

# EXPERIENCE WITH AUTOMATIC BOILER CONTROLS

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Automatic control of steam boilers is not new, and many boilers of different kinds are being controlled automatically, but there are very few in the sugar industry.

The reasons are not hard to find—load fluctuations are high, the fuel is difficult to handle, to meter and to burn, and it is erratic in both quantity and quality. However, the increasing need to reduce manufacturing costs and eliminate expenses such as auxiliary fuel has made automation essential to maintain operating efficiency.

During 1965, it was decided at Umfolozi to purchase a turbine to give 6MW of power, and a boiler rated at 125,000lbs/hr at 450psig. The question arose of how to control the new boiler. We were not satisfied that any of the controls fitted to the older boilers would be suitable for the new boiler, so we started analysing what was installed and investigating where the weaknesses lay. The results were as follows:

## (1) Drum Level Control

The simplest controller is the self acting on/off type, that opens the feed water valve fully when the level drops to the lower set point, and shuts off when it reaches the upper set point. This is very robust and easy to maintain, but it places a very intermittent load on the feed water pumps, and causes the boiler to steam sporadically, especially if the feed water temperature is low.

A refinement of this type is the controller that opens the valve in proportion to the drop in level. We have two of these fitted. The sensing element is an inclined steel tube connected to the boiler drum above and below the waterline, and mounted at the water level. The expansion of the tube is affected by the water level in this tube and is linked to act on the water valve. The disadvantages are:

(1) The expansion of the tube is also affected by the pressure in the boiler, so a change in pressure can upset the level set point.

(2) A change in steaming rate has the effect of upsetting the setpoint, because the valve is opened in proportion to the drop in water level only. At higher steaming rates, the valve needs to be wider open to keep the same level.

(3) A change in feedwater pressure also upsets the set point as the quantity passing through the feedwater valve is no longer in relation to its opening.

We also have three controllers of this type to which has been added a compensation for steam flow. This is an improvement, but it is very difficult to get the mechanical linkages correct. This is a two term controller.

In the light of this we decided to install a three term controller. The steam flow is measured, as is the water flow, and these signals are balanced by altering the valve position accordingly. The drum level applies a further signal.

## (2) Steam Pressure Control—Fuel and Air Flow

We have three boilers fitted with a master steam pressure controller, hydraulically operated. The only adjustment on the controller is the pressure set point. This is coupled by linkages to the fuel feeder variable speed gearboxes, and also to the F.D. fan damper. The equipment is very robust and reliable, but unsuccessful, because:

(a) The feeder variable speed gearboxes do not run at the same speed each time the lever is brought back to the same position. There is always some variation.

(b) The air flow through the F.D. fan is not directly proportional to the damper position, whereas the fuel flow is roughly proportional to damper position, so it is possible to obtain a correct air-fuel ratio for one position of the linkage only. Also, the bed of fuel on the grate has a varying resistance to air flow, altering the delivery pressure from the F.D. fan and hence the flow.

(c) Hunting takes place, and there is no means of stopping it.

(d) The pressure set point is offset by the steaming rate.

We decided therefore:

(a) It is necessary to measure the air flow into the combustion chamber.

(b) It is necessary to measure the feeder speeds, to compare with the desired value.

(c) The steam pressure controller must have proportional, integral and derivative action.

## (3) Flue Gas Analysis

Several years ago a complete set of CO<sub>2</sub> analysers was purchased and installed in the boilerhouse. Successive generations of engineers and instrument mechanics attempted to maintain these in working order, but eventually the conclusion was reached that the moisture content of the flue gas was too

high for these instruments. One oxygen analyser, working on the paramagnetic property of oxygen, was installed and proved very successful. Since then several more have been installed.

It was also decided to attempt, on the new installation, to correct the fuel air ratio automatically from the  $O_2$  content of the flue gas.

#### (4) Furnace Pressure Control

All the older Combustion Engineering boilers are fitted with a hydraulically operated furnace pressure control, acting on the I.D. fan damper. These have operated very successfully.

