A REVIEW OF THE DEVELOPMENT OF BOILER PLANT IN
THE SOUTH AFRICAN SUGAR INDUSTRY

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The object of the paper is to provide a short review of the work which is on record in the Proceedings of the Association on progressive developments in boiler plant in the South African Sugar Industry.

This review is intended mainly as a tribute to the painstaking work carried out over the years by the various sub-committees of the Association on boilers and boiler practice, and partly as an indication of how work of this nature, carried out progressively, has been of far reaching benefit to the industry.

Initial Commencement

The earliest records which the author has available is the Congress and Exhibition number dated 1924 which contains a short paper by Mr. Patrick Murray entitled "Boilers and Furnaces for Cane Sugar Factories". This paper gave an analysis of the main particulars of some eleven boiler settings in various factories in Natal and Zululand with a comparison with, what the author termed, “the model boiler setting”.

It is interesting to record all the boilers reviewed were of the multitubular type with step grate furnaces.

Although no actual complete tests were carried out, certain calculated figures were submitted which are interesting. Of particular interest are the figures listed under the heading of "Lbs. of steam per sq. ft. of heating surface". These vary from 2.98 to 4.6, while the author of the paper gave the ideal figure as 3 lbs. per sq. ft.

Earliest Recorded Work by a Sub-Committee

1926

The aforementioned paper stimulated a good deal of interest and resulted in the formation of a sub-committee by the then Natal Sugar Technologists Association. This sub-committee, under the chairmanship of Mr. Patrick Murray, put forward a most important and detailed report to the Fourth Annual Congress of the Association in 1926. The paper included three appendices entitled:

1. The theory of combustion as applied to bagasse.
2. The composition of Natal bagasse as a fuel and economies attendant upon modern improvements in care and design.
3. Typical drawings and settings of boilers and furnaces from various parts of the world.

The figures given in the paper are mostly theoretical calculations with observations on results of actual tests carried out on boiler plants in other sugar countries.

Items which would affect boiler efficiencies such as furnace volume, flue area, chimney draught, and air supply were, however, fully discussed and the increase in efficiencies due to air heating, feed water heating and reduction in bagasse moistures were all carefully worked out in detail.

Fig. 1. Setting for Stirling Boiler, Tongaat.
Setting for Multi-Boiler, Natal Estates.
The detailed work in this report well merits further reference, and as a matter of interest, two illustrations are reproduced, taken from No. 3 Appendix, giving details of actual boiler settings then in use in Natal.

It will be noticed that step grate furnaces were almost universally in use and no changes were either contemplated or recommended by the committee at that date.

The comparative figures are given for boiler heating surface for twelve Natal factories, and these range from 338 sq. ft. per ton of cane per hour to 620 sq. ft., the average being 461 sq. ft. The recommended figure put forward in the report is 500 sq. ft. per ton of cane per hour and it is interesting to note the equivalent figure to-day is nearer 300 sq. ft. per ton of cane per hour.

This report undoubtedly stimulated interest among the factory personnel and attention was focussed on one or two initial installations of air heaters. Economisers had been in use in one or two factories for some years previous to this period.

This was a period when the factory engineer was being guided to think in terms of “more steam per lb. of bagasse”.

The committee’s report of this year laid the real foundation for the valuable work to follow in later years.

Practical Results

Very little work was reported the following year except to present the results of tests on two Howden Lungstrom Air Heater installations at Darnall and Mount Edgecombe. The tests were carried out by the firms supplying the plant and did not come under the supervision of the committee.

The following figures were reported:

**Darnall**
- Boiler efficiency without preheating 64%
- Boiler efficiency with preheating 83.6%
- Evaporation per lb. fuel as fired 2.97 lbs/hr.
- Moisture in fuel 49%

The figures were severely criticised during the discussion on the report and would undoubtedly be queried to-day.

It is important to note that during the discussion, a recommendation was put forward by Mr. Camden-Smith requesting the Boiler Plant Committee to undertake or supervise boiler tests, and the Committee agreed to give this careful consideration.

The Report for the year 1928 again draws attention to the need for carrying out tests, particularly on new types of equipment, and the necessity for funds to be allocated for the purchase of the essential test instruments.

About this period an approach was made to the South African Sugar Association for the necessary funds, and a sum of £250 was eventually granted by the Association and arrangements made to permit Dr. E. P. Hedley to co-operate with the committee.

**Interest Increased, 1929**

During this year, the Committee did not present a report but it is important to note two papers were submitted to the Congress.

