The Steam Position at Darnall Mill

By E. P. Hedley

Dr. Hedley: Before reading this paper I want to say that I think it ought to have been mentioned in the printed paper before you that this was a private report to my Company and never intended for the Sugar Technologists' Association; but after the report was made it was naturally handed over to some of the engineers in Durban for their advice and assistance. It came into the hands of the Committee on Heat Balance in sugar factories, and it was discussed there. They thought that it was a pity to keep this paper private, and my Company was approached to get their permission to publish it. They concurred, and so I have to read this to you this morning.

The following series of experiments have been undertaken with the object of examining the steam raising and utilisation at Darnall Mill. Owing to the irregular running and other causes, a complete and exhaustive examination has not been made. In any case, what is required is not the results from one mill with a particular type of boiler setting, but a thorough examination of as many settings in different mills as possible with the object of getting the best and *most economical* one. With the high fibre which South African cane possesses there ought to be no shortage of fuel. It ought to be possible to raise steam and save fuel at the same time for week-ends, etc. It is done in other countries where the fibre in the cane is much less than that in South African Uba cane.

Water Evaporated per Hour.

In order to be able to form some idea of the performance of the boilers, it is necessary to know either the volume of steam evaporated from the feed per hour and its quality of dryness, or else the weight of feed water fed per hour per boiler and the dryness of the resulting steam. The latter course was chosen for various reasons, and a water-meter was installed on the boiler-feed range. The meter has a positive error of 3% at the temperature obtaining in the feed water. The meter was installed so as to measure the water feed to half the battery at a time, and later so placed as to measure the feed to the other half, in this way an average is obtained from which the evaporation per boiler per hour can be deduced. The boilers fall naturally into two divisions of six, and it was in each of these divisions the meter was used. The tests were taken over 6 to 7 hours and the meter was read half-hourly, at the same time the steam chart, showing the united average steam pressure, was also read. The temperature of the feed water was noted regularly also.

The following are the results obtained :—

Boilers Numbers 7—12.

Test No. 1.

Time in Hours.	Meter reading, Gals.	Steam Chart, lbs.	Feed-water temp.	Remarks.
Beginning	34,020	—	—	
½ ..	36,030	90—95	183°F	very steady
1 ..	38,720	90—95	185	work in fac-
1½ ..	41,520	100	185	tory and on
2 ..	44,500	80—85	185	mills.
2½ ..	48,050	80	190	No priming in
3 ..	51,150	90	185	boilers.
3½ ..	53,260	95	188	Cane crushed
4 ..	56,160	95—100	178	for the 24 hrs.
4½ ..	59,420	85—90	190	1617 tons.
5 ..	62,590	90—95	183	Weight of ba-
5½ ..	64,870	90—95	192	gasse made
6 ..	67,680	95	183	539 tons.
6½ ..	69,030	90—95	192	
7 ..	72,450	90—95	194	

The total evaporation for this seven hours' test for six boilers is therefore :—

$$72{,}450 - 34{,}020 = 38{,}430 \text{ gallons,}$$

$$\text{or } \frac{38{,}430}{7} = 5{,}490 \text{ gallons per hour,}$$

$$\text{or } \frac{54{,}900}{6} = 9{,}150 \text{ lbs. per hour per boiler,}$$

less error in meter, i.e. 3%, = 274

8,876 lbs. per hour per boiler.

Tests of this description were carried out frequently so as to get an average, and the following is the summary of the results :—

(Note :—Boilers 1 to 6 are on chimney, 7 to 12 on preheater-fan).

Boilers Numbers 7—12.

Test Nos.	Duration of Test.	Evaporation shown by meter. Gallons.	Average Steam on Chart. Lbs.	Average Feed-water-Temperature, °F.	Remarks.
2. ..	6 hours	33,740	90—95	180–5	Steady running for the 24 hours = Cane crushed 1,722 tons
3. ..	4.5 hours	25,400	85—95	180–5	Weight of bagasse = 585.4 tons. No priming.
4. ..	4 hours	21,190	90—95	180–5	Stopped, cane short. Boiler tubes being brushed *during* test.
5. ..	6 hours	32,760	90—95	180–5	Steady run, no stoppages, no priming.
					Second Series of Tests: Boilers Numbers 1—6.
6. ..	7 hours	31,820	90—95	180–5	Cane crushed = 1,569 tons. Bagasse = 576 tons.
7. ..	5 hours	25,400	95—95	180–5	Cane crushed = 1,539 tons. Bagasse = 499 tons.
8. ..	5 hours	28,320	85—95	180–5	Steady run, stopped due to cane shortage.

From these figures we get the following net results:—

	Boilers 7—12.						Boilers 1—6.		
Test number	1	2	3	4	5		6	7	8
Evaporation per Boiler per hour (lbs.)	9,150	9,371	9,407	8,829	9,100	..	7,576	7,697	7,686
Less error in meter reading (3%) ..	274	281	282	265	273	..	227	230	236
Net Evaporation	8,876	9,090	9,125	8,564	8,827	..	7,349	7,467	7,630
Average	= 8,896 lbs. per boiler per hour.						= 7,482 lbs. per boiler per hour.		