#### Choice of Instruments for the New Boiler

It now had to be decided what type of instruments to install. The only range of hydraulically operated instruments available could not offer the type of control we wanted, so the choice was between (a) electronic with pneumatic actuators, (b) electronic with electric actuators and (c) pneumatic.

The electronic instruments with pneumatic actuators seemed to combine the worst of both fields. The electric actuators have a "Hold on Failure" feature which is essential for boiler operation, but most instrument mechanics hold up their hands in horror at the sight of an electronic circuit. We have always been plagued by wet and oily air in our pneumatic controllers, so included with the pneumatic scheme would have to be an instrument air scrubbing and drying plant.

It was eventually decided to install a fully electronic scheme with electric actuators. The cost was considerably higher than the pneumatic, but the advantages were:

- (a) Standardised controllers with plug-up units facilitate maintenance and save downtime.
- (b) Because of the standardised measuring signals, it is possible to reconnect from one control loop to another.
- (c) Fault finding appeared to be easier in the electric and electronic circuits.
- (d) Calibration is easier and remains stable.

#### No. 10 Boiler Control Scheme

This panel automatically controls the desired ratio of bagasse and coal. The air flow may be controlled as (a) air flow-fuel flow, (b) air flow-steam flow, (c) air flow-steam flow with automatic correction for flue gas oxygen content, (d) air flow-fuel flow with oxygen correction, (e) a combination of (a) and (b) with or without oxygen correction. The feed water flow may be controlled as (i) drum level only or (ii) drum level with the anticipatory signal of steam flow balanced against water flow.

Referring to Fig 1; steam pressure is transduced to a 0-10V DC signal in pressure transducer 1010, and is fed into the pressure controller 1020. This is

a PID (proportional, integral, and derivative) controller and provides the pressure set point. The output from this controller is the demand signal.

This demand signal is split up in the ratio desired between coal and bagasse, and fed into the bagasse controller 1051 and the coal controller 1052. These controllers are in cascade, as the setpoint is dictated by the pressure controller. Each controller sends a signal to the respective actuators 1071 and 1072, connected to the feeder variable speed gearboxes, the balancing signal back to the controller coming from the tachometers 1061 and 1062 on the feeders themselves.

The air flow controller 2050 is also in cascade, the command signal being derived from either the summated fuel flow or from the steam flow transducer, or partially from each, or from the demand signal. This signal can be modified by the  $O_2$  correction controller circuit (not shown). The demand signal from this controller controls the actuator 2070 on the forced draught fan damper, and is satisfied by the signal from the air flow transducer 2060.

The drum level transducer 3010 feeds a signal to the drum level controller 3050. The signal is increased or decreased by the difference in the water flow and steam flow signals, and controls the opening of the feed water control valve 3070.

The furnace pressure control is a simple loop consisting of the furnace pressure transducer 4010, the furnace pressure controller 4050 and the induced draught fan damper actuator 4070.

#### Operating Experience

After one season's operating, we are very enthusiastic about the results obtained with this control. The boiler has a very low thermal inertia, and when burning bagasse there is virtually no fire on the grate at all—combustion takes place in suspension. The result is that the response of the boiler to change in fuel rate is less than 30 seconds. If the fuel is cut off while steaming at 80% capacity, the pressure drops from 425psig to 325psig in 4 minutes. It is therefore very difficult to control the steam pressure manually, as illustrated by the steam flow and pressure charts in Figs. 2 and 3. Trouble arises if there is any interruption of the fuel supply, as the boiler partially loses combustion, causing small furnace explosions when the fire takes again. We have installed alarms to detect shortage of bagasse in the chutes. The operator then has to add a very small quantity of coal to restore combustion on the grate. Only two of each set of six feeders are fitted with tachometers, these two being assumed to represent the average of the rest. This is false economy, as it is very difficult to get these feeders running at the same speed. Individual tachometers will be fitted at a later date.

