EXPERIENCES IN COMMISSIONING A BENT TUBE BOILER, SPREADER FIRED, BURNING BAGASSE OR COAL

By H. FOTHERINGHAM

Introduction

This paper is a short story of an integral type, bent tube, spreader fired, water tube boiler, burning coal or bagasse. The time covered is the first two years, from commissioning until most of the difficulties found were ironed out. Weaknesses and idiosyncrasies of this boiler have, we think, all shown up and have been successfully overcome.

A boiler on a sugar mill is one of the most important units, but is, nevertheless, only a small part of the whole plant. The experience gained on this boiler will, maybe, assist engineers to identify certain faults and irregularities without the need for long observation and research.

Description

The boiler under discussion is designed for a total evaporation of 100,000 lb. per hour, with a working pressure of 200 lb. per square inch, and a final temperature of 500°F, with feed water at 200°F.

The drums are of fusion-welded structure throughout, steam drum being 5 feet diameter by $1\frac{1}{4}$ inches thick, and the mud drum 3 feet 9 inches diameter by 1 inch thick, both being 24 feet long. The vertical convection bank of tubes between the two drums are 3 inches outside diameter and fed by downcomer tubes on the outside of the boiler between the steam drum and the mud drum. This ensures that no reverse circulation shall take place within the boiler banks.

Supplementing the convection bank is a fully watercooled combustion chamber, 15 feet square by 30 feet high, giving a grate area of 225 square feet approximately. Situated in the first gas pass is the superheater, which is of the self-draining type. The tubes, 96 by $1\frac{1}{2}$ inch o.d., are expanded into the top of the steam drum and with two 6-inch radius bends, outside the boiler, pass down through the first gas pass to a header, underneath and outside the boiler proper.

You will all be familiar with the spreader-type stoker so no description will be given except that this boiler is fitted with four coal and four bagasse feeders, one of each type discharging into a common chute at one of the four distributors.

The electrical set-up was:

Each of the four banks consisting of distributor, coal and bagasse feeder, was on separate circuit to the others. No coal or bagasse feeder could be started without the corresponding distributor running first. With the distributor running either the coal or bagasse feeders could be started but not both.

The above electrical set-up was insisted on by the suppliers of both the boiler and the stoker so as to ensure that there was no mixing of the fuels. This was eventually altered so that coal and bagasse could both be simultaneously fed into the furnace.

Ash disposal is by a continuous discharge chain grate. Its surface is made up of a large number of keys, designed with air spaces and deep ribs to provide cooling. Rows of keys are overlapped to prevent fuel and ash from falling through the grate. Speed of grate travel is by a constant speed motor with a variable speed transmission. The windbox under the grate is in three compartments, rear, centre and front, each having a separate damper. The installation of the boiler coincided with the erection of a second milling tandem, rather remote from the first, so the conveying of bagasse presented a problem. Also the only place available for the boiler was not in line with the bank of existing boilers. The method adopted was:

All existing scraper-type bagasse conveyors from the original tandem to the old boilers were left as before, and surplus discharged onto an inclined 36-inch belt conveyor running to the top feeder platform of the new boiler.

Bagasse from the new second tandem was elevated up, then discharged on to the inclined 36-inch belt about half-way up. This meant that this bagasse was not available to the old boilers.

A double-decked carrier on top of the new boiler scraped the bagasse across the front of the boiler on the top deck, then back again on the bottom, filling the feeders, any surplus being scraped up onto the top deck again. Provision was made for spilling excessive accumulation of bagasse onto a 14-inch belt conveyor out to storage. This bagasse was not available again for the boilers.

The idea of the double-decked conveyor was to carry a surplus of bagasse so as to allow for fuel supply variations from the mills and also to give the boiler operators time to stop the bagasse feeders, before they went completely empty, and start the coal.

We might mention here that the only instruments deemed necessary for the running of the boiler were:

(a) Draught gauges for reading—
 (1) Combustion chamber draught.
 (2) I.D. fan draught.
 (3) F.D. fan pressure.
 (4) Secondary air pressure.
 (5) Windbox pressures.
 (6) First gas pass draught.
 (7) Before air heater draught.