Priming.

At times, due to sudden calls on the steam and other conditions, the boilers prime, but during these evaporation tests there was no priming. Nevertheless, it is necessary to know the amount of entrained steam, and therefore a Barrus Calorimeter was constructed and put in the steam range above the boiler which is nearest the feed and induced draught and is therefore assumed to do the best work. In other words, the calorimeter was put on that boiler where the greatest amount of entrained water is to be expected in the steam. Moreover, during these tests the pyrometer readings of the furnace were as high as those taken during the above meter tests. The conditions, therefore, were as nearly the same as those obtaining previously as could be arranged.

The calorimeter was heavily covered with magnesia lagging.

The following are some of the results:—

Time.	Temperature of Steam.	Temperature of Wire-drawing.
8.30 p.m.	314.6 ..	212
8.45 p.m.	315 ..	212
8.55 p.m.	315 ..	212
9.05 p.m.	318 ..	212
5.30 a.m.	317 ..	212
5.45 a.m.	299 ..	212

It will be noticed that the temperature after wire-drawing is always 212°F.; this points to the deduction that there is too much water in the steam and therefore, since the Calorimeter ceases to be accurate above 5% entrained water we have to consider that there is at least 5% water entrained in the steam. (I should like next year to make an accurate measure of this figure. It could not be done this year, owing to irregular running of the Mill.)

This being true, it follows that the complete net evaporation per boiler is in the case of boilers 7—12, 8,896 – 444 (5%) = 8,452 lbs. per hour, and for boilers 1—6, 7,482 – 374 = 7,108 lbs. per hour.

The Analyses of Flue Gases.

The composition of the flue gases and their temperature, yield the most important data in determining the class of work done by the boiler-house. The analyses of the flue gases gives an index of the combustion, i.e. the working of the furnace, while the knowledge of their temperature provides an index of the heat transmitted by the boiler to the steam and water, or the heat lost in the flue gases. It is from these figures that it is possible to determine whether the bagasse is being burnt to the greatest advantage, and in the hands of the responsible officials in those lands where the cane is much poorer in fibre than that in South Africa these figures have been directly responsible for economical furnace settings, alterations of various equipment connected with the furnaces and better methods of operating the boiler, etc.

In those lands where the fibre is 10—12%, e.g. Cuba and Hawaii, 95% of their fuel requirements are met by the bagasse; and if these lands had our fibre, 16%, I doubt whether the mills would ever suffer from shortage of steam. It is because we are so wealthy in this respect because our fibre is so very high, that we have made so little progress in South Africa with boiler settings. Even with bad firing, bad feeding, etc., we can carry on, but because of uneconomical grates, etc., we are not able to store any bagasse for week-ends, cane shortage and the like.

When the analyses of the flue gases was first undertaken, many people with whom I spoke seemed to be of the opinion that 10% CO_2 represented very good work by the boilers, because it is about the figure attained and maintained by coal furnaces. No authentic South African figures, so far as I could find, had been published, though doubtless every mill has got its own, and therefore the analyses were repeated frequently so as to establish a reliable average. Tests were taken over hours at a time and from the composite sample duplicate analyses were made, and other tests were made by taking samples from the flue at the damper straight into the Orsat, and as soon as the analyses was completed another was drawn up and analysed, and so on for two hours at a time. During this work Mr. F. de Froberville and I worked together and six weeks were spent on this alone.

The following are the results obtained from the analyses of a sample taken over several hours at the damper of each boiler :—

Boiler Number	12	11	10	9	8	7
CO_2	12.8%	13.05	13.75	12.7	14.1	13.4
O_2	5.9%	5.2	4.55	6.5	4.9	6.0
CO	0.6%	0.4	0.1	0.1	0.1	0.0
Total ..	19.3%	18.65	18.9	19.2	19.1	19.4
Nitrogen..	80.7%	81.35	81.1	80.8	80.9	80.6
Excess Air	37.6%	34.3	26.5	43.0	24.8	35.6

Boiler Number	6	5	4	3	2	1
CO_2	12.7%	10.75	10.4	15.6	9.65	13.65
O_2	7.0%	9.05	9.0	2.75	10.25	4.8
CO	0.0%	0.0	0.1	1.45	0.35	1.45
Total ..	19.7%	19.8	19.5	19.8	20.25	19.9
Nitrogen..	80.3%	80.2	80.5	80.2	79.75	80.1
Excess Air	48.4%	73.0	79.1	14.7	61.4	28.8

AVERAGE.

