BOILER EFFICIENCIES IN SUGAR CANE MILLS

By S. G. COLINESE

INTRODUCTION

According to the *S.A. Sugar Year Book* **1953-54**, there is "scope for the improvement of the efficiency of many of the steam generators in the Natal Sugar Industry."

The year book does not provide any test data or any direct indication of what these efficiencies might be expected to be. It is, however, obvious that in many cases the equipment necessary for carrying out tests is inadequate and certain suggestions were made regarding the provision of CO_2 recorders and steam flow or water meters.

The purpose of this paper is to discuss the minimum equipment and to present test data as some kind of guide to those who are anxious to effect improvements. Since the tests referred to were not carried out in Natal there can be no question of divulging confidential information and the presentation of the test can be criticised without fear or favour.

THE PSYCHOLOGICAL APPROACH

It is not to be expected that the high boiler efficiencies attainable in modern power plants will be reached in the average sugar mill. (From 80 per cent. to 90 per cent.).

From 75 per cent. to 85 per cent. may be reached in exceptional cases where integral steam power plant operates at a high pressure and temperature, and the process steam is reduced in pressure and temperature to suit the evaporators in the boiling room. Refinements such as economisers and superheaters, and perhaps air heaters, would be incorporated in a plant of this description. It should be possible to reach at least 70 per cent. with simple plant generating dry staurated steam and having no economisers or air heaters.

Given an attainable and precise objective the engineers and chemists will team up well providing they are persuaded they will receive a fair share of the credit when substantial improvements are made. The personnel of many sugar mills form isolated rural groups and to use the obvious cliché they plough rather lonely furrows. Like others similarly circumstanced they are not over-fond of the technical "shooting stars" who flash over their horizon from time to time and make imposing suggestions after cursory inspections. The writer's experience in dealing with the problems of combustion in cane sugar mills shows that valuable improvements could be made without recourse to expensive modifications, providing the enthusiastic co-operation of the staff was first obtained in a planned atmosphere of good will.

MINIMUM EQUIPMENT FOR TESTING

1. Some means of obtaining the dryness fraction of the steam as it leaves the boilers is essential. This is of course unnecessary if the steam is superheated. The efficiency of a boiler cannot be accurately determined if the quality of the steam is unknown. Many of the losses attributed to the "Boiling House" are in fact due to the wetness of the steam received from the "Boiler House." It is not necessary to fit a throttling or separating calorimeter. They have their limitations as every student of "steam" well knows. A forty-gallon drum half filled with cold water, a well-lagged steam drain pipe of small bore and fitted with a stop valve, and a calibrated thermometer are the only requirements. It is assumed that reliable steam tables are available.

At the risk of appearing to be pedantic the method of finding the dryness fraction is given below. Frequent tests could be made to obtain a working mean value.

Example

The data given below refers to an experiment made to determine the dryness fraction of steam from a boiler having a working pressure of 140 lb. per square inch gauge. The small-bore steam pipe was well lagged and previous to commencing the test the steam was allowed to blow through the pipe freely to heat up the pipe and remove accumulated moisture.

Weight of water in drum at start	200 lbs.
Weight of water in drum at end	210 lbs.
Temperature of water at start	72°F
Temperature of water at end	126°F

Deductions (All heat units are in B.T.U.'s)

Heat units in water at start: 200 × (72–32)	8,000
Heat units in water at end: 210 × (126–32)	19,740
Heat units in 10 lbs. of steam: By diff. ...	11,740
Heat units in 1 lb. of steam	1,174

From steam tables for dry saturated steam (140 lbs. per square inch):

Sensible heat is	333.3 units
Latent heat is	862.3 units
Total heat is	1,195.6 units

If x be the dryness fraction then:

$$333.3 + x(862.3) = 1174.0$$

$$x = \frac{840.7}{862.3} = 0.975$$

Comment

It may be thought that this relatively high dryness fraction is hardly worth consideration. It represents, however, about 1.8 per cent. of the total heat and when the feed water is supplied at say 200°F is about 2.2 per cent. of the heat supplied.

If the steam is very wet the "dry pipe" or Tracy Purifier is not so efficient as it should be. Alternatively the boilers are being forced above their normal designed evaporative capacity. Personally I am convinced that dryness fractions of 0.9 to 0.95 are quite common in boilers being forced when their heating surfaces are dirty.

The moisture content of steam is one of primary interest to both engineers and chemists in cane sugar mills.