(b) Steam flow meter (of the indicating and recording type).

(c) Steam pressure gauges on the drum and on the superheater outlet.

(d) Automatic water regulator and leveller.

(e) Two types of distance reading water level indicators to be read from the operating floor at the bottom of the boiler.

Commissioning of Boiler

In July 1955, the boiler was thoroughly warmed, then opened onto the range with coal as fuel.

As no draught gauges nor steam flow meter had arrived, little was known of the conditions existing as regards evaporation, etc. Of course, temporary manometers allowed us to roughly check draughts. It was generally agreed that the boiler appeared to be working alright so an attempt was made to burn bagasse only. At this stage the new second tandem had not been started, so the bagasse available was only the surplus from one tandem. This proved not enough, with the result that feeders would run empty, allowing the entry of excessive air, and the grate not a deep enough coverage to keep the fire alive.

On starting the coal feeders as the bagasse ran out we found that there was not enough heat and not enough time for the coal to ignite, so wood and oil had to be used to help the fire to burn. This irritating feature was overcome by keeping the coal feeders running all the time and only running bagasse feeders if there was enough bagasse.

A week after starting the boiler, the second tandem started and the steam flow and draught guages arrived and were erected. With enough bagasse for the boiler an attempt was made again to run on bagasse alone. The first peculiarity to manifest itself was the action of the steam flow meter which varied from approximately 60,000 lb. down to zero, then back again within a few minutes. The bagasse on the grate heaped up on certain places then disappeared again only to heap up again elsewhere. Altering the speed of the distributors did not help at all. On a grate area of 225 square feet this presents quite a build up of unburnt fuel, any estimate of the quantity being unreliable owing to the inability to see through the incoming fuel and flame. This build-up meant that for periods the fuel was not being burnt as quickly as it was being fed in, hence the drop off of the flow meter. Then, as the accumulated fuel dried out (average moisture content 55 per cent approximately), there was a sudden release of heat causing:

(i) A sudden increase of rate of flow of steam from the boiler.

(ii) Sudden changes in draught conditions, often as much as half-inch vacuum to quarter-inch pressure in the chamber. Coupled with this was a change of half-inch windbox pressure to a vacuum.

(iii) Rapid and alarming movement of the water level in the boiler. The water was actually disappearing out of sight both ways so an extra labour unit was positioned at the hand clack valve to try and help control. The action of the water level related to the fuel and steam flow was:

 (1) Build up of fuel, drop off of steam flow and increase of water level due to time lag of automatic water leveller.

 (2) Rapid burning of accumulated fuel, rise in rate of steam flow and firstly a rise in water level due to sudden decrease of density of water then a very sudden lowering of level as the water was evaporated.

The only yardstick to judge the boiler performance was the general range pressure and an average steam flow calculated from the integrating part of the meter, plus the appearance of the fire and of the smoke from the stack.

The rapid alteration in rate of steam flow caused the flow meter to give altogether wrong readings or it just refused to work at all. Evidence of mercury spillage in the instrument gave us the reason for the fault. For erection reasons the orifice plate of the flow meter had to be in such a position that it did not take into account the boiler auxiliaries. When these auxiliaries were started before the boiler itself, or when the boiler was on range but steam generation had fallen off, as explained above, then the old boilers supplied the steam to these auxiliaries, and there was a reverse flow through the meter, which caused the trouble. This fault occurred nearly daily at first and it was frustrating not knowing if the new boiler was the cause of low steam range pressure. Not knowing what the boiler was generating was, I think, synonymous with a blindfolded man driving a car. He knows he is moving, but how fast? By isolating the meter, after a shutdown and by the eventual steadying up of the boiler this trouble ceased to exist.

Another thing which interfered with the running of the boiler was the double-deck carrier. If the boy on duty left the excess door open too long, the boiler ran out of fuel, and if he delayed opening when too much bagasse was being carried around, the carrier choked and stopped.