CO_2	12.75
O_2	6.32
CO	0.43

There can be no doubt as to the accuracy of these results. They were all done in duplicate and the analyses agreed very well one with the other. The samples were drawn from the aspirator by means of two tubes, one reaching just below the cork and the other nearly to the bottom of the bottle. A layer of paraffin was placed above the acidulated water and proved absolutely necessary to the accuracy of the results. The results show that the carbon dioxide does not settle down to the bottom of the gas sample. Examples of these analyses are as follows :—

Boiler Number	5	5	4	4	12	12
CO_2	10.8	10.7	10.4	10.4	12.8	12.8
O_2	9.0	9.1	9.0	9.0	5.9	5.9
CO	0.0	0.0	0.0	0.2	0.7	0.5

I can say, however, that it was some time before it was found out how to take samples which agreed satisfactorily. Having established this basis, it was then possible to proceed further and show the important and interesting results subsequently obtained.

Tests of particular boilers were also taken by simply drawing the sample of flue gases into the Orsat, analysing it and at once taking another sample, repeating this several times. Such results are unsatisfactory as a means of obtaining an average analysis of the flue gases, but are interesting as showing what varied composition flue gases may exhibit. Examples are :—

Boiler Number			**7**		
Sample Number	1	2	3	4	5
CO_2	15.0%	13.4	14.6	12.2	10.8
O_2	5.3%	7.2	6.0	8.5	9.8
CO	0.4%	0.2	0.2	0.1	0.1
Total ..	20.7%	20.8	20.8	20.8	20.7

Boiler Number		**5**	
Sample Number	1	2	3
CO_2	16.8%	18.6	17.4
O_2	2.6%	0.4	2.3
CO	0.0%	0.2	0.0
Total	18.4%	19.2	18.7

The high carbon dioxide in the case of boiler No. 5 is specially interesting, particularly as the carbon monoxide is almost absent. Such figures are not the exception when the boilers are being fed well, but they are peak figures, the average being more like that given below for all the boilers. Nevertheless, it is very noteworthy that in every case the carbon monoxide is particularly non-existent, showing that, in spite of the heavy feeding of the furnaces, which brought about the high carbon dioxide, combustion was practically complete.

Associated with these analyses are the temperatures of furnace and flue gases. Such temperatures were taken at the same time that the feed water meter readings were being recorded. They were also taken concomitantly with the samples of flue gases, and finally they were observed frequently when no other work was being done on the furnaces, the object being to get an average figure for the furnace and flue gases.

At the outset it must be remarked that it is not possible to get the temperature of the combustion space in the Darnall boilers. These are now set in a row of twelve, a practice followed in most South African Sugar mills; therefore, without special arrangements it is impossible to get at the combustion space. The so-called "furnace-temperatures" had to be taken in the space in front of the boiler face, where the gases, which have passed already under the boiler, and up the side, are about to enter the tubes of the boiler on the direct passage to the flue. It will be recognised that since the combustion gases have already been in contact with the boiler shell, they must have parted with a considerable portion of their heat, nevertheless since every temperature reading is taken under identical conditions the results are at least comparable and informative. This is true of all other boilers having the same type of setting as I have proved in readings I have taken in other factories.

It appears then, that just as in the meter readings, so in the matter of average temperatures, boilers 12–7 give better results than boilers 6–1. The temperatures shown by numbers 12–7, lie on the average between 1,360°F. and 1,260°F., while boilers 6–1 exhibit a temperature range between 1,180°F. and 1,080°F.

The temperatures of the flue gases in both cases lie between 500–530°F.; these are less sensitive to changes in the combustion space. I have seen 900°F. indicated in the latter, and at the same time the flue gases read 560°F. (on the same boiler, of course), while ten to fifteen minutes later, the combustion space at the boiler face registered 1,160°F., at the flue damper, 560°F. was shown.

These differences in results between boilers 12–7 and 6–1, are connected with the type of draught supplied. The former are on an induced draught fan and the latter a 150 feet chimney stack; also I think it may be due to a lighter feeding with bagasse as the conveyor approaches boiler No. 1. Boiler No. 12 which is situated just where the first bagasse conveyor empties itself on to that of the boiler, undoubtedly gets heavier stoking than boiler No. 1, which is at the other end of the row. The establishment of the facts and the tracing of cause is very difficult and I do not feel that finality has been reached. One important thing has been definitely established, and it is, that the combustion space is too small. This has been shown by collecting a sample of the products of combustion at the boiler face (where the pyrometer readings were made) and *at the same time* collecting another sample of the same gases (after they have passed through the boiler and given up their heat) at the flue damper. If combustion were completed after the gases left the combustion space, the percentage of the constituents should be the same there as at the flue damper. The analyses of samples taken continuously over two or three hours at a time at each place, show that they are never identical, and as such samples were taken on different boilers, it is clear that the same cause is operating in each case.