(1) A description of some desirable features of a multitubular boiler plant and practical working thereof—by J. E. Bihl.

(2) The steam position at Darnall mill by Dr. E. P. Hedley.

It is evident the previous work of the committee was bearing fruit and practical application of certain of the recommendations was being freely advocated.

A plea was put forward by Dr. Hedley for the introduction of recording steam flow meters and other instruments on the boiler installation.

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**FIG. 2.** The first “Cook” type furnaces installed in Empangeni in 1930.
Commencement of Reports on Tests
1932-1933-1934

By this time instruments had been purchased and tests were being arranged by the committee. In the meantime, a considerable amount of attention was being paid to new furnace designs and "Cook" type horseshoe furnaces with tuyeres and a flat hearth were installed at Empangeni, Felixton and Amatikulu. Instruments were also fitted to many new and existing plants.

The 1933 report is a most important step forward as it records the result of four months continuous work carried out by Dr. Hedley and the committee in the factories.

A summary is given of no less than eleven boiler tests on separate plants, on multi-tubular, Stirling and B. & W. type boilers.

The thermal efficiencies reported ranged from 35.6 per cent. to 61 per cent., the water evaporated per lb. of bagasse as fired from 1.93 to 2.31. Incidentally the later figure was obtained on a multi-tubular boiler with a step grate furnace.

Special attention was drawn to the need for superheating on the boilers, as tests revealed 17 per cent. moisture in steam in some cases.

In this period Mount Edgecombe had appointed an efficiency engineer, Mr. W. Mackesy, who presented a most valuable paper to the 1933 Congress entitled: "Heat Temperature Balances in a Sugar Mill Boiler House".

In this paper arbitrary costs were fixed for bagasse as a fuel, savings by airheater and economiser installations worked out in pounds, shillings and pence, and losses debited against the boiler house.

This paper created a good deal of interest and is a valuable record in the Association's proceedings.

The opening paragraph of the Report of the Committee for 1934 is worth repeating here:

"Last year's work on the boilers has made itself felt in many directions both directly and indirectly. The direct results are in the increased efficiency by the factories where alterations were made to the boiler plant as the result of the 1932 work on the boilers.

"The indirect effect is seen in the large number of factories in which either new boilers or structural alterations to the furnaces is being effected, based on experience gained elsewhere".

Results of nine boiler tests are reported with thermal efficiencies ranging from 49.8 per cent. on a multi-tubular boiler to 64.6 per cent on a water tube boiler.

It is interesting to note it had been found necessary in almost every instance to modify the construction of the horseshoe hearth furnace due to trouble experienced in cleaning the furnaces caused by excessive clinker and bulky ash deposits.

The fitting of a flat grate some 12 inches above the hearth, allowing forced draught to circulate under and through the fire, eliminated a good deal of this trouble.

About this time new designs of furnaces were produced in the country embodying the flat grate with tuyeres and of relatively simple construction.

![Fig. 3. The first furnace of this type installed on a multi-tubular boiler.](image)
North Coast employing high pressure boilers operating on bagasse, using pass out turbines and exporting the surplus power.

A very elaborate series of boiler tests were carried out at Tongaat to obtain the basic figures. Thermal efficiencies of 58 per cent. were obtained with "Turbulent" furnaces and without air heaters. Previously in 1932 on these boilers, when fitted with step grate furnaces, tests gave the efficiencies as 35.6 and 44 per cent. It was unfortunate these proposals were ahead of that time as they were sound in principle, and Hawai recently adopted a similar scheme where boiler units of 975 lbs./sq. in. are being installed to supply export power for irrigation and community services.

Comparison with Previous Tests—1935

The 1935 Report indicates work was so far advanced to be possible to report; re-tests on boilers previously tested on which improvements and modifications had subsequently been effected. This was a most important step forward in the work of the committee. The results are grouped side by side and the figures are most interesting.

Review by Dr. Hedley—1937

In place of the usual report of the committee, Dr. Hedley presented a paper entitled "Boilers, Furnaces and Boiler Equipment". This paper was a review of the work carried out over the previous eleven years and is most interesting and important record.

Illustrations are given in the report showing the progress which had been made with new designs of furnaces, and the results of tests are summarised and particular features explained.

A full description is given of a new boiler installed at Darnall, which was then reported to be the largest boiler unit in the sugar industry in the British Empire. The heating surface is given as 11,080 sq. ft. and the furnace was fitted with four horseshoe "Cook" type hearths.

