson. John Johnson is the inventor of the Johnson Boiler, one of the most efficient boilers in the marine service today. While the "Empress of Britain" was in the Port of Durban here, I had the opportunity of inspecting that boiler, along with the Chief Engineer, and he spoke very highly of it indeed. The title of the paper is "The Future of Steam Propulsion." (I. Mech. Eng. 1936. Vol. 132, 29). In the paper, he says he has hopes of attaining Boiler Efficiencies of from 92% to 95%, and the following extract from his lecture is perhaps worth while quoting. He states further:—

"I am well aware that the recovery of low grade heat is not an easy matter, and depends upon the careful adjustment of a number of factors. but, nevertheless, it may prove to be worth while, although this can only be determined by trial on a large scale, at sea.

If it is not worth while, we shall at least have established that it is no use expecting efficiencies above 92%, a figure which can only be attained by larger preheaters, whereby the excess air can be reduced from 10 to 5%. The position, therefore, appears as follows:—

- (1) Efficiency with funnel temperature of 210° F., 10 per cent. excess air, and normal preheater = 90%.
- (2) Efficiency with funnel temperature of 180° F., 5 per cent. excess air, and large preheater = 92%.
- (3) Efficiency with funnel temperature of 100° F., 5 per cent. excess air, and normal preheater, plus cooling by sprays = 95%.

Under present arrangements, with two-stage heating, the temperature of the feed water entering the boilers is about 300°F. With the system of recovering the heat from the funnel gases, heating by the use of bled steam in two stages would be retained, but the final temperature of the feed would be in the order of 350°F."

If Johnson attains his Boiler Efficiency of 95%, it will be a long time before steam propulsion is ousted in large ships by other means of propulsion.

There is one other point, that is in connection with the boiler feed water. From the table here—"A. Total solids in the feed, 2.15; B, 3.00; C, 51.60"—now that is very high for boiler feed water, and it seems to me a clear case for a water filtration plant and a water softening plant to be installed in that factory. "Solids taken from the gauge glass," 895 and 821 are very high indeed. Of course it can be explained in the case of C, but in the case of B, it seems that the blowing-down of the boiler has been omitted, otherwise the figures would not have reached that total.

Mr. JOHN MURRAY: I wish to congratulate Dr. Hedley on his paper. I think myself that No. 6 illustration is the best bagasse furnace in this paper, and the worst one is No. 5. If one considers that the bagasse has to be warmed up and the steam evaporated out of the bagasse before the fuel value in the bagasse is used, in No. 6 one gets all these conditions, and there is plenty of space for it to be properly burned before it reaches the cold surface of the boiler. Take No. 2. That old boiler with a step grate has done very well, and I understand this turbulent furnace, it has done very well indeed. So that anyone who is considering the installing of a furnace, I should advise them to have as model, No. 6 or No. 2 and 4. These, in my opinion, are ideal.

Mr. J. BIHL: Can Dr. Hedley tell us whether the high temperature obtained by the Murray Furnace No. 2, under Multitubular Boilers has had any detrimental effect on these multitubular boilers.

Dr. HEDLEY: No, these furnaces have given no trouble at all. They have worked efficiently, and there has been no trouble whatever in connection with the boilers. Mr. Camden Smith can tell you that, he has them in his own factory. There was some statement that rivets had sheared or given with these furnaces. That is not correct. There has been no trouble whatever due to them. There was trouble in boiler No. 5, and it has not got a turbulent furnace. It may interest you to know that we are not the only people who have put in that type of furnace, or one very like it, under multitubular boilers. They were introduced in Cuba, in 1928, and reported on by Babcock and Wilcox' man, who gave a very excellent report on their performance.

Mr. CAMDEN SMITH: I can bear out Dr. Hedley's statement regarding any expected adverse effect of high temperature on multitubular boilers. We did expect some trouble. We thought that we might experience leaky tubes or started rivets, and so forth. But it has been our experience, during the four years that these boilers have been in use, that no such trouble eventuated. We had some trouble with one of the boilers, but it was fitted with the old step grates and not the new turbulent furnace, and the reason for it was due entirely to a mechanical fault in the construction of the boiler, and not to any trouble which had arisen in use. We have had a great deal of benefit from this furnace, and as time goes on, and we get short of fuel, or expect to get short of fuel through the advent of the new canes, we shall continue to instal them. That is, of course, short of adopting a more modern type of boiler plant altogether. But the old question crops up. Every owner is adverse to scrapping any plant which is, for the time being, giving satisfaction and at least paying its way. The suggestions made in this paper are very valuable. The way to improvement is definitely indicated, but until the actual necessity for that improvement comes about, owners are very loth to take the necessary steps.