Boiler No.	At Boiler Face	At Damper
1	12.6% CO_2	16.4% CO_2
12	16.9% CO_2	17.4% CO_2
	0.1 O_2	1.9 O_2
	2.4 CO	1.7 CO
3	14.5% CO_2	15.0% CO_2
	0.1 O_2	0.9 O_2
	6.6 CO	6.2 CO
4	14.2% CO_2	16.0% CO_2
	0.2 O_2	1.1% O_2
	5.8 CO	3.0 CO

It will be noticed that the percentage of carbon dioxide is always greater at the Damper; this can only be due to combustion completing itself after the gases have left the combustion chamber. It will be noticed too, that the oxygen also is greater at the flue damper and this points indubitably to leaky settings.

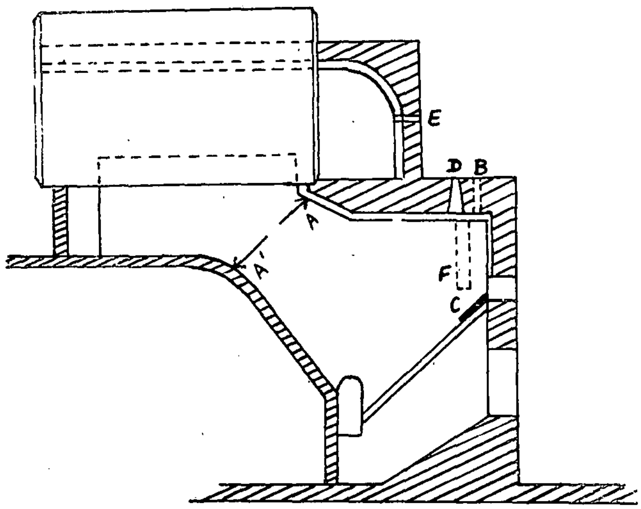
These figures were confirmed by analyses taken at another factory (not one of Hulett's Mills, but by kind permission of the chief engineer, where the boiler settings are the same as those at Darnall.

	At Boiler Face	At Damper
CO_2	10.3%	13.2%
O_2	1.4	4.8
CO	0.7	1.0

Here again we have the increase in CO_2 and the leaky setting resulting this time, in a great increase in oxygen or air. In this particular case, we particularly tried to avoid leaks, taking down the clay round the boiler cleaning doors, and replacing it with freshly prepared daga. During the taking of the sample, a boy kept careful watch that no leaks developed through the cracks in the seal. These tests were repeated, and as the boiler installation is a small one and could be easily overlooked, there can be no doubt that the new oxygen comes from leaky settings.

Discussion of the Results

There is no question but that the direct determination of the actual work done by a boiler is what is desired, but to carry out such a test, is an extremely difficult experiment. The water must be accurately measured—weighed for preference—and the bagasse weighed and fed evenly and regularly to the boilers. This is a problem not easily solved, especially when the boilers are not in single units, but in a battery with very limited space surrounding each member. Nevertheless, such difficulties have been overcome, and the test done in Cuba and Hawaii with signal results. We have not been able to carry one out at Darnall this year, and must therefore discuss average, instead of specific results.



The sketch represents a sectional elevation of a boiler and setting at Darnall. The boiler being a multi-tubular 8 feet by 14 feet, contains 160 tubes $3\frac{1}{4}$ inches outside diameter which represents a *heating surface of 2,200 sq. feet.*

The grate area is 27 sq. feet and the volume of the *combustion space is 259 cubic feet.* This is calculated to line AA.

With these figures to go upon, consider the performance of the boilers in conjunction with the results of the experiments recorded above.

The American Society of Mechanical Engineers have adopted a definition of boiler horsepower as equivalent to the evaporation of 34.5 lbs. of water per hour, from a feed-water temperature of 212°F. into steam at 212°F.

It is assumed also, that with bagasse, 12 sq. ft. of multi-tubular boiler will develop 1 horse-power per hour, or 2.5 lbs. of water are evaporated per sq. ft. per hour. The Darnall boilers therefore, should be

$$\frac{2200}{12}$$

or $183\frac{1}{3}$ horse-power boilers, and as such, should evaporate 183 and one third by 34.5 lbs. per hour, or 6,323 lbs. per boiler, per hour. Actual meter measurements show that they are evaporating 8,452 lbs. (boilers 7–12, page 3, of this report) and 7,108 lbs. per boiler per hour (boilers 6–1, page 3). They appear, therefore, to be well over their rating and doing good work. But is this work economically done? In test No. 1. (page 1) of the meter readings, it will be seen that the bagasse made, was 539 tons and burnt in the day.

$$\text{Bagasse burnt per hour} = \frac{539 \times 2000}{24} = 44{,}914 \text{ lbs.}$$

Taking 2.3 as the weight of water evaporated by 1 lb. of bagasse, the water this weight of bagasse should evaporate is 44,914 x 2.3 or 103,302 lbs. per hour for the battery of 12 boilers, or 8,600 lbs. per boiler. The average evaporation for a single boiler in the range works out, according to the measurements given above, as 7,780 lbs. This would mean, that although the bagasse is going into the furnace and being burnt *the maximum efficiency is not being* attained. That this is true is seen from the fact that CO_2 is lower at the boiler face than at the damper (see results recorded page 6) and that there is considerable carbon monoxide in the flue gases. As is well known, 1 lb. of carbon develops 14,544 B.T.U's. when burnt to CO_2, but when a boiler is over-fed, carbon monoxide is formed, and only 4,450 B.T.U's. are evolved, which means that 10,094 are lost to the furnace. An insufficient supply again will bring about the same result, and both causes obtain at Darnall at different times.