2. Carbon Dioxide and Carbon Monoxide Recorders

These instruments require close and expert attention to keep them in order. In those mills where it is found that they are not quite robust enough to stand up to the prevailing conditions a CO_2 indicator is sometimes to be preferred. The slotted sampling pipe should run well across the width of the flue in a horizontal position and about one-third of the flue height as measured from the base. CO_2 is much heavier than the N_2 in the flue gases and a poorly positioned sampling pipe will give unsatisfactory results.

3. An ORSAT Flue Gas Analyser

This enables a complete check to be carried out on CO_2, CO and O_2. The analysis could be carried out, if necessary by the chemist, once per week. The sum of the percentages of CO_2, CO, and O_2 should be close to 19.5. CO of course should not be present. Less than 5 per cent. of O_2 may lead to the formation of CO or CH_4 (methane). The furnace brickwork, etc., should be carefully checked for signs of infiltration of air before the analysis is carried out.

4. Feed Water Meter

This is to be preferred to a steam flow meter as it ensures that a record is made of the total evaporation including auxiliary steam, safety valve losses, etc. If a feed water meter is supplied it is essential to fit a by-pass. It is of course possible to measure the total evaporation in a tank, and this is perhaps the most reliable when such a tank is available. Hotwell tanks are often used for this purpose.

5. Pyrometer

A pyrometer should be available for measuring the flue gas temperature at the chimney base.

6. Optical Pyrometer

For special occasions a portable optical pyrometer could be borrowed for giving instantaneous readings of the furnace temperatures. For good combustion the temperature would be from 1,850° to 2,000°F.

N.B.—It is taken for granted that the following are part of the normal equipment:

(*a*) thermometer for taking atmospheric temperature,

(*b*) sootblowers or steam lances for cleaning the external surfaces of the tubes,

(*c*) a gauge for measuring the draught in inches W.G.,

(*d*) facilities for weighing the bagasse,

(*e*) means of obtaining the L.C.V. of the bagasse by approved methods.

COMMERCIAL TESTS FOR BOILER EFFICIENCY

A commercial test may be defined as one in which no specialist operatives are engaged in supervision. The results will show what is happening from day to day under normal working conditions. The data obtained can be interpreted and used by the staff to suit local conditions.

Commercial tests could be carried out for a period of say four hours and at least three times during each season. Expert advice could be asked for if necessary. It is "the man on the job", however, who will have to decide, as a rule, upon the conditions best suited to an all-round efficiency. If it is found, for example, that a fairly high CO_2 with a correspondingly high furnace temperature shortens the life of the furnace refractories then the optimum CO_2 will have to be decided by trial. It may be found that a slight reduction in the CO_2 will lengthen the life of the brickwork and also increase the thermal efficiency. After a few commercial tests have been carried out it may be advisable to have a full-scale supervised test in case there should be any points needing clarification.

LOWER CALORIFIC VALUE

Before commencing a test the explicit method to be used in arriving at the lower calorific value of the bagasse should be agreed upon. There is no reason why unanimity should not be reached for general application throughout the industry. Reference is made to this in an Appendix. Source of steam tables should be mentioned.

A TYPICAL TEST

The fullest possible details of a typical test and the general manner in which it is carried out is given below. For convenience it is grouped under several headings—

(*a*) Purpose of test.

(*b*) Plant data.

(*c*) Test data with calculations and comments.

(*d*) General observations.

Purpose of Test

To ascertain the equivalent evaporation per pound of bagasse as fired, and subsequently to compare the result with those obtained over a whole season in a sugar mill in an adjoining terrain.

To estimate the efficiency and prepare an approximate heat balance the following are required:—

Callendar's Steam Tables.

Dr. G. L. Spencer's Handbook for approximate ultimate analysis.

Proximate analysis from staff chemist.

Method of calculating available heat in the bagasse as shown in Appendix.

Plant Data

There were five water tube boilers each having a heating surface of 3,580 square feet. Stepped grates of 40 square feet per boiler. Ratio of heating surface to grate area about 90 : 1. Soot blowers were fitted but were not used during the test as they tend to disturb furnace conditions for some time. No economisers or superheaters. The furnace walls were in good condition. The daily crush of cane was 920 long tons. Bagasse was 32 per cent. of the cane. No auxiliary fuel was used. Recorded excess bagasse after pans were shut down was 2 per cent.

Test Data

Plantation Analysis

Fibre	51.17 per cent.	Moisture	44.89 per cent.
Sucrose	2.89 per cent.	Non-Sucrose	1.05 per cent.