Mr. MACKESY: I should also like to congratulate Dr. Hedley on the paper. It is a most valuable one to have in our proceedings. I think it is quite fitting for it to come from him, as it is more or less a resume of the activities of the Boiler Committee, and Dr. Hedley has been the life and soul of that Committee for many years. He has done the donkey work, and to him really is due most of the credit for anything it has done.

There are one or two grouses I have got with Dr. Hedley about this paper. The first one is that this paper reads as a history of the Natal boiler efficiency during the last ten years. It will be published in the general press for the benefit of Australia and England in the Sugar Journals. It will be read as a history. But it does not do justice to our firm—the Natal Estates, but speaks of

preheating having been introduced about eight years ago. Eleven years ago there were two 5,000 foot Babcock Boilers, which had been there for four years. They were both fitted with superheaters. Then he has omitted all reference to our big bagasse fired boiler, which is the father of this Darnall boiler illustrated here. It is of the same construction as figure No. 6, the side elevation is absolutely identical with ours. The difference between the two is that in our boiler, the suppliers have added another drum and an additional cook furnace.

This boiler introduced two things—a huge furnace; and it re-introduced the preheater of different type. Preheaters had been introduced about ten years ago in this factory and others in Natal. They were re-introduced there, and worked very well. Now nearly every other mill is following the example that was set then. Not credit has been given to the Natal Estates for that step.

Now we come to the preheater. He gives us a little equation $300^{\circ} \text{ plus } 80^{\circ}, \text{ over } 2$, gives us a temperature of 190° . That 190° temperature of the plate is well over the dew point. That assumes that there is a fairly equal flow goes on each side of the plate. You get local places where this is very far from correct. Many times there is as much cold air blowing on the plate as there is gas on the other side. You get your local figures and start the whole trouble. In the Sugar Industry we are under the unfortunate necessity of shutting down our boiler and preheater over the weekend. It is very different to a power station.

Dr. HEDLEY: Mr. Chairman, and Mr. Macksey. I knew, of course, that the Natal Estates led in this particular boiler, but there was no intention of slighting Natal Estates.

A Paper was read in 1933, to the Institute of Certificated Engineers, in which your boiler was actually described completely, and I did not think it was necessary to refer to it any further.

With regard to this temperature of 190°F. , I quoted Harlow. I took his statement, and it is well known that the temperature is not uniform in the preheater, that is why corrosion starts and hence the necessity for re-circulation of hot air which is now practiced in all our air preheaters.

Mr. P. MURRAY: I thank Dr. Hedley very much for his Paper and also the "donkey work" he has done. With regard to our President's remarks regarding the efficiency of the Johnson Boiler, I noticed the President of the Sugar Association smiling. I hope he does not expect bagasse fired boilers to give 95% Thermal Efficiency, we cannot get anything like that, it is absolutely impossible, the greatest efficiency we can expect with 50% Moisture in Bagasse is round about 70% (gross Thermal Efficiency). With regard to the best furnace, I would like to point out that the

"Stewart" Turbulent Furnaces at Maidstone (fig. 4) with "Stirling" Boilers gave a gross Thermal Efficiency of 57.9 when under test by the Electricity Supply Commission, and they were only straight boilers without superheaters or air preheaters or anything else. This compares favourably with 61.5 at Natal Estates, and Doornkop 64.5%. To get 57.9% on a straight boiler is a remarkable figure.

All credit is due to the Boiler Committee and Dr. Hedley for the remarkable advances made, and I feel they should be rather proud of themselves for the work done voluntarily and it is an example to all the other Committees to go on and strive for better work.

Mr. MACBETH: I wish to associate myself with previous speakers in commendation of Dr. Hedley's paper. There are just one or two questions I would like to ask Dr. Hedley. Since he started the preheater at Doornkop, what is the overall efficiency of those boilers? Further, what is the temperature of the exhaust gas on the boiler, and what is the rate of evaporation?

