AUTOMATIC CONTROL OF BOILER PLANT IN THE CANE SUGAR INDUSTRY

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in co-operation with Noodsberg Sugar Co. Ltd.

1.00 Cane Sugar Factory Operating Conditions

Boiler plant in the cane sugar industry is required to operate at constant pressure. The load is normally made up of:

(1) An electrical power generation load.
(2) A cane preparation and milling load.
(3) A process load.

While the total load is reasonably steady, large load swings, mainly due to erratic milling, can occur. Fig. 1 shows a typical total steam flow chart. This was taken from the new Sucoma factory in Malawi where one 66,000 p.p.h. boiler supplies the total factory requirement.

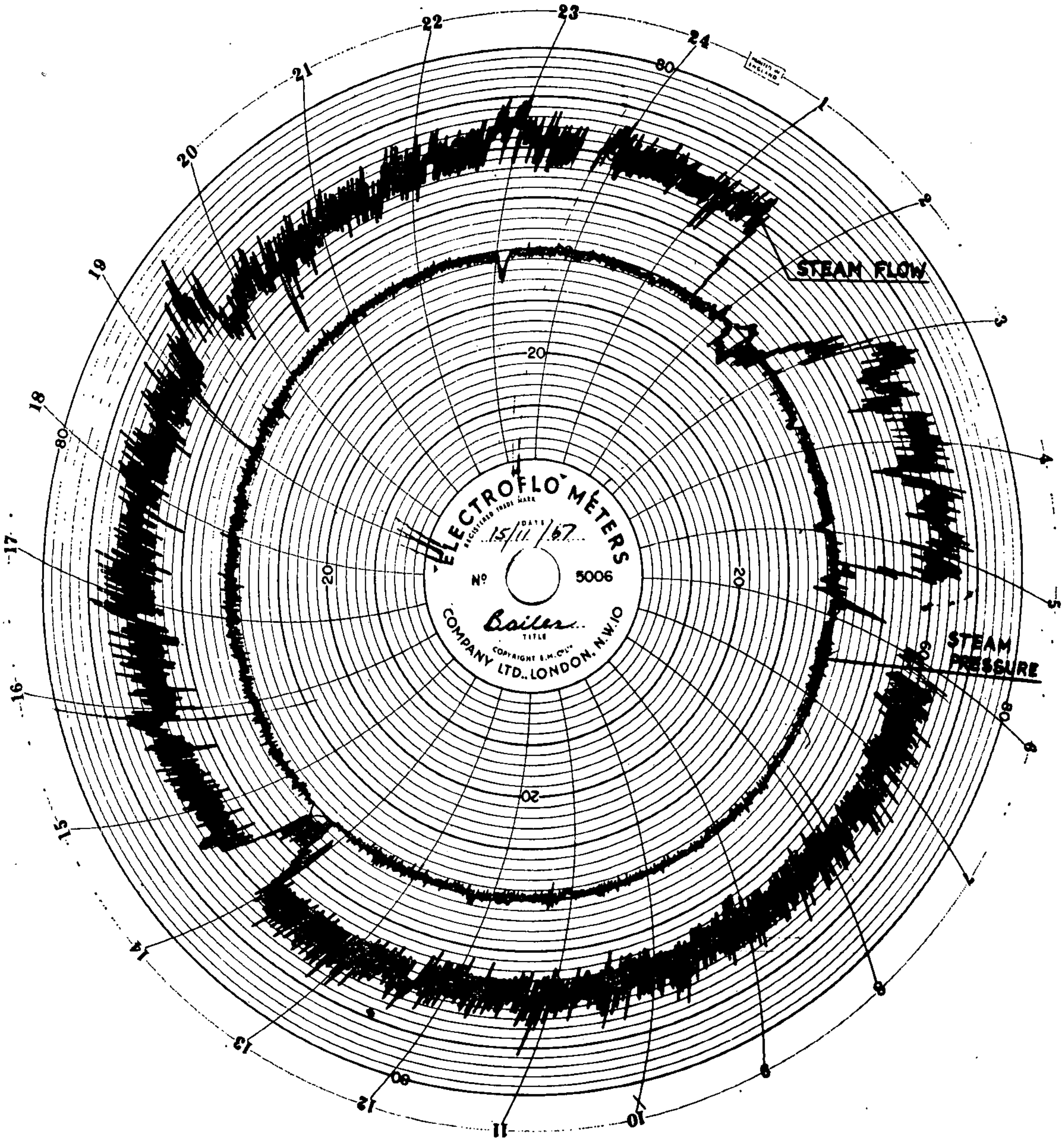

FIGURE 1: Steam flow/Pressure chart, Sucoma, Malawi. This chart illustrates the type of total load normally imposed on boiler plant in the cane sugar industry. The boiler is a 66,000 p.p.h. unit fitted with self-feeding furnaces, single element "Copes" feedwater regulator and a master steam pressure controller coupled to the F.D. fan damper. While furnace pressure controls are fitted these were not operating on the day the chart was recorded.

2.00 Boiler Plant Operating Parameters

2.1 Firing Response Rate

If a fuel is "ready to burn" the rate at which combustion takes place is a function of the amount of air supplied to it. A fuel is defined as "ready to burn" when a change in the quantity of air supplied will effect an immediate change, measured in practical boiler terms, of the combustion process. An incandescent coke bed spread uniformly over a grate through which an evenly distributed supply of air is able to pass would be classed as "ready to burn".