As the full rating of this boiler represents approximately 50 per cent of our total steam generated by all boilers, it will be appreciated that breakdowns and failure to generate a steady supply of steam has a profound effect on the factory, causing a drop in pressure to the mill engines. This either slows them or stops them, and interrupts the supply of bagasse to all boilers. This compounding effect of low steam, interrupted fuel supply, then, still lower steam pressure means, above all, lower extraction and throughput, so it can be seen that at all costs a steady supply of steam is the first requisite of any sugar factory.

Now the starting of a new milling tandem must of necessity be very slow. Everything must be watched and the plant slowly speeded up and loaded. Irregular running was the order of the day at first, as each new labour unit learned his job, and erection and design faults showed up. Each stop meant irregular bagasse supply to the new boiler. This in turn dropped the steam pressure. The old tandem pulled up. No bagasse to the old boilers and so on. As the amount of bagasse storage at the old boilers was limited, it became necessary to keep the old mill going by decreasing the load. This had the effect of increasing the bagasse particle size and the moisture, both of which aggravated the conditions in the combustion chamber.

The theory of the spreader stoker is that the incoming fuel on being thrown through the hot gasses and flame dries out and the small particles burn in suspension and the heavier pieces fall to the grate. Now it follows that bigger pieces take longer to burn, especially when lying on the grate. Also if the moisture content varies, then the rate of burning varies. Thus milling conditions have an intimate reaction to what is happening in the boiler furnace.

With low steam the main feature of the shift engineer's log book, it was felt that the new boiler, still showing 60,000 lb. to zero was definitely not pulling its weight.

Now at this point it might be mentioned that the controls of the boiler in the hands of a semi-skilled man, consisted of:

(1) Induced draught fan speed and damper. (Note: All fans are turbine driven.)
(2) Forced draught speed, and main damper.
(3) Windbox dampers, one to each of the three compartments.
(4) Secondary air damper.
(5) Coal feeder speed control.
(6) Bagasse feeder speed control.
(7) Distributor speed control.
(8) Grate speed control.
(9) Surplus bagasse door.
(10) Air heater byepass damper.
(11) Manually operated feed water valve.

All of these controls have an effect on output, efficiency and safety of the boiler, stoker and grate. But what was the correct combination of the controls ? No mathematician was necessary to give the total number of combinations and still obtain the same amount of steam from the boiler. For example, a drop-off in steam due to low efficiency was overcome simply by speeding up only the feeders and altering nothing else.

The damper positions were, I think, the most puzzling feature of the boiler. Alterations made seemed to have little or no effect on the output, and any movement that did, did not show immediately. The speed of the grate was set at about half speed, to give a fair thickness of ash, so any alterations made to dampers, coal and bagasse feeders distributors and grate speed, did not show up for, sometimes, six hours, i.e. time taken for the grate to travel from back to front.

Speeding up of the fans and bagasse feeders to their maximum did not give us all the steam we wanted, so, as bagasse was required for paper-making we decided to augment the fuel by adding coal. As the feeders were interlocked the only method was by switching off one bagasse feeder at a time, and starting the interlocked coal feeder. Each pair was done in rotation to try and keep a constant coverage on the grate. Immediately we started doing this an improvement in steam was felt, the flow going up to 100,000, and not dropping back to zero every time but fluctuating between 30,000 and 100,000. The variations on the meter were not as rapid as before but the water level and the combustion chamber pressure varied more. At frequent intervals, sometimes days apart, there would be what can only be called an explosion in the chamber. The balanced draught gauge would quite suddenly move off .2-inch draught to the maximum of 1-inch draught, hold it for a few seconds then suddenly swing over to 1 inch pressure. Smoke and flame would belch out of the distributors, then, within seconds, all would be as before.

As there was slight variation in the quality, or should we say the burning characteristics of the bagasse when it reached the boiler, there was corresponding variation in the combustion chamber pressure. The operator's main job was to try and hold .15-inch to .2-inch by operating the F.D. and I.D. dampers. You will all appreciate that this figure can be obtained with the F.D. damper fully closed or fully open. It was rather difficult to teach the operator just which way to move the dampers, but by our increasing the evaporation to near the maximum, the induced draught fan had to be speeded up to its full speed.