What is the cause of this loss in heat, this incomplete combustion? It seems to me to be due to several contributing causes. (1) The combustion space is too small (2) The grate area too small. and (3) Unsatisfactory use of the air admitted to the furnace with the bagasse.

If we consider what happens to the air which enters D (see sketch of boiler setting, page 6), it must be clear that a portion of it slides along towards A without mixing with the products of the bagasse. Due to this cause the arch between D and A is kept cooler than it ought to be and the drying value of the radiant heat is lost, the products of combustion too, are cooled by mixing with the cold air in the flue and this valuable heat is lost to the boiler. All this could be avoided if a curtain wall were placed as shown by the dotted line at F. The air entering with the bagasse would be forced down into the furnace, there to assist in the combustion.

It would be much better too, if the bagasse were fed into an enclosed or mechanical hopper, such as the Ramsay Patent Stoker and thus exclude a rush of surplus air entering with the bagasse. Such Stokers are in use in factories in Hawaii, Peru and Cuba, giving complete satisfaction.

That the combustion space is too small, has been proved as shown above when discussing "the analyses of the flue gases" at the Boiler Face, i.e. at the pyrometer hole E. (sketch on page 6), and at the Damper at the back of the boiler. Indeed, while the tests were being taken, it was possible to see the sparks of burning bagasse passing in the flue on the way to the chimney.

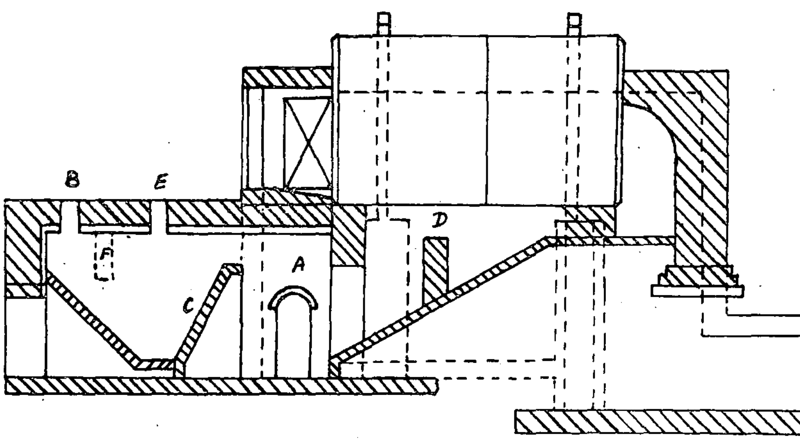
The third contributing factor to inefficient combustion, is the small grate area. All through Natal, in most of the sugar factories can be seen smuts which have been carried off the grate and up the stack before they were burnt. This is due to the smallness of the ratio of grate area to combustion space, or to heating surface and to too great velocity of the products of combustion through the combustion chamber. In Darnall, the ratio of grate area to heating surface is 1 to 80, at the Zululand Sugar Milling Co., this ratio is 1 to 55 and at Verulam 1 to 46. At both these factories, fuel troubles are unknown and one of the contributing causes undoubtedly is to be ascribed to this ratio.

Recommendations

The shortage of steam which obtains at Darnall at times is due, amongst other causes, to inefficient boiler settings. Another boiler is now to be installed and it would be advisable to alter the setting so as to get as efficient a setting as possible. The one in use at Sezela, is a great advance on the Darnall setting. It is sketched here and embodies many desirable features, and works well at Sezela.

This setting is undoubtedly more efficient and with a grate area of 40 sq. ft. as against Darnall's 27, much better results must follow.

Another furnace which is doing excellent work, is the turbine furnace, which Thom is agent for. I have seen this furnace at work in two factories, and both speak very highly of it being able to compare with others in the *same* mill. One of these mills, very kindly allowed me to conduct some experiments on it so as to get an idea of its work. Some of the figures are reported on page — which show that the combustion space is too small, but as they copied the setting of Darnall this is only to be expected. The temperature of the combustion gases as taken at the boiler face (just as in Darnall) show 150°F. higher than Darnall's and the flue gases were 500 to 510°F. as against those at Darnall usually 530 to 550°F. The heating surface in either case is practically the same. They say there is no comparison between the work done by this boiler and the multi-tubular boiler. Since the two turbine furnaces were installed in this factory, steam troubles have ceased, and the surplus bagasse pile grows bigger daily—most factories are not in a position to make surplus bagasse.