Ultimate Analysis Approximate (Dry Fuel)

Carbon	46.5 per cent.	Hydrogen	6.5 per cent.
Oxygen	46.0 per cent.	Ash	1.0 per cent.

Steam and Water

Steam pressure (lbs. per sq. in.) 135.9
(Assumed to be dry saturated)

Feed water temperature . ... 165°F
(Normally this was 200°F)

Actual evaporation (four hours) ... ... 248,400 lbs.

Air and Flue Gases

Atmospheric temperature at boiler front ...	100°F
Temperature of gases at chimney base	530°F
Draught in inches W.G.	0.75
CO_2	14.5 per cent.
O_2	5.0 per cent.
N_2	80.0 per cent.

Fuel

Weight of bagasse burned (four hours). 109,900 lbs.

Comments

A large bagasse platform of structural steel and having a concrete floor made weighment relatively easy. It served also as a reserve bunker. Handrails were tubular and carried water service to reduce fire hazards.

Evaporation

Actual evaporation per lb. bagasse ...	2.26 lbs.
Equivalent evaporation...	2.48 lbs.
Evaporation per square foot of H.S./hr.	3.46 lbs.

(This latter figure is based upon the actual evaporation.)

Heating Surface

Heating surface per long ton hour ... 471 sq. ft.

Conclusions

The equivalent evaporation of the bagasse as fired was 2.48 lbs. from and at 212°F. In cane sugar mills in an adjacent terrain the equivalent evaporation over a full season of 3,363 milling hours was 2.34 lbs. from and at 212°F.

The second value is about 5.65 per cent. less than the first but serves to indicate the difference between a supervised test of short duration and the normal conditions prevailing during a whole season. The equivalent evaporation should always be used for the purpose of making comparisons. The heat required to change one pound of water at 212°F to steam at the same temperature was assumed to be 970 B.T.U.'s.

Estimated Boiler Efficiency and Heat Balance

These calculations are shown separately, as the primary purpose of the test was to find the equivalent evaporation per pound of bagasse. For the benefit of those who may wish to state the equivalent evaporation in terms of dry fuel the result from the supervised test with the fuel at 55 per cent. of the bagasse becomes 4.509 lbs. of steam from and at 212°F for each pound of dry fuel. Reduced to these terms comparisons are easier to make.

Heat put into Dry Saturated Steam by One Pound of Bagasse

From the steam tables the total heat per pound of dry saturated steam at a pressure of 136 lbs. per sq. in. is 1,195 B.T.U.'s. Deducting the heat in the feed water which is (165—32) B.T.U.'s the heat put into each pound of feed water is 1,062 B.T.U.'s. Also 1,062×2.26 is 2,400, and 970×2.48 is 2,400.

Calorific Value of Bagasse

The Higner Calorific Value was estimated to be ... ... 4,571 B.T.U.'s

The available heat was estimated to be ... ... 3,451 B.T.U.'s

(Refer Appendix for details).

Estimated Boiler Efficiency

This is $\frac{2,400 \times 100}{3,451}$ = approximately 70 per cent.

Comment

It was considered that the calculated efficiency was good. Also that the average efficiency based upon the evaporation of adjacent mills over a whole season of 3,363 milling hours would be about 66 per cent., and a good sustained performance without special supervision.

Heat Balance

The available heat of 3,451 B.T.U.'s is the basis upon which the heat balance has been prepared. It should be noted that a deduction for the heat absorbed in raising the temperature of the moisture in the bagasse from 100°F to 212°F and subsequently converting into steam at this same temperature has already been made. Also that the hydrogen, combining with the oxygen, in the fuel to form steam has been treated in precisely the same manner.

Heat Lost in the Chimney

Weight of air supplied per pound of dry fuel. This from the standard deduced equation is:

$$\frac{N_2 \times \text{Carbon per cent.}}{33(CO_2 + CO)}$$

From data previously supplied: Carbon—46.5 per cent.; CO_2—14.5 per cent.; CO—Nil; Nitrogen—80 per cent. 33 is a constant.

Weight of air supplied per pound of dry fuel is:

$$\frac{80 \times 46.5 \times 2}{33 \times 29} = 7.78 \text{ lbs}$$

Products of Combustion Per Pound of Dry Fuel

Weight of nitrogen $\frac{77 \times 7.78}{100} = 5.99$ lbs.

Weight of CO_2: $\frac{0.465 \times 11}{3} = 1.70$ lbs.

(1 lb. of carbon unites with 2.66 lbs. of oxygen to form 3.66 lbs. of CO_2.)