This meant the damper was also full open, and the operator only had the main and windbox force draught controls to worry about. Familiarity breeds contempt, so as time went on, the operators paid less and less attention to the fluctuation in the chamber. They got to know that even if the .2-inch draught changed to a pressure they had only to wait a while, and it would return to normal. This delay was the main reason why the chain grate started to give trouble.

After about four months of operation the grate keys started to get a weathered appearance. This progressively got worse until every week-end holes about a foot in diameter were found in the grate. This worrying feature caused a lot of sleepless nights, when all sorts of theories and explanations were thought up, tried out the next day, and proved of no avail.

We found the answer one night by taking a walk round the boiler at a time when all honest men should be asleep. The operator was waiting for the draught to return to normal, but by the time this happened the front of the stoker had warmed up considerably. Instead of the usual dead ash, there was a molten stream cascading into the hoppers, and the keys of the grate were red hot. Severe reprimanding cured the trouble for a little while, but human nature being what it is, holes again started forming.

The only sure cure will be a mechanically-operated induced-draught damper following intimately the variations in the combustion chamber and at all times holding .15-inch draught.

The grate through being constantly burnt finally broke, which in itself was not too big a mishap, but unfortunately the shear key had been inserted wrongly. So instead of only shearing a $\frac{3}{8}$-inch pin when the grate jammed, a 1-inch square had to go. Of course, the resistance offered by the 1-inch square was so much that before it sheared much damage was done to the grate and supporting steelwork.

An examination of the boiler after about four months' running showed that internally it was clean and free of scale, and generally in good order. Only the side-wall tubes of the combustion chamber were starting to distort, giving the impression of lack of freedom of expansion.

Shortly after this distortion was first noticed, one of the side-wall tubes burst. This happened one Sunday night, two hours after the boiler was on full load. No harm came to anyone and the only other damage was a general deterioration of the distortions of the other side-wall tubes. The tube burst into two, about four feet up from the grate. Sections cut at varying distances from the break showed a distinct thinness on the one side which could only be a fault in manufacturing. The swelling which took place prior to bursting showed no overheating, so the reason for the break remains obscure. Possibly it could have been a waterhammer caused by a very low water level stopping circulation.

Although fitted with a grit-collector, the induced draught fan blades after a short time showed considerable erosion and at about five months the runner collapsed. A new runner fitted was tried with aluminium tips but was not a success. It is felt that manufacturers, as yet, do not realize the abrasiveness of fine bagasse ash dust on high-tip-speed fans. The fan in this case was probably running faster than was thought necessary owing to the high bagasse moisture.

Water feed treatment plans for the boiler were under way but unfortunately the troubles associated with new milling tandems and expansion programmes left us without any means of clarifying the water when the river came down in spate. We tried to use all make-up on the old boilers but at certain periods the muddy water had to be used in the bent tube. Frequent tests for solids were made and the boiler often blown down; nevertheless at times the solids went up to about 300 p.p.m., which at the temperature and pressure was not excessive.

Unfortunately the method of taking water tests did not account for all the mud and insoluble solids, which as often as not, cake immediately in tubes and drum and do not show up in tests. An interesting example of this will be given later.

Sugar leaking into the return condensate suddenly released the build-up of mud and scale, and we were once again in trouble. Firstly priming took place, and as the priming diminished so the two pressure gauges on the boiler started to read differently, the drum pressure being slightly higher than the superheater pressure, but not enough to effect anything other than cause worry. The first real effect of the mud came when the induced draught fan turbine slowed up, the steam output dropped, and one mill had to be stopped. We stripped the turbine and found the blades choked with mud, which was removed with great difficulty. This happened twice in twenty-four hours and on the second occasion a labourer showed us how easy it was to wash the blading clean. So when assembling again we connected the boiler feed line with the steam supply to all the auxiliary turbines, and also fitted thermometer pockets. When any of the turbines slowed up afterwards, which they all did, we simply opened the water for a few minutes, watching the temperature carefully, and invariably they picked up again to normal speed.