Mention was made in the paper of the failure of practically all of the air heater installations in early years of service through corrosion of the elements, due to the acid nature of the furnace gases, and the very low dew point at which the gases deposited moisture. Subsequent investigations largely overcame this trouble by recirculation of the primary air

Fig. 4. One of the boiler plants tested in 1953.
to ensure the elements were maintained at a temperature well above the dewpoint of the gases.

It was established by tests in South Africa that the dewpoint of the gases was in the region of 160°F., and not 130°F. as had been previously reported elsewhere.

British practice has been to add additional air heater surface to provide for heating over 30 per cent. of the air recirculated, to maintain an inlet air temperature of 175°F. There is the danger of by-passing some of the heating surface in the heater due to drop in velocity. American practice is to maintain velocities and cut down on air leakage through the boiler settings and furnaces.

**Introduction of the Ruth's Accumulator—1938**

The Proceedings in 1938 records a paper on “Thermal Storage as applied to the Refinery” by G. C. Wilson. This paper gave a very detailed analysis of the results obtained at Hulett’s South African Refinery at Rosshburg and the advantages claimed for this system.

It was from this introduction that several factories eventually installed thermal storage plant to assist on the low pressure process side. Although very expensive in first cost, maintenance is low and results appear to justify the expenditure. South Africa is, however, the only sugar country to have found this system necessary.

**Period Up Till 1953**

During the war, the activities of the committee appear to have lapsed, and although a great deal of activity had been taking place on development work in the factories, no further tests are reported until 1953. By this time the Sugar Milling Research Institute was in operation and had taken over the work previously carried on by the committee.

A paper was submitted in 1953 by A. F. McCullock of the Institute, giving very complete and detailed results on tests carried out at two different factories on boiler plants.

Thermal efficiencies were reported up to 68.2 per cent., a big increase on any previous tests.

**Present Activity**

Dr. Hedley, whose useful reviews were always a welcome feature of the Congress agendas, is no longer actively associated with the work of the Association and an endeavour will therefore be made to give some idea of present activities.

It is evident that beyond replacing obsolete boiler units by more modern equipment, very little further real progress would be made. Test results were equal to any reported elsewhere, and in fact better than quite a number of other sugar countries.

Considerable interest has however been shown in the larger boiler plants installed within recent years.

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**Fig. 5. The action of the rotary distributor on a spreader stoker.**
in other sugar countries and the radical alterations to boiler designs and firing equipment employed.

Single boiler units with an output of up to 165,000 lbs. of steam per hour have been installed, incorporating water cooled furnaces with spreader stokers in place of standard design furnaces.

Installations of this type have been in use for some considerable time on bark refuse, wood chips and other cellulose fuels, with exceptionally good results and with very high efficiencies. It was natural, therefore, to expect this equipment to eventually be used on bagasse fired boilers.

There are two types in use, one having pneumatic feeders and the other variable speed rotary distributors. A considerable amount of work was necessary to adapt the equipment to handle bagasse, and only within recent years have details of the installations been publicised.

The first commercial unit with a bagasse spreader-stoker operated in a Cuban mill in 1948 with a peak

Fig. 6. A new boiler unit fitted with bagasse spreader-stokers.
load of 83,000 lbs. per hour and a thermal efficiency of 67 per cent. Bagasse moisture varied from 45 to 64.5 per cent. and the lowest CO₂ figure is given as 15 per cent.

Two units of this type replaced ten large horizontal return tube boilers in one factory, resulting in a considerable reduction of labour units and a saving of $150,000 in extra fuel per season.

This system comprises a compact co-ordinated stoker and furnace design which can be applied to almost any type of boiler.

The stoker includes a variable speed feeder, rotary distributor, dumping grates for easy fire clearing and provision for forced draught combustion air. The fuel feed, air supply and furnace draught can therefore be co-ordinated, whether manually or automatically controlled.

The outstanding features of this system are the uniformity of fuel feed, minimum cleaning time, low maintenance and adaptability to fully automatic combustion control.

Initial installations will be in operation in this country during the coming season and the results will be watched with interest.

Whilst the initial installations will have dumping grates arranged in sections operated by steam cylinders, larger units would normally be fitted with continuous grate discharge where the ash is delivered continuously over the end of the grate. Particularly on the American Continent and sugar countries adjacent, it is usual to fit oil firing auxiliary equipment to the boilers. This is convenient for starting up, shut down periods and in case of emergency...

In this country wood has been used almost universally for these services, but this is becoming increasingly difficult to obtain and the cost is a considerable item.

Spreader-stokers of this type can be adapted to burn coal as an auxiliary fuel where necessary or desirable.