Before bagasse can be classed as "ready to burn" it has to be dried and the volatile distillation process started. In hearth-type furnaces where large quantities of fuel are stored in the furnace (measured in minutes equivalent steaming capacity) sufficient fuel is available in the "ready to burn" state to enable an almost instantaneous combustion response rate to be achieved. In suspension-fired boilers where only a very small quantity of fuel is stored in the furnace (measured in fractions of a minute equivalent steaming capacity), a large increase in load would require a relatively large proportion of "green" fuel to be introduced into the furnace. This would have to be conditioned before the combustion rate were increased which would tend to suppress the firing response rate. Control circuits can be designed to cater for this condition but have to be far more sophisticated than the control circuits associated with hearth-type furnaces.

2.2 Feedwater Control

In a boiler having no water storage capacity operating at constant steam output and firing rate a change in feed flow rate would result in an immediate change in operating pressure. A 10% change in feed flow rate would require approximately a 2% change in combustion rate. This change is well within the capacity of most boilers.

As the water capacity of a boiler is increased the effect of irregular feed flow is dampened. Most boilers in the industry have a water content equivalent to about 50% of their hourly maximum evaporative capacity.

Where two or more boilers are operating in parallel off a common feed range irregular feeding can induce violent load swings from one boiler to the other (see Fig. 2). This characteristic is far more important than small irregularities in feed water control.

2.3 Boiler Thermal Inertia

The effect of thermal inertia or total water equivalent of boilers installed in the cane sugar industry can be gauged by reference to Fig. 3, which shows the time taken to re-establish design pressure conditions from 200 p.s.i.g. at Noodsberg for varying excess firing rates. Most boilers in the industry have similar thermal inertia characteristics and will hence behave in a similar manner. (See Table 9.1—ref. 2.)

3.00 Control of Operating Parameters

3.1 Firing Response Rate

In common with all automatic control equipment combustion controls will only function satisfactorily if the combustion equipment is capable of satisfactory manual operation. To obtain good automatic control combustion equipment and combustion chambers must be carefully designed. The three basic control variables are:

3.11 Air Quantity

The heat output for constant air/fuel ratio conditions is directly proportional to the quantity of air taking part in the combustion reaction. A change in the heat input to heat output ratio manifests itself as a change in boiler operating pressure. By measuring this change in pressure a proportional control signal can be generated which can be made to vary the quantity of air supplied to the furnace. Provided that there is sufficient "ready to burn" fuel in the furnace boiler pressure can be maintained therefore at a constant predetermined level.

3.12 Fuel Quantity

The quantity of fuel being introduced into the furnace must be equal to the quantity which is being burnt at any one instant. In boilers fitted with self-feeding furnaces such as those installed at Noodsberg the geometry of the combustion chamber equipment controls the fuel flow automatically. Where boilers are fitted with suspension firing equipment a fuel metering device is required. These are normally volumetrically characterised and since heat input is a function of the weight of fuel being burnt per unit time, a change in fuel density will affect their characteristics.

In order to avoid a build-up of fuel on the stoker mat which would adversely affect the distribution of air in the furnace, or a dearth of fuel in the furnace which would reduce the combustion efficiency by leaning out the air/fuel ratio, some sort of device must be incorporated in the control circuit to enable the operator to readily adjust the air/fuel ratio. Fuel density corrections can be effected automatically by measuring the composition of the exhaust gases and correcting the air/fuel ratio