While the auxiliaries were giving trouble the pressure difference between drum and superheater increased until with the drum blowing off at 200 lb. per square inch, there was only fifty in the main steam range. This could mean only one thing, that the superheater was choked.

The scale inside the tubes can only be described as fired clay, as hard as a brick, and in most cases completely blocking the tubes. Fortunately this severe scaling was only for a distance of six feet near the top of the tubes where the hot gasses leave the combustion chamber. In case there was a repetition of blocked tubes, flanged bends were made and fitted during the next shutdown period, in place of the welded bends. The overheating of the tubes when they were full of scale resulted in many developing leaks as the season progressed.

On the first occasion we had to repair leaking superheater tubes, we were shocked to find, lying in the bottom of the first pass, a fourteen-inch length of one of the main bank of convection tubes. It had been burnt out of the middle of a tube, and the tube had not leaked. Mud had solidified in the whole length of the tube and had withstood full boiler pressure. The cause of only this tube choking was that the mud had built up on a piece of firebrick which had somehow found its way into the tubes. This firebrick was found in the burnt-off piece.

The replacement of the superheater tubes, with bigger bends on the bottom end, was done at the end of the first year's run, and since then no more trouble with scaling or cleaning has been experienced.

We also replaced the combustion chamber sidewall tubes, and since then there has been no further distortion. Steadiness in steaming may account for this.

At this time we started to treat and filter the make-up water through a sand bed. We also started to use the condensate from all the vessels of our quadruple effect evaporator, and we evolved a double hot well designed to give the bent tube boiler preferential condensate, with all make-up going to the old boilers.

When starting the boiler for the second year we took certain steps which we felt would ensure more steady steaming and would possibly eliminate any more damage to the boiler.

These were:

(1) Removed electrical interlocks from the coal and bagasse feeders so that they could both be run simultaneously.

(2) Removed speed control levers from the bagasse feeders, so that the operators could not alter the speeds.

(3) Altered the fan dampers to make them more central and controlable.

(4) Locked the three windbox dampers in fixed positions.

(5) Installed a new 36-inch belt conveyor from the double-deck carrier on the new boiler back to the old boilers. This set-up meant that bagasse from both tandems could be used in any boiler and that all bagasse had to pass the new boiler first. By not scraping up on to the top deck of the double-deck carrier we eliminated one weakness. By the extra length of the conveyors we increased the "no bagasse" time lag, and we ensured that the boiler most sensitive to fuel supply had first call.

Starting the boilers again for the second year we fed only coal and managed to get very steady steaming at about 30,000 lb., which was all we required with no mills running. When one mill started we increased the coal but fed no bagasse until the steam rate was 60,000 lb. When the second tandem started we started the bagasse feeders as well and from dead slow we speeded them up until we had about 80,000 lb. output. By simultaneously speeding up the bagasse and slowing down the coal we maintained the output. The boiler remained steady with no fluctuations in water level at all and only slight movement of the steam meter. Eventually the coal feeders were running dead slow and the bagasse feeders about three-quarters full speed. It was necessary to burn coal in order to provide bagasse for paper-making, so we never had to run the boiler on bagasse alone. In fact we had to speed up the coal again to give us the excess bagasse required.

The boiler continued to run throughout the season in the same steady manner and there was nothing to suggest any trouble at all, except perhaps the appearance of the superheater at the same place where it originally choked. An examination at a weekend showed no signs of overheating, but when the boiler was on load the superheater was in the flame coming out of the combustion chamber, and appeared to be very hot.

The boiler was also as before not sensitive to the dampers, so with the idea of finding out just what effect each damper had on the running and efficiency of the boiler, we approached the S.M.R.I. and asked for a loan of a CO_2 recorder.

This they kindly did, and when first installed gave a reading of 5 per cent. By sealing air leaks and altering damper positions we eventually obtained 14.5 per cent CO_2 and ½ per cent CO. While this experimenting with dampers was going on we found four things happening:

(1) It was necessary to decrease the amount of coal being burnt quite appreciably.

(2) The flame surrounding the superheater in the first pass moved back into the combustion chamber.