Various combinations were tried to control the air flow, but the most satisfactory was found to be air flow following steam flow in a fixed ratio. This

has the effect of increasing or decreasing the combustion to follow short term fluctuation in the steam demand. The oxygen analyser worked satisfactorily, but the air correction controller was found to be rather superfluous, and did not operate satisfactorily.

The signal from the drum level transducer had to be decreased relative to the steam flow/water flow difference, but its proportional band was made very small. The water level remained unbelievably constant (Fig. 4).

Several faults occurred on the instrumentation side of the panel in the first few months, most of them being broken leads within the transistorised circuits. They were all located without difficulty.

#### **Future Plans**

Now that the H.P. boiler is being satisfactorily controlled, the next step is to control the L.P. boilers. As there are normally five boilers on the L.P. range, the system inertia is very much greater. Two or three boilers will be used as base load boilers, and the control will be done on the three C.E. watertube boilers. These all have variable speed bagasse feeders. No allowance will be made for coal.

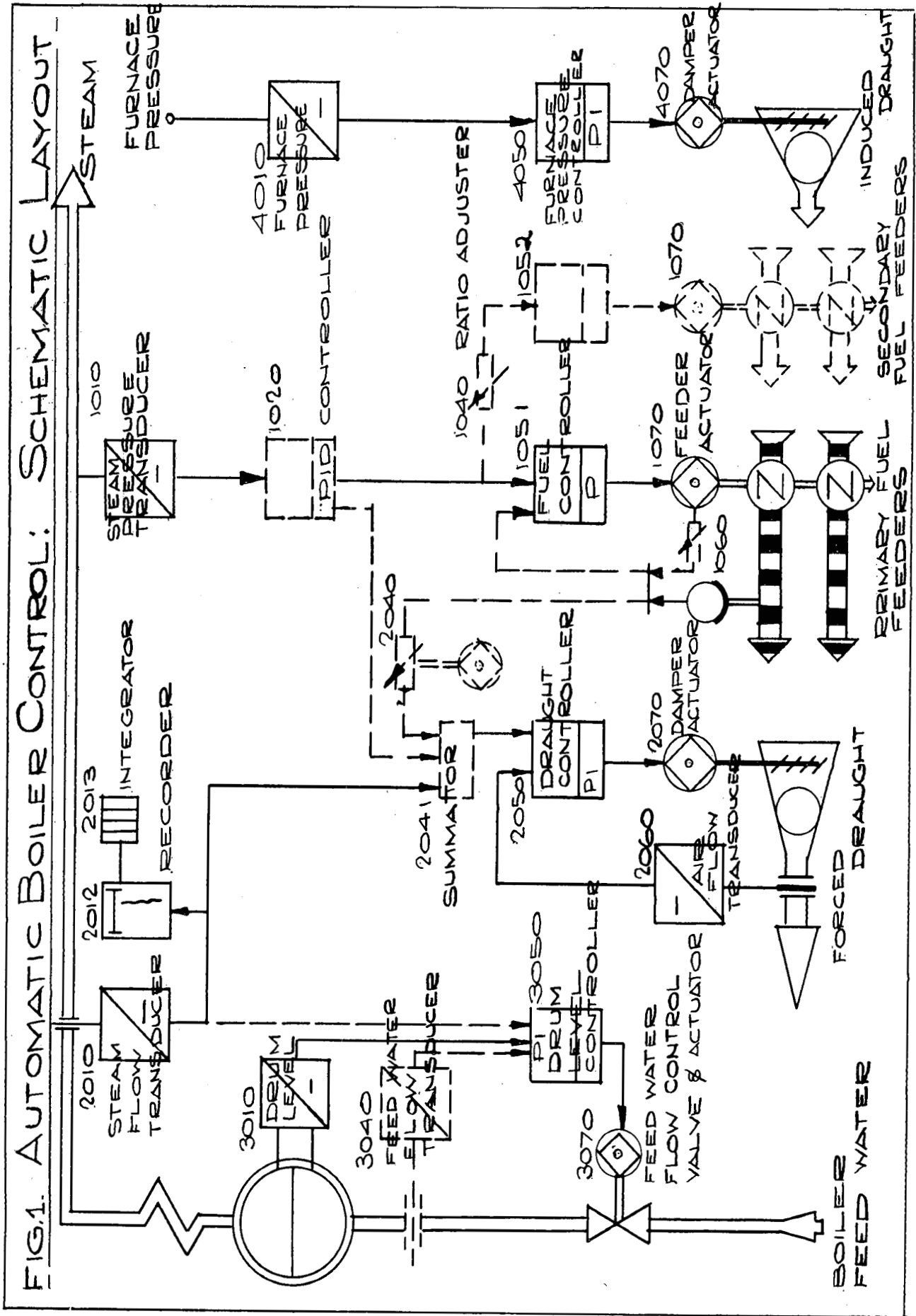
To ensure that the boilers share the load proportionately, a steam pressure transducer will be connected to the range to feed the master pressure controller. The demand signal from the pressure controller will be split six ways, two for each boiler. One will be the demand signal for the fuel controller, and one for the air controller. Tachometers connected in series on the fuel feeders supply the feedback signal for the fuel controller, and the air flow transducer on the F.D. fan the feedback for the air signal.