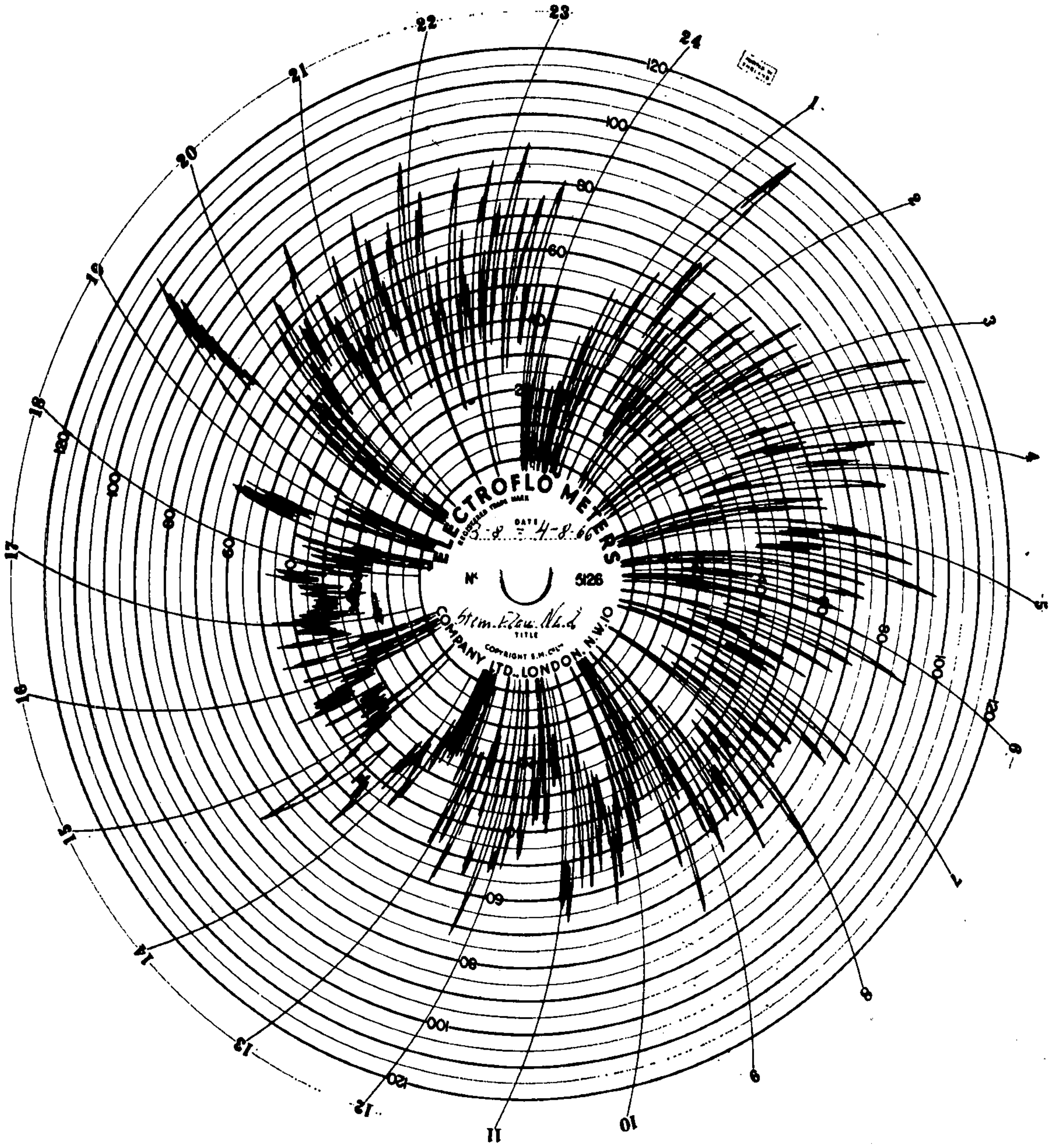

FIGURE 2: Steam Flow Chart, No. 2 Boiler, Noodsberg. This chart illustrates load swing from No. 2 boiler to No. 3 boiler (No. 1 boiler not yet commissioned) prior to the single element "Copes" feedwater regulator being commissioned. The boiler plant comprises three 100,000 p.p.h. units fitted with self-feeding furnaces, one master steam pressure controller coupled through loading relays to the F.D. fan dampers and individual furnace pressure controls.

accordingly. Due to the dirty nature of the exhaust gases, however, sampling equipment must work under very arduous conditions and must be regularly maintained. In practice small manual adjustments are adequate to ensure reasonable results. (See Fig. 5.)

3.13 Combustion Chamber Pressure Control

Combustion chambers are generally designed to operate under a slightly negative pressure. As air requirements vary in relation to heat output combustion chamber pressure will vary. A simple control loop incorporating a combustion chamber pressure measuring device coupled to equipment which will vary the quantity of exhaust gases being handled by the induced draught fan is usually sufficient.

3.2 Feedwater Controls

Apart from the necessity to control the feedwater level in a boiler within very close limits to ensure safe operation, the flow of feedwater to the unit must closely follow the steam demand to avoid imposing undue heat load demands on the combustion control equipment. The design and selection of feedwater control equipment is closely linked to the design of the feedwater circuit as a whole, especially the performance character-