Mr. P. MURRAY: The gross Thermal Efficiency at Doornkop was 64.5%, the evaporation averaged 5.6 lbs. from and at 212°F. per square foot. The temperature of the exhaust gases after leaving the air heater was 326°F.

Mr. PORTEOUS: This paper sets forth the very marked progress made in the past few years. I think the Boiler Committee are to be thoroughly commended on the results they have achieved.

Dealing with the paper itself, on page 4, Dr. Hedley referred to an evaporation of 8 lbs. per sq. foot on the Darnall boiler. Was the steam registered on the recorder and corrected for pressure and temperature, because that has a very significant influence on the figures recorded. In the third paragraph from the bottom, the same column, he refers to use of super-heaters increasing the boiler efficiency by 12 to 13%. I found on looking up the Proceedings that the absolute increase was not 12 to 13%, it was 6 to 7%—12 to 13 per cent. is the percentage increase on the previous overall efficiency.

With regard to the Tracey Purifier, I have only seen one installation of a purifier. Have these installations been installed in the boiler drum, which is the logical place to instal it? In my opinion, your evaporation would markedly increase if this steam purifier were put in the boiler drum. There are types available which can be fitted there if conditions were at all reasonable.

On page 7, the bottom paragraph, first column, he says: "It has now been shown that 2,000 lbs. of steam may be raised in a modern furnace from 2,000 lbs. of cane." I wish Dr. Hedley could submit those figures with his paper, because they would be most interesting.

I would say, in conclusion, that I am very grateful indeed to have confirmation of the fact that bagasse from soft cane is practically identical with that obtained from Uba Cane.

Dr. HEDLEY: 2,000 lbs. of steam from 2,000 lbs. of cane were got at Doornkop. They were not published at the time.

8 lbs. per sq. foot of heating surface, as Mr. Bihl will tell you, is what they actually got at Darnall, corrected for pressure and temperature.

The Tracey Purifiers are in the drums at Doornkop. The Tracey Purifier is not in the drums everywhere. I think in the Natal Estates, it is outside on the main steam pipe to the turbines; in Mr. Camden Smith's case it is in the steam line, and also at Tongaat.

Mr. BECHARD: I want to refer to the loss of temperature in the feed water heating. This loss of temperature I point out is not due to heat losses in condensate, but is mostly due to the quantity of make-up water. On careful measurement, I have come to the conclusion that we waste anything from 20% and over of make-up water. This has got more than one inconvenience; it has also got the inconvenience of introducing solids. The solids in the water introduced may amount to so much as seven or eight grains per gallon.

Mr. P. MURRAY: In 1932, I wrote the Committee's Report between Capetown and Madeira. I sent it back here. Some members criticised the evaporation figures, then $7\frac{1}{2}$ lbs. Now, today, we are obtaining 7 and 8 lbs. as an ordinary figure. I have seen 11 lbs. for over a quarter of an hour on the boiler fitted with furnaces as fig. 1.

Now, with regard to furnaces. Many factories are putting in air heaters before they attend to their

furnaces. You can get a long way more additional steam by putting in proper furnaces. I think it is a wrong step to put in your air heaters until the furnaces are put right. Putting in furnaces you get a high temperature; you can put in air heaters afterwards. I think every factory should attend to its furnaces before anything else. You want to improve your boiler plant; you want more steam. You get 14% extra from an air heater; you can get anything up to 40% extra, by putting in the newer type of furnaces.

Mr. COIGNET: Can Dr. Hedley say whether the amount of smuts coming from some furnaces is due to the fitting of the furnace itself, or from the nature of the bagasse.

Dr. HEDLEY: It depends; the nature of the crushing has a marked effect. Where there is shredded bagasse, the smuts are very small. Where the bagasse is burnt in furnaces, with a large combustion chamber, like that at the Natal Estates and Darnall, there are no smuts unless the boiler is over-fed. Where the bagasse is burnt in a furnace that is being forced, then we get smuts, because the bagasse comes through before it has time to get burnt. Shredders are being installed in certain factories, this season, and it will be very interesting to watch what happens. When smuts are precipitated in a preheater, they will absorb moisture, and that would be a source of corrosion. In one factory, they put down a smut chamber and completely got rid of them, but that really is a waste of fuel.

The PRESIDENT: I would like to thank Dr. Hedley very much for his paper. The truest reflex of how the paper was appreciated is the discussion which arose, and I would like you to join me in a very hearty vote of thanks.