(3) The amount of grit from the separator decreased tremendously.

(4) Most important of all, slight damper movement showed immediate reaction, and we at long last felt we had the boiler under our complete control.

One thing happened during the second year of running which I am sure will interest and possibly puzzle you all. On opening up the mud drum one Sunday we found in heaps between each blow-down outlet large numbers of hard black balls, varying in size from about ⅛-inch to 1½-inches diameter. These balls had, when broken open, cores consisting of small pieces of welding slag and they appeared to consist of pure carbon. Smut from the chimney finding its way into the make-up tanks and hot wells was most probably the source of the carbon. Altogether there was about a hundred-weight of these perfect balls but the frequent water testing did not give us any idea that this could be taking place.

One other thing that happened to the boiler which may interest you all, was the development of leaks in the clinker chill tubes. These tubes run horizontally a few inches above the grate and have a strip of flat iron 1-inch by 3/16-inch spot-welded every 3 inches on the top and bottom for the complete length of the tube where it passes through the combustion chamber. With the intense heat the flat iron burned away between the welds but the pieces adjacent to the welds remained intact. These pieces then started to curl-up and in some cases actually pulled the welding out of the tube and caused the leaking. Apparently fins welded on in a position of intense heat should not be spot-welded but welded all the way.

I sincerely hope that sufficient interest has been raised to encourage a lively discussion and that other experiences of the same type will also be discussed for our mutual benefit.

The President thanked Mr. Fortheringham and said this was a most interesting paper which should raise a lot of points for discussion. Things such as the spot-welding of the clinker cooling tubes, the accumulation of black balls in the boiler are minor points but they are interesting and should raise some discussion.

Mr. G. E. Seymour said that Mr. Fotheringham's presentation of this paper was most courageous and something which would enable other people to avoid the mistakes which had been made. It was an example which should be followed in future.

Mr. W. H. Walsh echoed the sentiments expressed by Mr. Seymour and said this was the first time that a boiler of this nature had been used in conjunction with a spreader stoker, and neither the makers of the boiler or the stoker had had the experience of Mr. Fotheringham and he felt that his observations would be of much value to the makers.

Dr. Douwes Dekker recalled a certain Java experience. In that country feed water consisted of steam condensate and vapour condensate from the second, third, and if necessary, fourth vessel of the quad. The steam condensate usually contained oil which was often deposited on the heated surfaces of the boiler as an iron oxide-containing smear which caused over-heating and even deformation. By adding about two per cent of unfiltered river water to the mixture of steam and vapour condensates it was possible to prevent the oil from being deposited on the walls of the boiler. Instead small black balls were formed consisting of sand and mud particles originating from the unfiltered river water, lime salts, iron oxide, *and oil*. It seemed desirable to have the balls found at Felixton analysed in order to find if we had here to do with a similar phenomenon.

Commenting upon the use of the S.M.R.I. CO_2 recorder, he said that the low CO_2 figure found initially pointed to the necessity of installing at all mills reliable recording instruments.

Mr. Fotheringham said that he would like to be able to get a recorder where the recording part could be kept far away from the boilers, so that it could always work and be reliable.

Dr. Douwes Dekker said that in Java every factory had two or three CO/CO_2 recorders and they proved to be extremely useful and quite practical.

Mr. E. Camden-Smith said that the spreader stokers were first installed at Pongola and did not attempt to burn coal mixed with bagasse. However, many of their experiences were similar to those at Felixton. He asked Mr. Fotheringham when he mixed fuels if he did not find clinkers forming and blocking up the grate. He pointed out that at Pongola when bagasse alone was used no such trouble was experienced.

Mr. Fotheringham said that ash came out quite powdery and the only time he experienced any trouble was when the draught was not properly maintained.

Mr. D. J. Munro stated that at Umfolozi with a bent tube type of boiler he had also had trouble and he asked Mr. Fotheringham especially as he had no grit collector, etc., if Mr. Fotheringham could relate further the experience he had had by changing fans and type of blades.

Mr. Fotheringham said that he had had trouble with fans but he intended installing a larger fan with a different type blade.