The bagasse feed is set back to the outside wall, thus using the ladder to its fullest extent. At Darnall, the feed is placed at D (page 6) and the bagasse therefore does not get the full drying that is possible. It would be better if the feed on the existing boilers at Darnall were set at B shown by the dotted lines (page 6) and fell on to a dead plate or fire brick at the tip of the ladder. This is a desirable feature (which does not obtain at Sezela). It is round the top of the ladder that much cold air is admitted without first passing through the bagasse, and the blocking up of the top of the ladder with brick, prevents this and the radiation from it helps to dry the bagasse.

The gases resulting from combustion are then compelled to mix by passing up and over C, under A, and once more over D. This should ensure thorough mixing and as the combustion space is much bigger than that at Darnall, more efficient combustion must result. Never-the less, I think when building this furnace, the curtain wall at F, in dotted lines, should be inserted for exactly the same fault is in this design as in Darnall's. At E, there should be an observation hole so that the temperature of the furnace could be taken.

The great difference between the work done by each boiler is very clearly seen in the fact that it is possible to take off a multi-tubular boiler for cleaning its tubes, and the effect on the steam position is scarcely felt, but it is not possible to do the same to the turbine furnace without the steam falling seriously. It is noteworthy that the draught in this factory varies from $\frac{3}{8}''$ to $\frac{1}{2}''$ at the boiler face, and at Darnall, it is $\frac{3}{4}''$.

Either of these two furnaces would be preferable to continuing to build more furnaces like those at Darnall I do not mean that they are very bad, but since another boiler is to go in it is advisable to improve where possible.

Moreover, in the strongest possible terms, I urge the desirability of installing recording instruments on the boilers, a carbon dioxide recorder, which can be switched on to any boiler at will, and a pyrometer for flue and furnace. In factories in this country which are noted for their efficiency, such instruments will be found. They have been installed in the sugar factories of Hawaii and Cuba, and in the latter place, by their means, Prof. Kerr reports raising the carbon dioxide in the flue gases from round about 10% to round about

15%. Such instruments will pay for themselves in showing where improvements can be made and in maintaining these when made. A Bristol steam recording gauge is already installed, and these instruments are just as useful. This has been the experience, my personal experience, and that of the personnel in the places mentioned. Can we, even with our 40% more fuel in our cane, afford to ignore these results of scientific management?

In the coming season, Darnall will be requiring more steam than ever previously and every effort should be made to produce it. It is the intention to crush 75 tons of cane per hour, and in this connection it is interesting to consider the following figures. During 1928–29 crop, the average crush per hour at Darnall was about 68 tons, the total heating surface is 26,400 sq. ft., which gives 381 sq. ft. of heating surface per ton of cane per hour. In 1929–30 season, if we crush 75 tons of cane per hour, and have 13 boilers, we shall not increase our heating surface per ton per hour at all, it works out as

$$\frac{2{,}200 \times 13}{75}$$

equals 381 sq. feet of heating surface per ton per hour.

In view of the requirements of new pan and other improvements, it becomes an urgent necessity to conserve heat in every possible way. There is much more in this direction to be done, and the subject matter of this report can only be considered as touching the fringe of the question. So far as I know, there have been no exhaustive experiments made on boilers and settings in this country, such as have been carried out by the mills in other sugar growing countries to their lasting benefit. The amount expended by the company in a single year on extra fuel, if devoted to the examination of the steam question, should solve it once and for all.

Loss of Heat from uncovered pipes.

The loss of heat by radiation from this source has been very great. The insulation of all steam pipes, those between the bodies of the quadruple effect, the pans, and exhaust steam range, in fact everywhere that live and exhaust steam pass, will pay for the cost handsomely, not only in the money saved, but in providing more steam for use in the mill. That this statement is true, is well borne out by the consideration of the following facts. One square foot of uncovered pipe surface carrying 100 lbs. per square inch (the boiler pressure at Darnall) will dissipate about 3 B.T.U's. per hour per 1°F. difference between the steam temperature and the atmospheric temperature, that is 50 B.T.U's. per hour at ordinary atmospheric temperature, that is about one third H.P. per hour. A 50 ft. length of uncovered 4″ piping conveying steam at 100 lbs. pressure will condense not less than 40 lbs. of steam per hour, or over two tons in 120 hours i.e. about a weeks run and the loss in 25 week in horse-power would defray the expense of proper lagging several times over.

The following table taken from the Transactions of the American Society of Mechanical Engineers, shows the enormous saving in heat (B.T.U's.) by using a first class pipe covering :—

Loss in heat from steam pipes with steam at 300°F. (about Darnall's conditions)

Loss in B.T.U's. per *hour* per square foot of pipe surface.