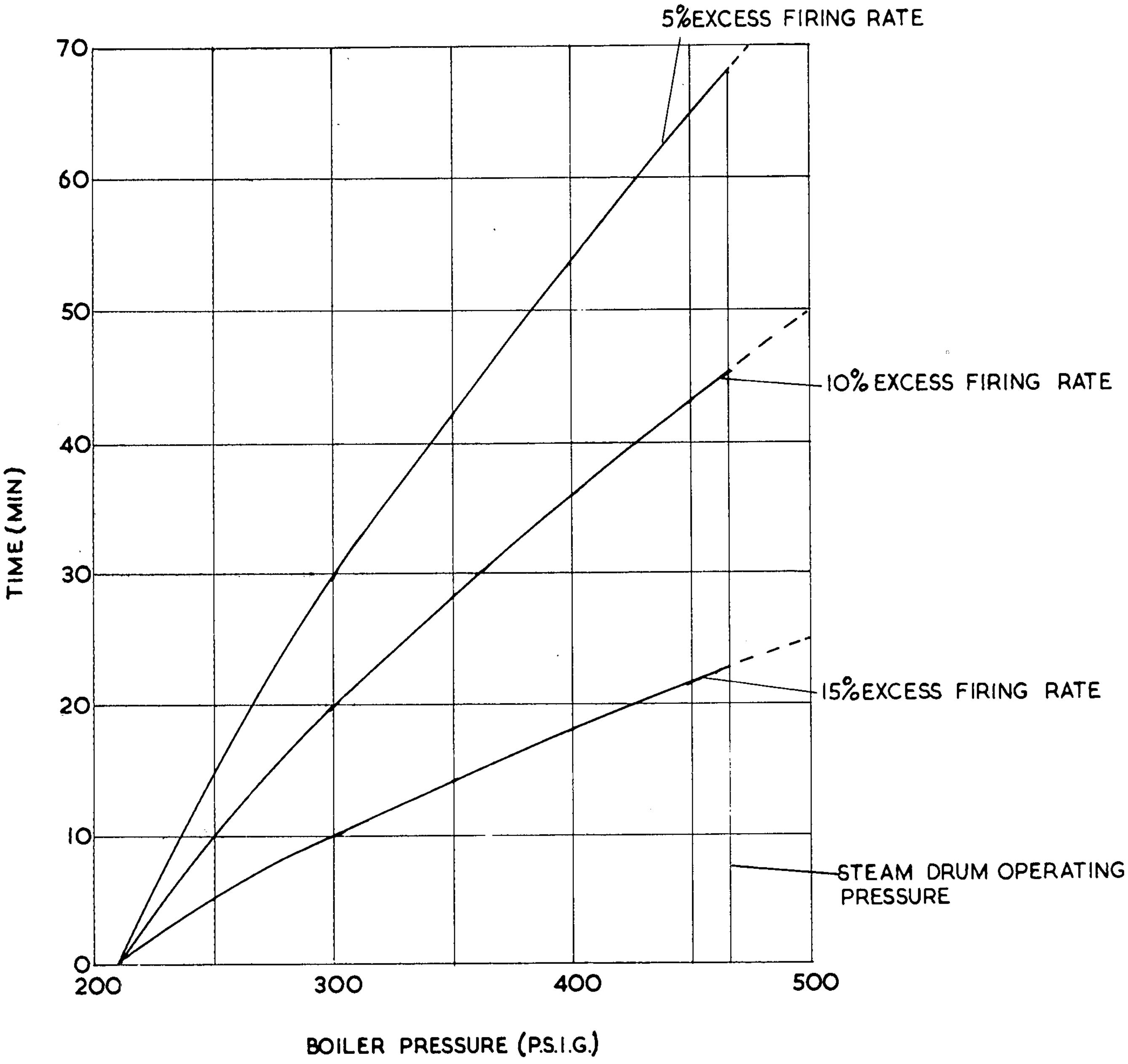

FIGURE 3: Curves showing approximate rate of increase in boiler pressure for varying percentage firing rates when steaming at full load on the Noodsberg boilers.

NOTE:

Boiler design parameters are:

M.C.R. Evaporation	100,000 p.p.h.
N.E.R. Evaporation	80,000 p.p.h.
Working pressure at Superheater outlet	450 p.s.i.g.
Final steam temperature at N.E.R.	775° F.
Feedwater temperature	220° F.
Water capacity of boiler at Mean Working level under operating conditions	47,000 lbs.
Total Water equivalent or effective thermal inertia	86,000 lbs.

istics of the feed pumps and the water capacity of the boilers. As explained under paragraph 2.2, a boiler having a large water capacity is not as susceptible to irregularities in feedwater supply as a boiler having a relatively small water capacity. Feedwater control valves are normally designed to create a pressure drop in the feed circuit of about 25 p.s.i. under full load conditions. If the ratio of no load pressure drop to full load pressure drop exceeds 3 to 1, careful consideration should be given to the design of the valve in order to ensure satisfactory low-load operation.

In general single element control, based upon drum water level, is quite adequate to ensure that the water level remains within safe predetermined limits. Single element controls, however, will regulate the water level such that at low load the level will