Mr. Thumann asked how the pH varied when it was necessary to supply only condensate from the evaporators and condensed steam.

Mr. Fotheringham replied that by using this water the pH dropped considerably and a considerable amount of caustic had to be used.

Mr. Grant said that at Felixton they had no trouble with oil in the feed water so they came to the conclusion that as their hot wells were not covered this formation of balls was due to carbon smuts. He stated that they did not have any oil separators.

Mr. J. R. Gunn said that although steps were taken at Madistone to remove oil he still found these balls in the boilers. He said that those balls which had been tested consisted mostly of carbon but there was little possibility of smuts entering the boiler feed water.

Mr. A. D. Elysee said that at Amatikulu they found a large amount of ammonia present in the condensate from evaporators and he would like to ask engineers what the effect of this would be. He understood that this was detrimental and incidentally pH of the water to the boiler was about 8 pH.

Mr. H. Rohloff said he regarded Mr. Fotheringham's approach to the commissioning of the boiler as an empirical one which could be opposed by a theoretical method. In order to explain this, he wanted to select three prominent points from Mr. Fotheringham's paper:

(1) The author had said that it did not require a mathematician to work out the repercussions on the whole boiler by altering any one of the many variables. In fact, a mathematician would establish that the number of possibilities of boiler conditions with the quoted number of variables is enormous. This large number of possibilities can be appreciably reduced by making a few of the variables constant. One of them which could be was the control of the amount of combustion air, and another the control of furnace pressure.

(2) He did not know the type of boiler or the type of stoker, but, in any case, a fuel of a given calorific value must be burnt with a definite amount of air in order to get the optimum heat output. This fact cannot be disproved, but the ways and means of achieving the result may have to be varied to suit conditions. In order to enforce complete combustion, it is also necessary to

(3) stabilize the furnace pressure. A negative furnace pressure must be avoided, because it would cause atmospheric air to leak in which can neither be measured nor controlled. It was usual to maintain a very slight positive pressure in the combustion chamber. If these two factors, viz. the amount of combustion air and the furnace pressure were maintained at constant values, the commissioning of new and the operation of old boilers would be considerably facilitated.

Mr. Fotheringham said that engineers were only taught a theoretical approach to running a boiler but when one got down to actual practical working one found so many variables and deviations from theory so that one never had anything solid to work out anything on. The only way to control a boiler properly was by instrumentation.

Mr. Lindemann said in connection with these small balls, he had some sent to him which had been found in a steam trap. These from analysis were found to be welding slag with some carbon in their composition. In connection with the furnace it would appear that it was out of tune with the construction of the boiler itself. He pointed to the enormous heat loss due to the 55 per cent moisture in bagasse. He thought that this should be taken into consideration by the designers of the furnaces. He demonstrated on the blackboard the curve showing the relationship between percentage of carbon dioxide and air used. The use of chemicals in boiler feed and the composition of the boiler feed varies tremendously. He also found large differences on each side of the furnace of a stirling boiler.

Mr. W. H. Walsh pointed out that in a big expansion programme led to all kinds of troubles. If the boiler had been the only new piece of plant it could have been more easily dealt with. Manufacturers went into all possible points but they were adamant that not more than 52 per cent moisture in bagasse should be allowed, and they usually recommended that either coal or bagasse be used, but not the two together. He realised that it had to be done in this case but the conditions for coal and bagasse were quite different and the best conditions could not be obtained when using both.

Mr. H. Rohloff then demonstrated on the blackboard the theoretical aspect of the problem by means of a diagram: He said that a boiler is designed to produce a certain amount Q of steam at a certain pressure P. The product $Q \times P$ represents a definite amount of calories which can only be produced by burning an amount of fuel that yields these calories. The fuel quantity must be increased by a margin that is determined by an efficiency factor. It is logical to say, therefore, that the quantity of steam required in the factory at any one moment should govern the amount of fuel to be burnt. Any fuel conveying system could thus be controlled by the steam quantity at constant pressure.