#### **Summary**

Transistorised electronic controls have become an extremely useful addition to the instruments available. While they may be classed as an extravagance in the simpler controls, their versatility and ease of maintenance more than justifies the higher initial cost for involved instrument schemes.

#### **Acknowledgement**

Thanks are due to A. Keller and Co for assistance in supplying information used in the preparation of this paper.



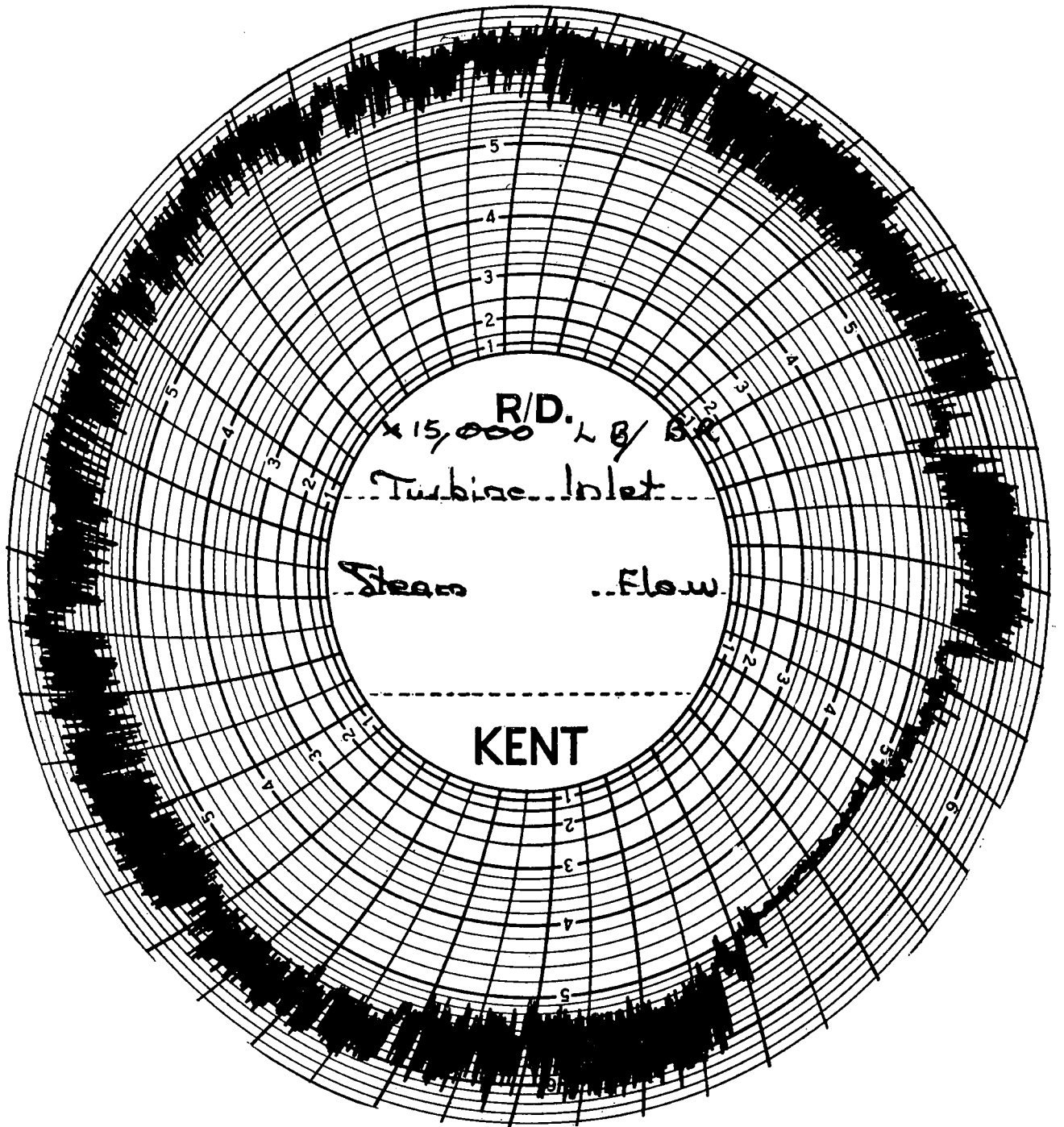


FIGURE 2

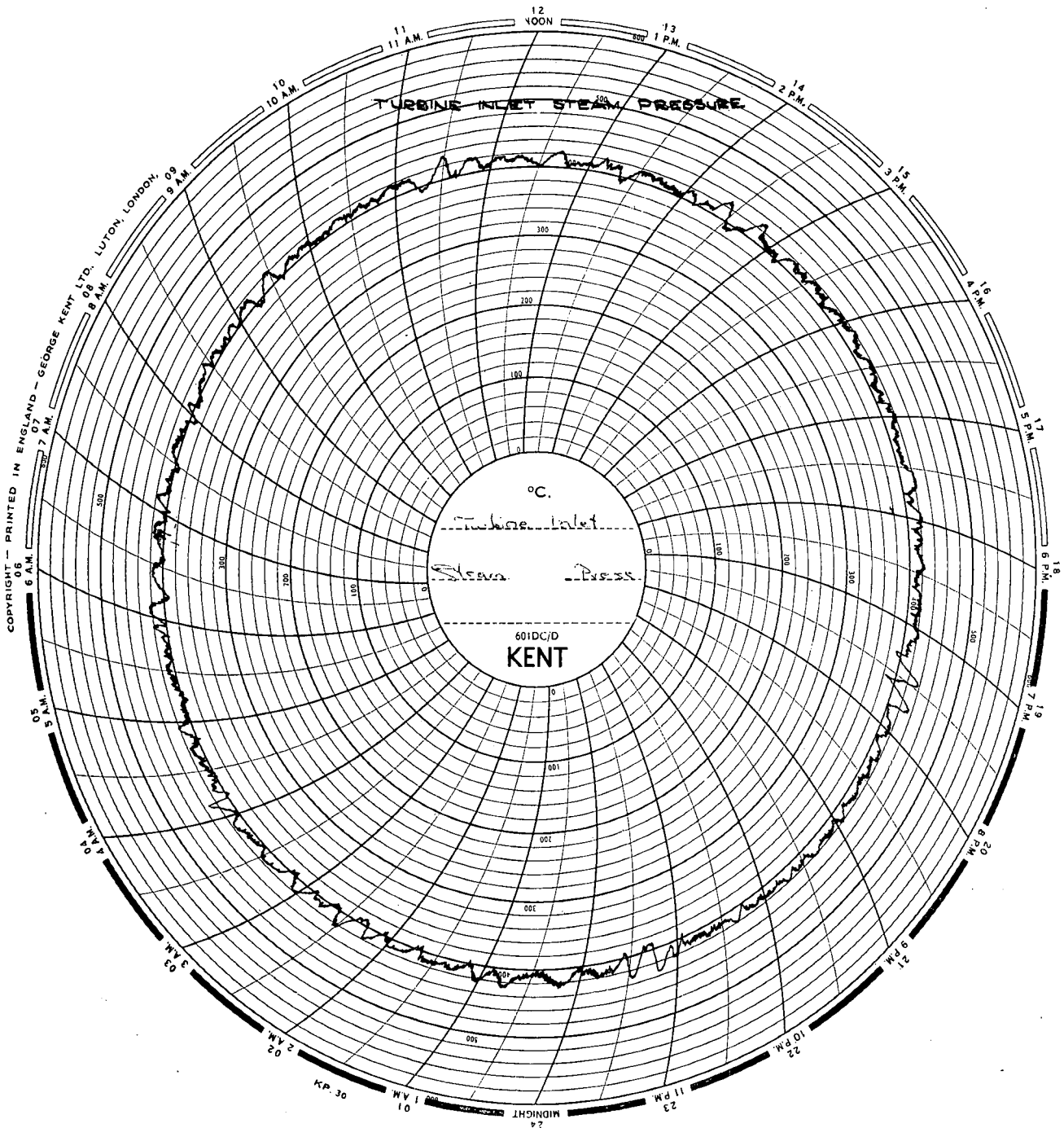


FIGURE 3

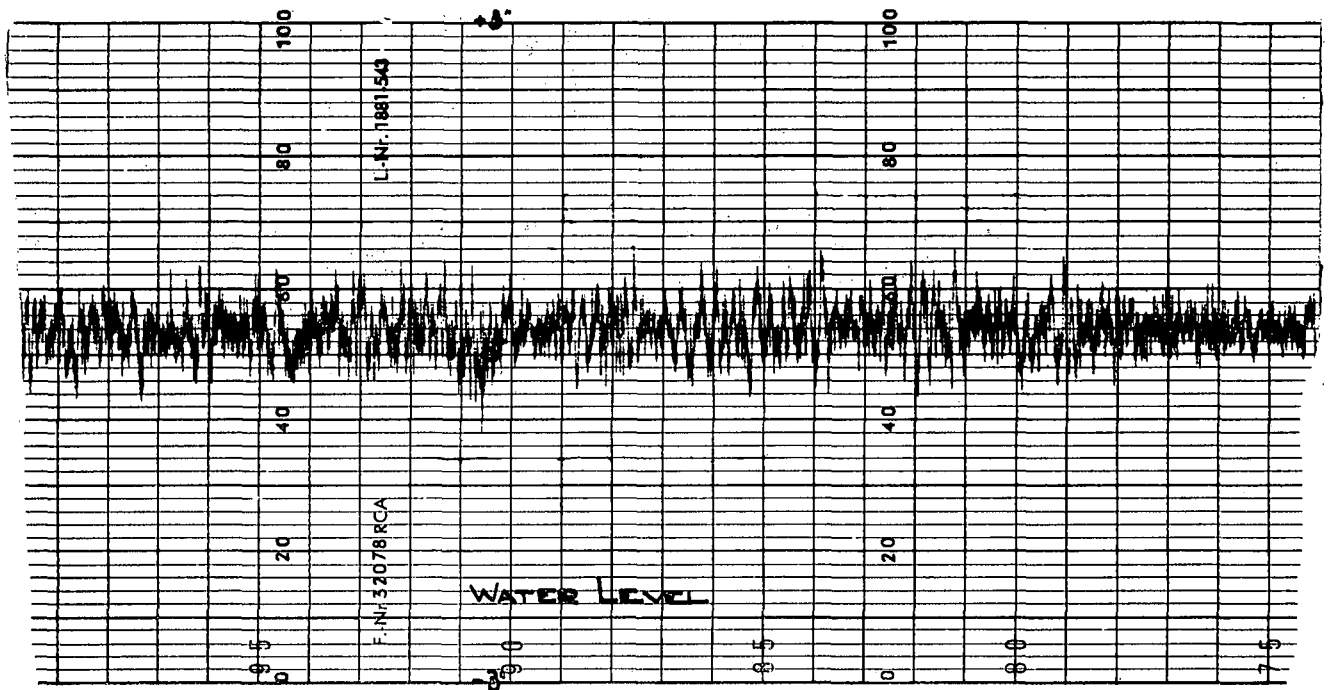


FIGURE 4

### Discussion

**Mr. Allan:** How do you measure air flow on the F.D. fan?

**Mr. Hurter:** Normally there would be an orifice in the duct. Instead of this we measure the pressure drop across the air heater.

**Mr. Main:** Can you control the dew point in your flue gas supply?