Weight of steam: $0.065 \times 9 = 0.585$ lbs.

(1 lb. of hydrogen unites with 8 lbs. of oxygen to form 9 lbs. of steam.)

Weight of oxygen: $\frac{5 \times 32 \times 5.99}{80 \times 28} = 0.428$ lbs.

(Relative weights of equal volumes will be the same as the relative molecular weights.) The above value was also checked by comparison with CO_2.

Total ... ... 8.703 lbs.

As a check it will be noted that 7.78 lbs. of air plus 1 lb. of fuel weighs 8.78 lbs. The difference of about 1 per cent. is negligible.

Heat Lost in the Gases (Per Pound of Dry Fuel)

It may be noted here that the gases are heated from 100°F to 530°F. The steam is heated from 212°F to 530°F as a deduction has been already made for the heat required to raise it from water at 100°F to steam at 212°F.

Heat lost =

Weight × temperature difference × specific heat.

CO_2	$1.7 \times 430 \times 0.224 =$	136.5 B.T.U.'s
N_2	$5.99 \times 430 \times 0.251 =$	650.0 B.T.U.'s
O_2	$0.428 \times 430 \times 0.225 =$	41.5 B.T.U.'s
Steam	$0.585 \times 318 \times 0.45 =$	84.0 B.T.U.'s
	Total	912.0 B.T.U.'s

Heat lost per pound of bagasse =

$912 \times 0.55 = 502.0$ B.T.U.'s

Heat Lost in Chimney due to Superheating the Moisture in Bagasse

Taking moisture as 45 per cent. and the mean specific heat as 0.45 the heat lost in the chimney, but excluding the products of combustion is:

$0.45 \times (530 - 212) \times 0.45$ ... ... 64.5 B.T.U.'s

Heat Balance

Heat given to steam	2,400 B.T.U.'s
Heat lost in chimney by products of combustion	502 B.T.U.'s
Heat lost in chimney by superheating moisture	64.5 B.T.U.'s
Radiation, etc., by difference... ...	484.5 B.T.U.'s
Total ...	3,451 B.T.U.'s

Heat Lost by Radiation, etc.

This of course includes losses by hot ashes, combustible in ash and perhaps miscellaneous minor leakages. In this case it is about 10.5 per cent. of the total heat in one pound of bagasse as fired. It is difficult to estimate radiation losses with accuracy. The somewhat excessive value estimated here suggests the advisability of carrying out a test over a longer period.

Checking Excess Air

It is interesting to check the excess air as it serves to confirm or to question the accuracy of some of the calculations and observations.

The minimum air required for one pound of dry fuel is deduced as follows:

Oxygen to unite with carbon:	
0.465 × 2.66	1.24 lbs.
Oxygen to unite with hydrogen:	
0.065 × 8	0.52 lbs.
Total oxygen required:	1.76 lbs.
Subtract oxygen present in fuel	0.46 lbs.
Net oxygen required	1.30 lbs.
Minimum air required $\frac{1.3 \times 100}{23}$ =	5.65 lbs.

Since the air supplied is 7.78 lbs. then the excess air is 2.13 lbs. This is approximately 38 per cent. and it is of interest to note that, according to B & W's useful tables page 115, a 14.5 per cent. of CO_2 is stated to represent an excess air of about 40 per cent (wood fuel).

Comments

There is no need for the staff of a sugar mill to prepare a comprehensive test report. A few commercial tests will provide a lot of useful data. If a heat balance is considered to be desirable it could be prepared and checked externally. The preparation of a heat balance is akin to an auditor's trial balance. It quickly reveals inconsistencies, irregularities and errors in observation. A few years ago it was quite common to insert a "tolerance clause" in contracts with a specified efficiency. This amounted to 5 per cent. for so-called errors in observation. It was a plus or minus value, and was considered to be fair when penalties could be imposed or bonuses claimed for performances deviating from the fixed level.

Finally, and with particular reference to the supervised test of short duration, it will be noted that the CO_2 at 14.5 per cent. (and an excess of air of only 38 per cent.) must be regarded as a maximum. If some of the heat from the chimney gases could be used to preheat the air supplied for combustion there would be an added economy but there are serious technical difficulties in the way of modifying plant so that this can be done cheaply and efficiently. Afterthoughts are usually expensive.

Careful treatment of feed water with the object of reducing or eliminating scale-forming constituents is worth consideration but no suggestions are offered here as they are considered to be outside the scope of this paper.

REFERENCES

Cane Sugar Handbook. Spencer/Meade.