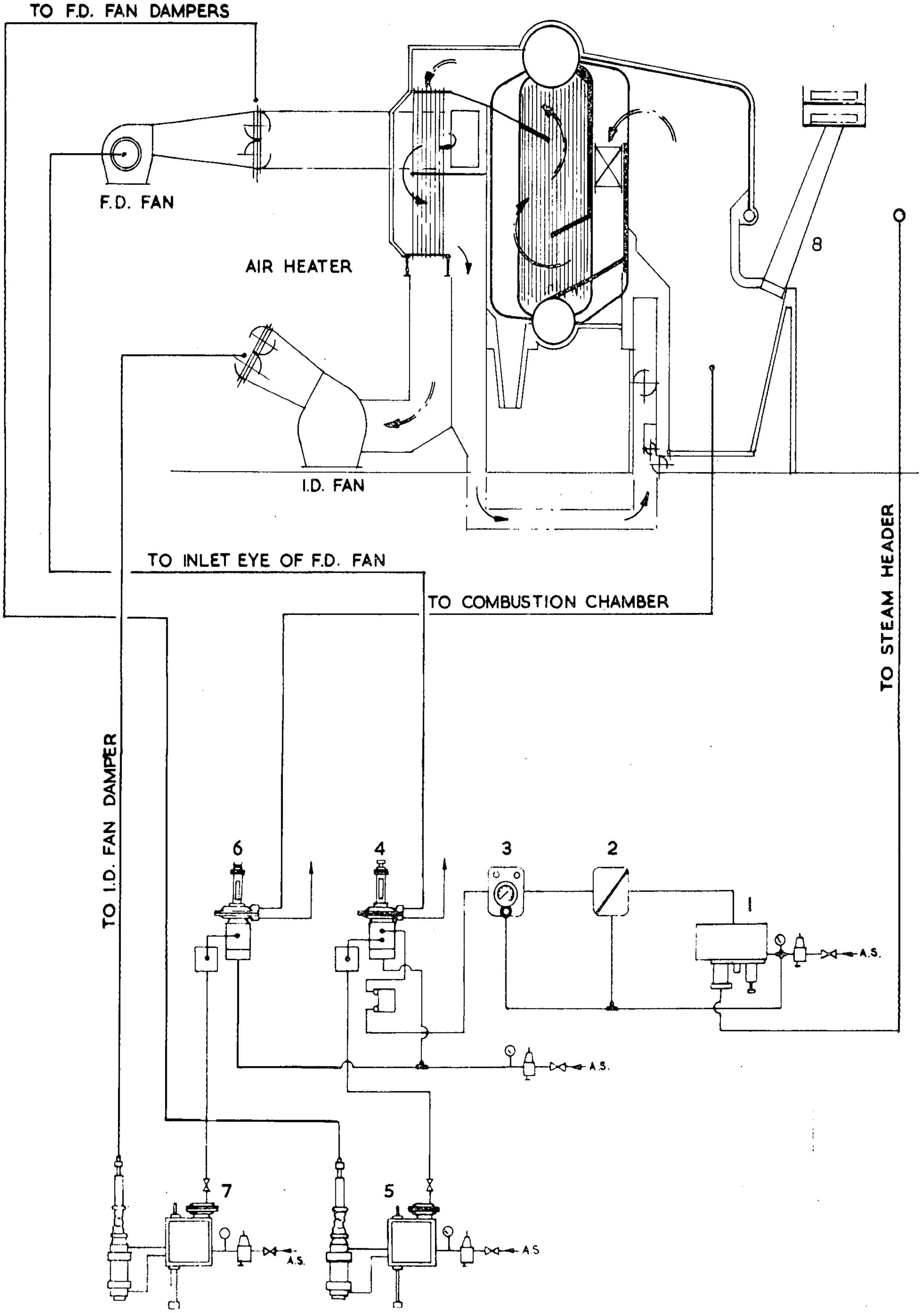

FIGURE 4: Automatic Combustion Control loop for boiler fitted with self-feeding furnaces.
LEGEND:

1. Master steam pressure controller.
2. Loading relay.
3. Auto-Manual control transfer station.
4. Primary air flow control relay.
5. F.D. fan damper positional regulator.
6. Furnace pressure control relay.
7. I.D. damper positional regulator.
8. Self-feeding bagasse chutes.

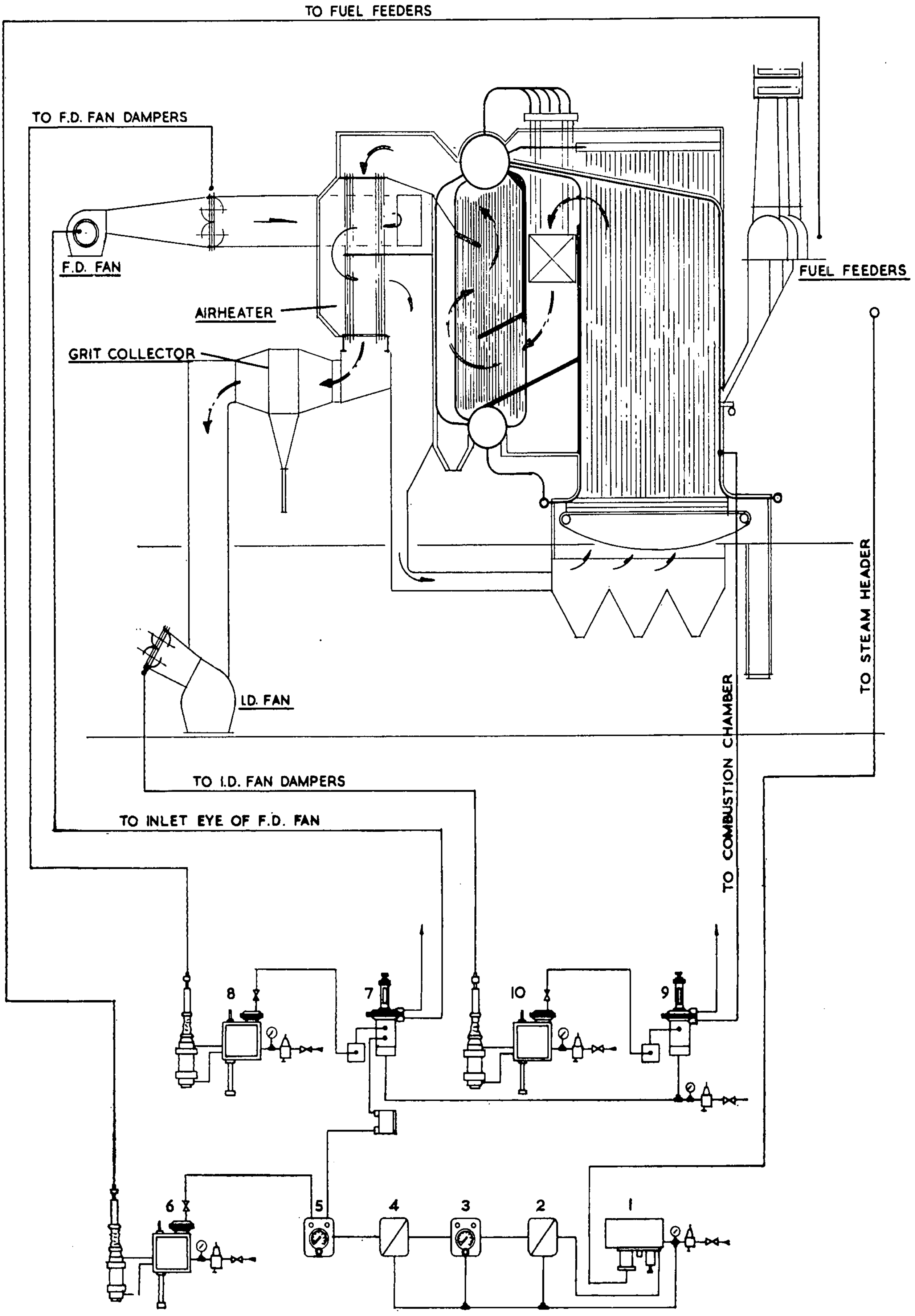

FIGURE 5: Automatic Combustion Control Loop for boiler fitted with Suspension firing equipment.