	1″	2″	4″	6″	8″	12″
Bare Pipe	1,100	1,070	1,010	945	920	880
Magnesia Covering						
0.5″	340	280	250	240	235	230
1.0″	260	200	170	155	148	140
2.0″	195	140	110	100	92	87

It will be noticed that as the pipe diameter increases, the loss in heat units gradually decreases, but there is still an enormous loss. The use of 0.5 inch covering reduces this loss to about 25% of that suffered by a bare pipe, while 1″ very sensibly reduces the loss still further. It is doubtful whether the cost of increasing the insulation to 2″ is worth while.

These points are stressed because these losses obtain at Darnall and next season with the installation of the 50 ton pan, all the steam that can be got will be needed. Dry steam itself, is not a good conductor of heat, but water is, and therefore its presence in steam pipes and cylinders should never be permitted, since by acting as a conductor between the steam and the metal, it sets up active condensation and absolutely prevents economical results being obtained even in engines of the best design.

I should like, before concluding this report, to record my sincere thanks to Mr. Bihl and his staff for the very willing way they assisted my work in the factory. Their kindness in carrying out the repeated alterations I required made the work a pleasure.

APPENDIX.

As a result of this work, the setting of the new boiler at Darnall has been altered so as to provide a much bigger combustion chamber and a larger grate area. This latter has been done by widening the grate from 4 feet 6 inches to 6 feet and the side walls have been carried on under the boiler thus widening the combustion chamber. Additional volume has been added to the combustion space by giving the ramp a curve, which latter should also assist in the mixing of the gases.

The combustion chamber has been increased in this way from 260 to 458 cubic feet. It is recognised that we are not providing a secondary combustion space like that in use at Sezela, as suggested in the report, but it is not possible to build the new boiler grate 6 or 7 feet back from the row of boilers at Darnall. If this were done it would not be possible to feed it without very expensive and far reaching alterations to the bagasse carrier ; therefore, we have done the best that can be done under the existing conditions.

In addition to these alterations the bagasse feed has been set back so that the fuel will be delivered on top of the step-ladder. At present it does not fall quite on the top. At the top of the ladder the front wall has been cobbled over just under the top three steps. This has been done so as to prevent cold air from rushing into the furnace over the top of the bagasse without taking part in the combustion.

Further, to prevent the cold air entering with the bagasse from creeping along the top of the combustion space, as pointed out in the report, a curtain wall 9″ in width has been built in. This wall is 9″ from the front wall of the furnace, and there should be plenty of room to allow bagasse to slip down the ladder and not block up this space.

On the other side of the wall, the boiler side, an opening 6″ wide extends across the top of the furnace. This is to be used as an opening through which the furnace can be cleaned, and as an observation door.

Beyond this opening there is a sloping arch which should assist greatly in the work of the combustion space.

We realise that there is considerable difference of opinion as to the value to be attached to some of these alterations e.g. the wide grate area, but the coming year will prove whether such are justified and we shall then have experimental proof on the questions. Should the grate be too wide, it will be a simple matter to build up a fire-brick wall on either side and thus to reduce the width to 4ft. 6ins.—a width already known to be satisfactory.

Chairman: Papers such as have just been read to you make me very conscious of my limitations as Chairman. I find it very difficult as a chemist to make intelligent comments on these papers. I should perhaps be emboldened by the example of Dr. Hedley, as I recollect that at last year's meeting he told us that it was with the greatest diffidence that he spoke on matters of engineering. This year he seems to have made a very successful incursion into that domain. The subject of combustion is perhaps one of those matters where the co-operation of the chemist and the engineer is most to be desired. I would like to endorse Dr. Hedley's remarks regarding the necessity of having proper instruments for recording such things as the temperature of flues, carbon dioxide in flue gases, and steam recording gauges. These are found as a matter of course in the more efficient factories overseas, and I think should be universally adopted here. I greatly welcome these most interesting papers. We have not had a report from the Committee dealing with the subject of heat balance this year, but I think these two individual papers fill the place very well.

Mr. John Murray: I am sure we thank Dr. Hedley very much for the paper, and seeing the very thorough way in which he has tackled the job, and that he is assisted by Mr. de Froberville and Mr. Bihl, I have no doubt the results are correct. Since the paper is the first published boiler trial in South Africa, Messrs. Huletts are to be congratulated on their technical staff carrying out these tests and allowing them to be published. Dr. Hedley is of the opinion that the Darnall setting is not efficient. This was also the considered opinion of the Committee in 1926 on this type of furnace. However, it seems to do fairly well at Darnall in spite of all the criticism. In altering bagasse furnaces one has to be very careful that one gets increased efficiency and not chaos, as the want of steam in a sugar factory is certainly chaos in the worst form. Although I was a member of the Committee that drew up the paper in 1926, I don't take much credit for it, but I think it is the best paper on bagasse furnaces we have had, and I would advise anyone to study it. In the appendix to the paper Dr. Hedley says it is impossible to get a secondary combustion furnace at Darnall. I don't agree with him. Mr. Simpson has got it at Mount Edgecombe. An illustration is to be found on page 29 of the 1926 Conference, on "Types of Bagasse Furnaces and Boilers." Mr. Simpson is to be congratulated on getting such a fine design. It is specialliy suited to multitubular boilers like you have at Darnall. It is a splendid setting. I have seen it myself, and the results are absolutely good. I don't agree with Dr. Hedley about the width of the grate. I think the setting of 27 square feet grate area to 2,200 square feet heating surface is absolutely good; it is a ratio of 80 to 1. There are twelve factories in Natal which give an average of 78 to 1, and the lowest we find was about 55. The factories that had the bigger ratio had any amount of fuel and very small boiler power, so they banged in the bagasse to get plenty of steam with small inefficient heating surfaces. On the question of the total heating surface of the boilers I quite agree with Dr. Hedley. Three hundred and eighty-one square feet is far too small per ton of cane per hour; it should be nearer 500. I suppose you would want at Darnall about 18 boilers to get the steam. The Zululand Sugar Milling Company in their new scheme I believe have 7,200 units.