A Handbook for Cane-Sugar Manufacturers and their Chemists. (John Wiley & Sons, Inc., New York; London: Chapman & Hall Ltd.). 1929.

Callendar's Steam Tables 1939 (London: Edward Arnold & Co.).

APPENDIX

Calorific Value of Bagasse

Heat in fibre:	... 8440 × 0.5117 =	4,340 B.T.U.'s
Heat in sucrose:	7120 × 0.0289 =	206 B.T.U.'s
Heat in glucose, etc.:	6750 × 0.0105 =	71 B.T.U.'s
	Total	4,617 B.T.U.'s

(See page 52.)

Subtracting 1 per cent. for ash the H.C.V. is . ... 4,571 B.T.U.'s

Available Heat in Bagasse

The heat expended in heating the moisture and evaporating it when the boiler house temperature is 100°F is (112 + 970 B.T.U.'s) per pound. This is 1,082 B.T.U.'s.

The heat lost in this way is:

$$1{,}082(H_2 \times 9 + \text{moisture}).$$

The percentage hydrogen is 6.5. The percentage moisture is say 44.89. (See page 3.)

$$\frac{1{,}082\ (6.5 \times 9 + 44.89)}{100} = 1{,}120 \text{ B.T.U.'s}$$

The available heat is therefore (4,571 − 1,120) which is 3,451 *B.T.U.'s*.

This value is less than the laboratory determination for the L.C.V., but its chief merit lies in the fact that it takes into consideration the actual conditions under which the fuel is being burned in the boiler house.

Some authorities have in the past suggested that the latent heat of steam at atmospheric pressure (970) should be used whilst others prefer to use the latent heat of steam at 60°F (1,055). Where the moisture content is so great as it is with bagasse the method outlined above seems to be preferable.

Mr. J. B. Grant thanked Mr. S. G. Colinese for his most interesting paper, and threw it open for discussion.

Mr. Lindemann said that it was known that the thermal efficiency of a heat engine depended upon the relationship of $\frac{T_2 - T_1}{T_2}$ or $1 - \frac{T_1}{T_2}$, in absolute units of temperature.

Since a steam raising boiler was a heat exchanger it was reasonable to adopt a similar view in its case.

It could be shewn that efficiency figures obtained by this simple method (T_1 and T_2 being the furnace and exhaust gas temperatures respectively) agree with those reached in actual boiler trials within a tolerance of three per cent. If T_1 be taken as the furnace temperature, T_2 as the exit gas temperature of the boiler, and assuming dry fuel at 14,500 B.T.U.'s with the ambient temperature of the boiler of 100°F, the per cent Thermal Efficiency=

$$100\left(1 - \frac{\text{Temp. of Exit Gases}}{\text{Temp. of Furnace}}\right).$$

To allow for moist and lower grade fuels a correction must be added to the foregoing expression.

Generally it would appear that a difference of 10 per cent exists between low and high grade fuels, reducing the efficiency figure proportionately from 10 to

$$\left(10 - \frac{\text{Fuel calorific value in B.T.U.'s}}{1450}\right)$$

Substituting the figures mentioned in the paper in the formula, namely furnace temperature at an average of 1925°F, gases at chimney base 530°F, bagasse fuel at 3,451 B.T.U.'s and the ambient temperature at 100°F (which reduces the absolute figure of 460°F to 360°F), reveals a Thermal Efficiency of 53.5 per cent which is considerably less than that given in the paper—70 per cent.

The following table disclosed the small differences existing between the results of the Boiler Trial Survey and formula based upon data taken from the Proceedings of the South African Sugar Technologists Association.

Moisture in Bagasse	Temperature F. Furnace	Boiler exit	Thermal Efficiency Test %	Formula	Difference %	Type of Boiler
48.3	1600	500	47.0	49.1	2.1	Multi
46.5	1840	580	48.4	50.3	1.9	Multi
51.8	1646	469	35.6	51.7	16.1	Stirling
51.4	1854	462	44.1	55.8	11.7	Stirling
51.6	1584	465	53.7	50.6	3.1	B & W
53.0	1663	550	48.4	48.0	0.4	B & W
49.1	1550	526	43.3	46.6	3.3	B & W

On the question of baffling, it is my firm opinion, that an improvement in efficiency can be achieved by the removal of the back-wall baffle and placing it alongside the down-comer tubes. This would mean passing the exhaust gases underneath the mud drum to the base of the smoke stack, thus ensuring proper convection circulation, allowing each tube to generate its quota of steam, which at present is doubtful.