LEGEND:

1. Master pressure controller.
2. Loading realy.
3. Auto-Manual control transfer station.
4. Booster relay.
5. Fuel/air ratio valve and indicator.
6. Fuel feeder characterised positional regulator.
7. Primary air flow control relay.
8. F.D. damper positional regulator.
9. Furnace pressure control relay.
10. I.D. damper positional regulator.

NOTE.—If an auxiliary fuel is used such as coal items 5 and 6 can be duplicated to control these additional fuel feeders.

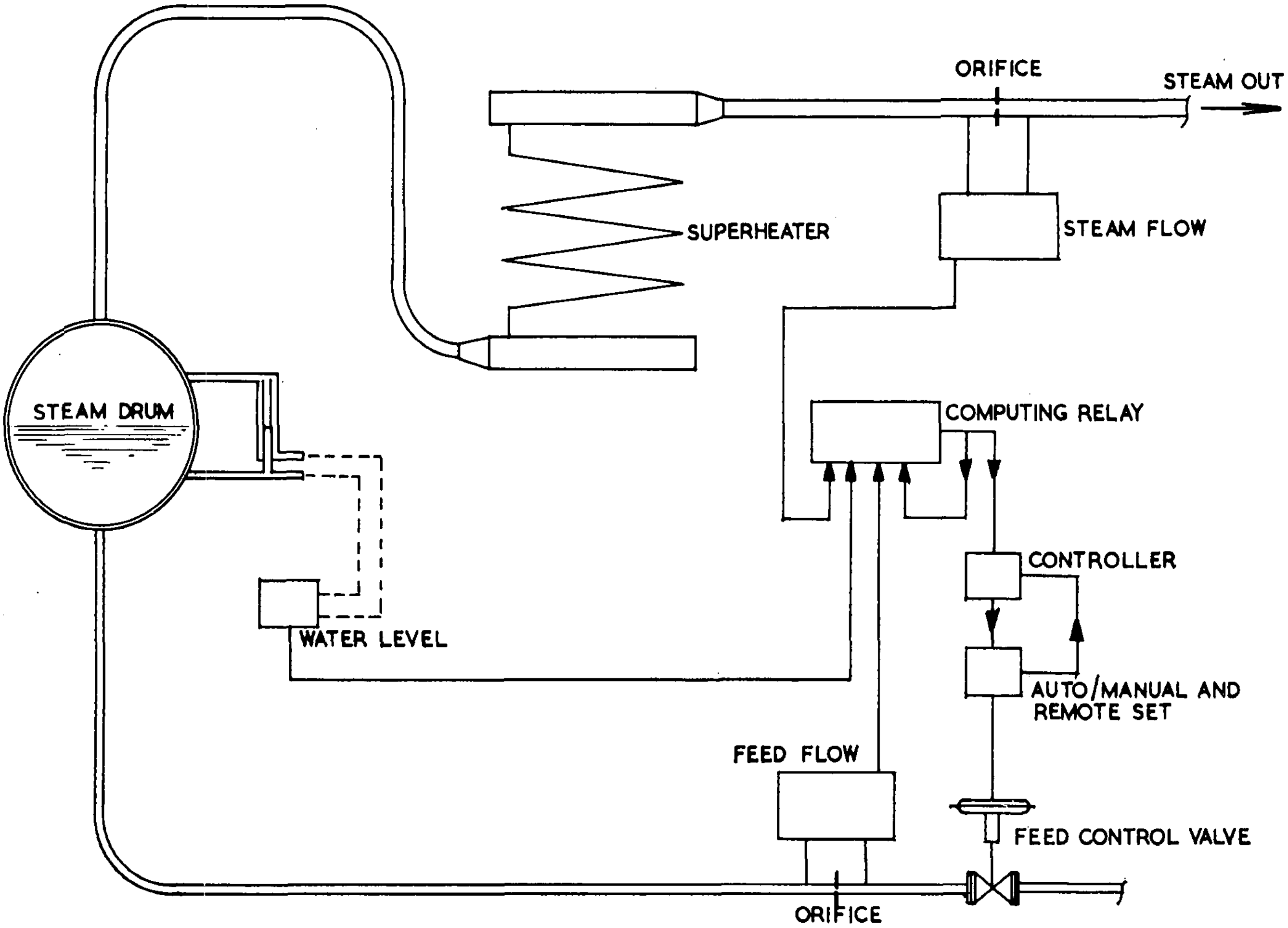

FIGURE 6: Three element boiler feedwater control loop.
NOTE:
(i) Where boilerplant has a large water capacity SINGLE element (water level) control is adequate.
(ii) Where load swings are large and reset action is required TWO element (water level plus steam flow) control is required.
(iii) Where boilerplant has small water capacity THREE element (water level, steam flow and feed flow) control is required.
In general Cane Sugar factory boilerplant will operate satisfactorily on single element control provided that the feed water system as a whole is designed as an integral unit.

be above the mean water level while at high loads the level will be below the mean water level. This characteristic can be corrected by fitting two element control, i.e. a reset action to mean water level can be built into the system by biasing the water level signal to the feedwater regulator by means of a signal derived from a measurement of the steam flow rate. Where the water capacity on a boiler is extremely small (this does not normally apply to the cane sugar industry) a further biasing signal can be derived from a measurement of the feedwater flow rate. (See Fig. 6.)