**Mr. Hurter:** There is no control in the circuit but it would be possible by by-passing the air heater. However, we do measure the O<sub>2</sub> content, which is more positive than the CO<sub>2</sub> content to keep steady flue gas conditions.

**Dr. Douwes Dekker:** Umfolozi is trying for maximum efficiency from the boilers, which means they are trying to reduce heat losses as much as possible, one of the most serious being incomplete combustion whereby CO is produced instead of CO<sub>2</sub>.

CO must therefore be measured to check this. The heat of combustion difference between CO and CO<sub>2</sub> is large and it is not possible to determine how incomplete the combustion is merely by measuring O<sub>2</sub>. I see you have had trouble with CO<sub>2</sub> analysers so may I suggest you let a chemist work on them.

**Mr. Holton:** I understand the small heating unit in the recorder is affected by hydrogen and deteriorates very quickly. The big power stations now have oxygen meters in conjunction with their automatic controls.

**Dr. Douwes Dekker:** The trouble occurs if you are burning coal which contains sulphur but bagasse has no sulphur. To measure exactly how the fire is burning CO and CO<sub>2</sub> must be measured.

**Mr. Hurter:** CO certainly is very important in combustion but with a boiler always burning approximately the same fuel and with approximately the

same load, if you compare the CO and O<sub>2</sub> content of the flue gas you will find they are remarkably constant. Once the desired flue gas analysis has been achieved one should not be worried about formation of CO.

**Mr. Bruijn:** I think there is some confusion. Dr Douwes Dekker is referring to the Mono Recorder, which is chemical, and Mr. Hurter to an electrical bridge.

**Mr. Ashe:** When we were using the CO<sub>2</sub> recorder we were using a lot of coal and that caused the deterioration of the analysers.

**Mr. Main:** The variation between coal and bagasse being burnt might also have affected the recorders.

**Mr. Hurter:** On one leg of the recorder a sample of flue gas was drawn through and air through the other leg. The CO<sub>2</sub> content was given in terms of thermal conductivity of these two gases. The first complication was pumping the same amount of gas through each leg and then the flue gas inside the measuring cell condensed and formed a corrosive liquid.

**Mr. Renton:** We have a boiler at Darnall similar to Umfolozi's and it has a fairly simple pneumatic control which works quite well. The pneumatic control cost us about R6,000, so what did Mr. Hurter's more elaborate system cost?

**Mr. Hurter:** It cost about double that figure. We are also going to apply the system to our low pressure station, which will not need such precise control, and it will cost about R11,000 for two boilers.

**Mr. Connor:** A pneumatic master controller can also be used, and in fact power stations use up to twelve boilers with one controller. They work on the 3 - 15 p.s.i. signal and are interchangeable.