From what was said before, the fuel quantity must, in turn, determine the amount of combustion air, and it should do this preferably by weight: For every pound of fuel, a given number of pounds of air must be available. Unfortunately, each fuel type required its own specific air volume, and Mr. Rohloff considered the attempt to burn two different fuels, such as coal and bagasse, in the same furnace as an interesting experiment which would, however, not produce satisfactory results.

Mr. J. P. N. Bentley congratulated Mr. Fotheringham on demonstrating that he could do practically which was theoretically impossible. He said that he had always been rather afraid of using condensate from the evaporators because of the possibility of entrainment and he would like to know if there was any entrainment at Felixton. He mentioned that there was an instrument which could automatically test the amount of sugar present in condensate so this could be diverted from the boiler if necessary. With boiler pressures now going up the subject of entrainment became more important. An instrument such as he had indicated was becoming increasingly necessary. He asked for details of the make-up water treatment, pointing out that filtration through sand would remove solids only.

Mr. Fotheringham said that now the water was pre-treated with aluminium sulphate and sodium aluminate to form a floc before passing through the sand bed.

Mr. C. Dent related that he had experienced in slug dosing caustic soda into the boilers, particles of the Apexior protective coating were removed, thus rendering these patches liable to electro-chemical or oxygen corrosion. This effect is particularly marked in the case of Sterling boilers.

He disagreed with Mr. Rohloff in so far as maintaining a positive combustion chamber pressure was concerned, for after considerable experimentation he had found that a suction of approximately 0.2 inches water gauge gave the best steaming conditions when burning bagasse. A positive pressure had the effect of the flame blowing back up the feed hopper.

Mr. G. G. Ashe pointed out that a mistake usually made was to watch the steam flow meter but this could give only the demand from the boiler and did not actually show how well the boiler was working. To use this steam flow meter without a CO_2 meter was wrong.

Mr. G. E. Seymour said with relation to Mr. Rohloff's theoretical consideration, bagasse was one of the most difficult of fuels to control and this rendered the spreader stoker also difficult to use as one required a steady fuel supply which it is impossible to get with bagasse. This type of control indicated by Mr. Rohloff was in operation at Amatikulu but had proved unsatisfactory when bagasse was being delivered intermittently.

Mr. Leclezio asked if there was any system used in this country to control draught automatically by varying the speed of the fan or the pitch of the blades and also what steps were taken to remove oil from condensates before using them as boiler feed.

Mr. Fotheringham replied that variable speed control of fans was not used.

Dr. Douwes Dekker said that oil could be separated from steam by steam separators, or from the condensates by filtration. The problem was, however, not very simple since to avoid trouble from the presence of oil in boilers it was necessary to reduce the oil content to a very low value. If 1 to 2 per cent river water was used, the Java factories did not find it necessary to reduce the oil content of feed water to less than 5 mg/l.

Mr. Gunn pointed out that variable speed fans were used at Tongaat but these were not automatic.

Mr. J. W. Main remarked that the control of oil in feed water had not received the attention in this country as it had in other parts of the world. He knew where very efficient oil separators were used especially in closed feed circuits. This subject required much more consideration in this country.

Mr. G. Nickson said that he thought that oil might have had an effect on the formation of the balls found in the boiler. The acidless tallow used in compounded cylinder can act as a bonding agent for carbon, silica and other impurities. Compounded cylinder oils have been used without causing trouble in boilers in a number of factories for many years, oil generally being removed by an overflow system in generously proportioned hot wells. The increased use of superheated steam has made the problem more difficult and four factories have installed exhaust steam oil separators of various types which are working satisfactorily. It has been found essential in some factories to use compounded cylinder oils, particularly where superheated steam is used in horizontal mill engines with "D" slide valves.

Mr. H. Rohloff said this in connection with slight pressure in combustion chambers: He pointed out that most furnaces were made of bricks which allowed a certain amount of air to penetrate if there was a negative pressure in the furnace. The statement that certain boilers work better with a negative pressure can be explained by the facts that

(1) not enough combustion air is supplied by the f.d. or i.d. fans; or

(2) the combustion air is not getting through the thick fuel beds, so that leak air is helping the air-starved sections in the furnace.