Hence in order to keep a daily check of the boiler efficiency the engineer would require a furnace pyrometer and thermometer in the boiler exit flue, recording type or otherwise, thus satisfying the engineer's dream for simplicity.

Mr. Colinese, in reply to Mr. Lindemann, said that as no furnace temperatures were recorded during the test under discussion no deductions could be made from the use of the upper and lower temperatures. The use of the Carnot Cycle efficiency was not admissable. It was purely hypothetical and had never been reached in practice. The formula given by Mr. Lindemann was interesting but there were no means of reaching such a high efficiency. It was to be regretted that the moisture content of the steam was not taken. It was assumed however that the steam was dry as the evaporation per square foot of heating surface was low. The efficiency figures published in the past by the Associations' various Boiler Committees were good but we should go forward and improve upon them.

Mr. P. Murray said that the Boiler Committee in the past did an excellent job and he did not think that the efficiency obtained as a result of their work could easily be improved upon.

Dr. C. van der Pol supported Mr. Colinese in his statement that the formula given was quite inapplicable to ordinary boiler practice. He wished to know why in the figures given by Mr. Colinese 1 per cent was deducted for ash, and asked when the heat value of the fibre was calculated, if the ash was included as well.

Mr. Colinese replied that when the heat values of the fibre, sucrose, etc., were deduced from the ash free fuel it became necessary to allow for the ash in the fuel as fired.

Mr. J. M. Cargill inquired if combustion of the fuel could not be improved, and a higher boiler efficiency obtained by giving the operator something which would make the control of the boiler more easy as far as fuel and air control was concerned. He had experience of oil fired boilers where means were provided for testing the smoke in the flue gases. He wished to know if any such device had been applied in the sugar industry.

Mr. Colinese said that in feeding bagasse it was difficult to regulate the fuel to air ratio; far more difficult than in the case of coal or oil fired furnaces. Although smoke and smog were not liked, the fact remained that close to the black smoke line the boiler was at its highest efficiency.

Mr. Reynolds said that he had no doubt that the majority of Natal sugar mill engineers would be surprised at the figure of 70 per cent which was given as the efficiency of the installation referred to by Mr. Colinese. He thought that few boilers in Natal operated at such a high efficiency, due largely to the fact that the rates of evaporation per square foot were in general much higher in Natal practice than in the case referred to in the paper. Furthermore, combustion rates per square foot of grate area were also considerably in excess of those mentioned by the author. Overloading and high efficiency do not go hand-in-hand, and unless ratings on the majority of boilers in Natal could be reduced, it could not be expected that efficiency figures of 70 per cent could be attained.

Commenting on Mr. Lindemann's remarks, Mr. Reynolds said that removing the rear baffle from a Babcock and Wilcox Boiler would have the effect of reducing the mass flow of gases, and accordingly would reduce the rate of heat transfer from gas to water, and he considered that such a modification would result in a reduction of evaporation instead of the increase which Mr. Lindemann had suggested.

Mr. W. B. Heslop said that assuming that the boiler plant was correctly designed from the point of view of capital cost, etc., a big improvement could come through the extensive use of instrumentation and to more regular attention to blow-down and to feed water.

Mr. Colinese stated that the Heat Engines Trials Report published by the Institution of Civil Engineers in co-operation with the Institution of Mechanical Engineers and the Institution of Electrical Engineers is still regarded as the best and most comprehensive work on Plant Efficiencies, and the manner in which tests should be carried out. It is a magnificent publication and was published originally at a price of about five shillings. Its codes are accepted without qualification by a great majority of contractors and purchasers. It would be unwise to attempt to depart from their carefully considered recommendations. If, as a matter of curiosity, it is thought to be worth while to estimate a rough approximation of the maximum attainable efficiency of a boiler plant based upon the upper and lower temperatures it must be borne in mind that there is a vast difference between the specific heat of the furnace gases at say 2,245 degrees F (as given in the 1934 proceedings) and the mean specific heat of the chimney gases at a temperature of say 530 degrees F.

Gas	*Specific heat at* 600 F.	*Specific heat at* 2,000 F.
CO_2	0.222	0.310
O_2	0.216	0.231
N_2	0.247	0.265

It may be of interest to owners of plant in the Natal sugar mills to know that, in view of the relatively low grade labour available for construction and operation in certain countries outside the Union, all brickwork was constructed with an additional half brick thickness, furnace volumes were kept rather large, rate of combustion per square foot of grate area was kept low and the rate of evaporation per square foot of heating surface was accomplished without forcing.