I thank Dr. Hedley and Mr. Bihl for their papers.

Dr. Hedley: There is one point in Mr. Murray's remarks which might call for reply. I don't know that we want 18 boilers. Given an adequate supply of bagasse continuously we have been able to have ample steam. If the bagasse is not coming in continuously of course, since we can't make it we have no reserve, and one of the points I tried to make is that with our 16 per cent. fibre in bagasse we ought to be in a position to get the calorific value of it and yet make bagasse. Mr. Dodds referred to my temerity in speaking to-day. Mr. Dodds evidently does not know that I am a chemical engineer. A chemical engineer is a person who in the presence of engineers is a chemist, and in the presence of chemists is an engineer! So that when they get together he sort of bridges the gap, and if he is a wise man he keeps his mouth shut! (Laughter.)

Mr. Patrick Murray: The only way to get the Mount Edgecombe setting at Darnall is to move the boilers back, but I don't think it is possible to do that at Darnall.

Mr. Bihl: We went very carefully into the settings, and it is utterly impossible to get the Mount Edgecombe setting in. We would very much like to do so if it was possible, but it was not possible.

Dr. Hedley: I may say we did study the report referred to by Mr. John Murray. The men who made it up deserve every credit, and it is a masterpiece. Mr. Patrick Murray spent a good deal of time in getting these drawings out. The thing we would all like to see is to get efficiency reports from the settings in the different mills. I know that Mount Edgecombe—as Mount Edgecombe so frequently does—is experimenting, and they have ordered a very large number of instruments, to the value of several hundred pounds, and among them are instruments such as we recommend, and I hope that Mr. Simpson will be able to be in a position to give us something about the efficiency of his boilers next year. This is not the end. We are going to experiment very much next year, and sufficient experiments will be tried on the boilers so as to get to know more about the settings. There is a very fine setting at Sezela. I should like some reports on that. We should have more experiments to get more knowledge on the working of our boilers. The day is coming when bagasse is going to be used for a number of purposes, and the greatest economy in fuel consumption will be necessary.

Mr. Patrick Murray: We are very pleased to have this paper from Dr. Hedley. Before the Committee can do much on boilers I think the Association should buy a set of instruments for the testing of boilers. I would like to propose that we approach the Sugar Association to provide us with a complete set of instruments so that we can get proper tests on boilers.

Mr. John Murray: I will second that. I would also like to ask the Secretary to write to Java, Hawaii and Queensland and get the bagasse settings from them so that the Committee will have some data to work on. It has only been through individual firms writing in the past that we have been able to get these things. If the Secretary wrote to the different countries and got these settings it would help us greatly.

Dr. Hedley: I wrote to Hawaii and asked for copies of one of their annual reports because it contained information which would have been very valuable to us. I got a polite but firm refusal; they would not allow anyone who is not a member of the Association to have these reports. I wrote back also kindly but firmly that I was very disappointed that such was the case; that as a scientific man, being a member of many societies—some seven in fact—I knew that anyone could go to them, and if they were willing to pay whatever the price of the journal was they could get that journal, and yet we who were an infant industry providing only one per cent. of the sugar of the world could not get the courtesy which was meted out in other scientific societies working in other countries. It seems such a great pity as Hawaii has done so much, that you cannot get those papers unless you are a member.

Chairman: I might state that since the Experiment Station was established two years ago we have had copies of the annual proceedings of the Hawaii Sugar Technologists' Association. They are willing to send one copy annually to Experiment Stations or Institutions of that nature, but not extra copies to individuals. But a single copy of each of the last two years is available at the Experiment Station. That applies only to the annual proceedings of the Hawaii Sugar Technologists' Association. The "Hawaii Planters' Record," which contains a lot of other useful information, and is published more frequently, so far as I know is not circulated outside of Hawaii. I think it is a matter which will largely settle itself in time. As soon as people overseas see that we have useful information and ideas to exchange as the result of our study and work, that exchange will be much freer, but at present we have to realise that the advantage has been mainly on our side.