3.3 Boiler Thermal Inertia

Once a boiler has been designed and constructed no control can be exercised over its thermal inertia.

4.00 Practical Results

When a boiler is first put on range the automatic feedwater regulating device must be properly commissioned. Inadequate feedwater regulation will hinder any attempt to set up the automatic combustion controls. Fig. 2 illustrates the effect of erratic feedwater control on steam production from boiler No. 2 at Noodsberg during the initial commissioning (boiler No. 3 was on line as well). Fig. 7 illustrates how adequate feedwater control smoothed out the violent load fluctuations.

Once feedwater control has been stabilised combustion conditions must be manually optimised over the full operating range. Only then can the automatic combustion controls be tuned and the unit set on auto. Combustion chamber pressure controls should be commissioned first then the primary air controls and finally the fuel feed controls. Fig. 8 shows how properly tuned controls at Noodsberg maintain boiler pressure within very close limits. Fig. 1 shows similar results being obtained at Sucoma.

Adequate feedwater control has been strongly stressed in this paper. Equally important for

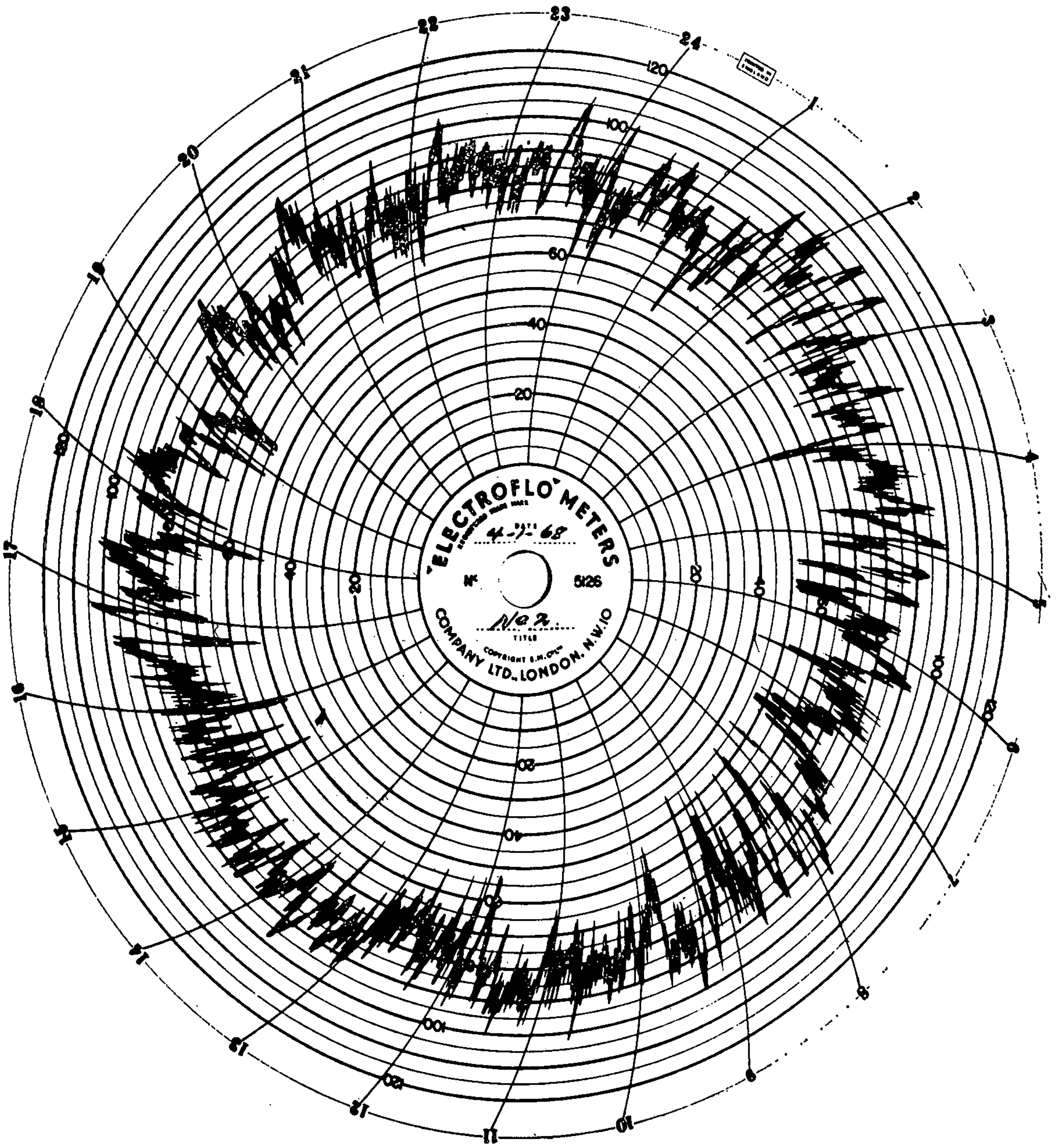

FIGURE 7: Steam flow chart No. 2 Boiler, Noodsberg. This chart shows how load swing has been evened out following commissioning of the feedwater regulator.