Certain pre-conceived ideas about the handling and feeding of bagasse to the furnaces will have to be modified to suit the new installations, and certain troubles are bound to be experienced, due to the varying conditions and characteristics of the local bagasse.

Surplus bagasse is to-day a saleable asset—labour is a vital item in ever increasing costs. Saving on both will prove well worthwhile.

The future trend is likely to be a reduced number of larger boiler units in the boiler house with increasing amount of automatic control.

The South African Sugar Industry is by no means in the background as regards boiler equipment and is not likely to lag behind.

The foregoing is not intended to be a technical paper, but chiefly a review of the results achieved by successive boiler sub-committees during a period when outstanding development work was encouraged and exceptional interest maintained.

This paper was followed by a film showing the working of a new bagasse spreader-stoker furnace.

Mr. Grant, the Chairman, thanked Mr. Walsh for presenting a paper which was such a useful record of past work. The film he showed demonstrated a furnace which was coming into increasing use and some of the local engineers were worried as to whether it could handle very high moisture content bagasse such as we have here. They would probably have to re-adapt themselves to such a type of furnace.

Mr. Gunn said that while he did not want to detract from the work done by the Sugar Milling Research Institute on a boiler at Tongaat, the boiler tested was too large for the testing procedure used and did not truly reflect Tongaat figures. He noticed in the film shown by Mr. Walsh that the downtakes for bagasse were enclosed and he wondered what would happen when they got blocked and whether there was any method of clearing them quickly.

Mr. Walsh replied that Mr. Gunn's query about the blocking of the bagasse tubes was a very practical problem and one which took many years to overcome. The drum feeders were so designed that the feed was very slow and there was little danger of the bagasse packing. There was a variable feed on both the distributor and on the feed as well.

Dr. Douwes Dekker pointed out that in connection with the tests done at Tongaat, Mr. McCulloch had had great difficulty in weighing the bagasse and that this difficulty was increased. He therefore thought that the smuts trouble would not get any better, but it was possible to arrange some method of collecting smut and returning it to the furnace as had been done overseas. The fly-ash trouble would have to be overcome, as for instance had been done in power stations.

Mr. McKenna asked if the newer furnace would eliminate some of the trouble now found with smut.

Mr. Walsh said that the amount of smut depended upon the fineness of the bagasse and after a shredder this difficulty was increased. He therefore thought that the smuts trouble would not get any better, but it was possible to arrange some method of collecting smut and returning it to the furnace as had been done overseas. The fly-ash trouble would have to be overcome, as for instance had been done in power stations.

Mr. Grant said that in our present furnaces a considerable quantity of white ash was deposited in the combustion chamber, which had to be cleaned out at the week-ends. What happened to this ash in the spreader-stoker furnace? Did it deposit in the...
furnace or was it carried over through the tubes and discharged out of the chimney.

There appeared to be big possibilities of applying fully automatic control with this type of furnace.

He also considered that in a properly designed and operated furnace, the bagasse charcoal should be consumed with the consequent elimination of the smut nuisance.

Mr. Walsh replied that in the new type of grate, combustion conditions would be quite different and that there would be less danger of ash being blown away. A big advantage was that ash could be cleared away more easily by dumping the grate regularly.

Mr. Grant stated that at some factories there were types of bagasse which, apparently of the same calorific value, did not burn readily, he wondered what the effect of these would be in the spreader-stoker furnace.

Mr. Walsh said that with a very thin layer of bagasse on the grate and much better control of air that there was better prospect of burning this troublesome bagasse, but we would have to wait and see the result.

Mr. Reynolds thought that with a layer of bagasse only six inches in thickness on the grate there would be a very small fuel reserve in the furnace, and with the periodical stops that occur in sugar mill operation he would like to know what would happen when the bagasse supply to the furnace was interrupted for more than a very few minutes.

Mr. Walsh pointed out that he had already said that some of our preconceived ideas about feeding bagasse would have to be changed. In other countries the bagasse feed was carefully controlled and when there was too much it was by-passed and returned on special carriers, so that the boilers were fed constantly, irrespective of what the rest of the plant was doing.

Mr. Heslop said that although in bagasse-fired boilers one endeavoured to burn all fuel and avoid any carry-over into the boiler, carry-over occurred even in coal-fired boilers, where a much heavier fuel is burnt in suspension and he expressed the opinion that this position would be aggravated with bagasse.

Mr. Walsh replied that this type of trouble was a difficulty experienced in any plant and it was necessary to provide ducts under the air preheaters to remove any carried-over fuel and return this to the furnace.