NOTE.—Load swing can also be induced by erratic firing conditions, but this condition is not usually as severe as that illustrated in Fig. 2.

good combustion control is to ensure that the correct amount of fuel is available to meet the steam demand. Because of the low bulk density and low specific heating value of bagasse difficulties can be experienced in maintaining a uniform supply of fuel to the boiler. In general fuel feeders take their supply directly from the bagasse carrier. In order to ensure that the controls are given a fair chance of metering the fuel the supply to the feeders should be consistent. Bagasse carriers should circulate more bagasse than is actually demanded (see Fig. 10.1—Reference 2) and surge capacity consisting of diverging chutes between carrier and feeders should be incorporated even if this is only capable of storing 30 seconds supply of fuel. At Noodsberg and Sucoma where self-feeding furnaces are installed this problem is eased considerably (cf. Figs. 8 and 9).

5.00 Typical Control Circuits and Costs

Figs. 4 and 5 show typical control circuits which have been successfully fitted to boilers with self-feeding furnaces and suspension firing equipment respectively. The circuits are simple, rugged and inexpensive. The installed cost of the circuit shown in Fig. 4 should not exceed R6,000 per boiler while the installed cost of the circuit shown in Fig. 5 should not exceed R7,500 per boiler provided that a clean dry instrument air supply is available.

6.00 Summary

The paper describes the effect of boiler operating parameters on the design of automatic

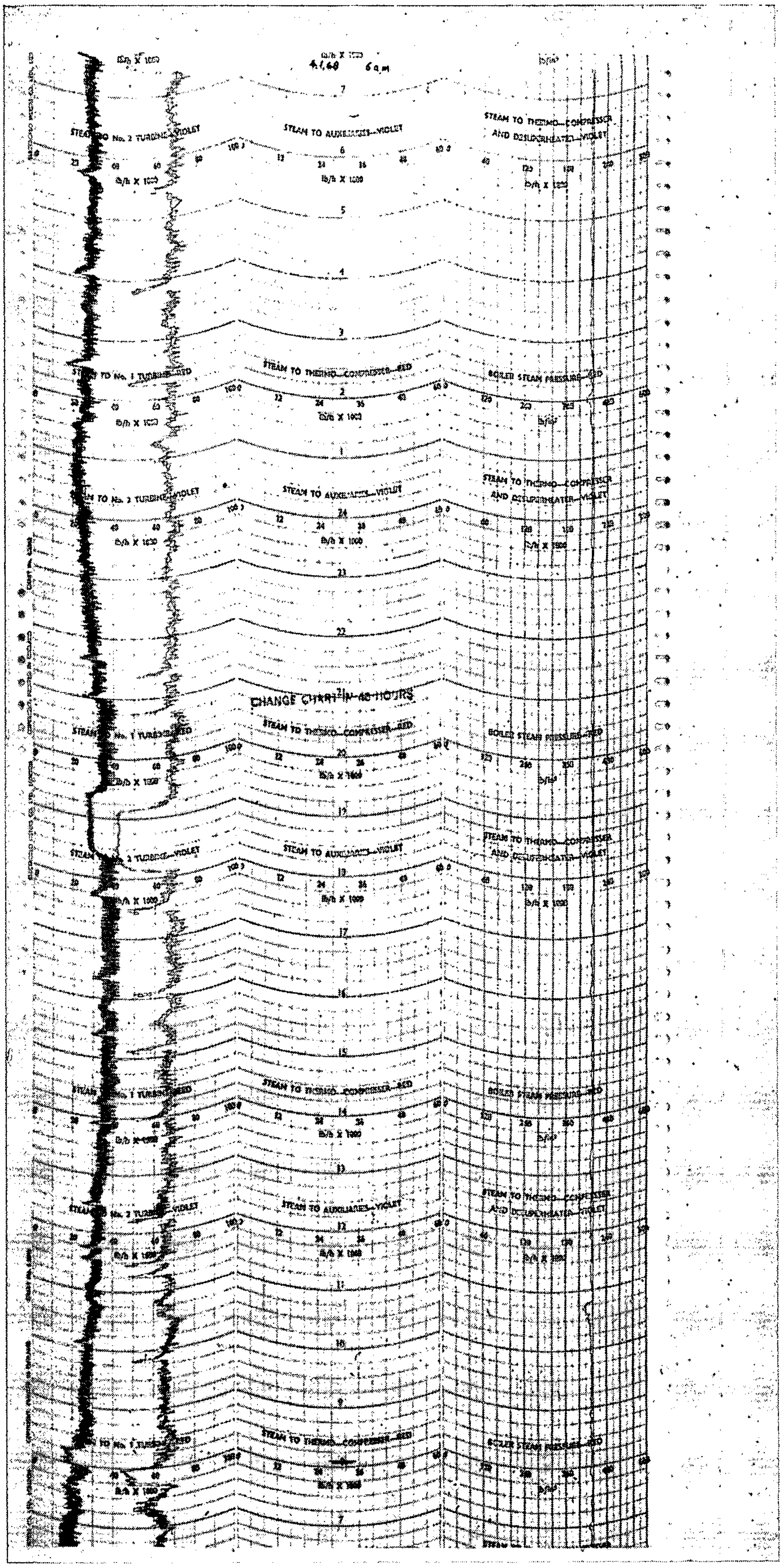

FIGURE 8: Steam flow to Turbines 1 and 2 and Boiler Pressure Chart, Noodsberg. All controls (see Fig. 4) commissioned.

NOTE: Steam flow is equally divided between Nos. 1 and 2 Turbines. The difference on the chart is due to a manometer fault.

control systems. The need for adequate feedwater regulation before attempting automatic combustion control is stressed. Typical control circuits and their approximate installed costs are described as well as recent experience gained at Noodsberg and other mills during commissioning and subsequent commercial operation.

Acknowledgements

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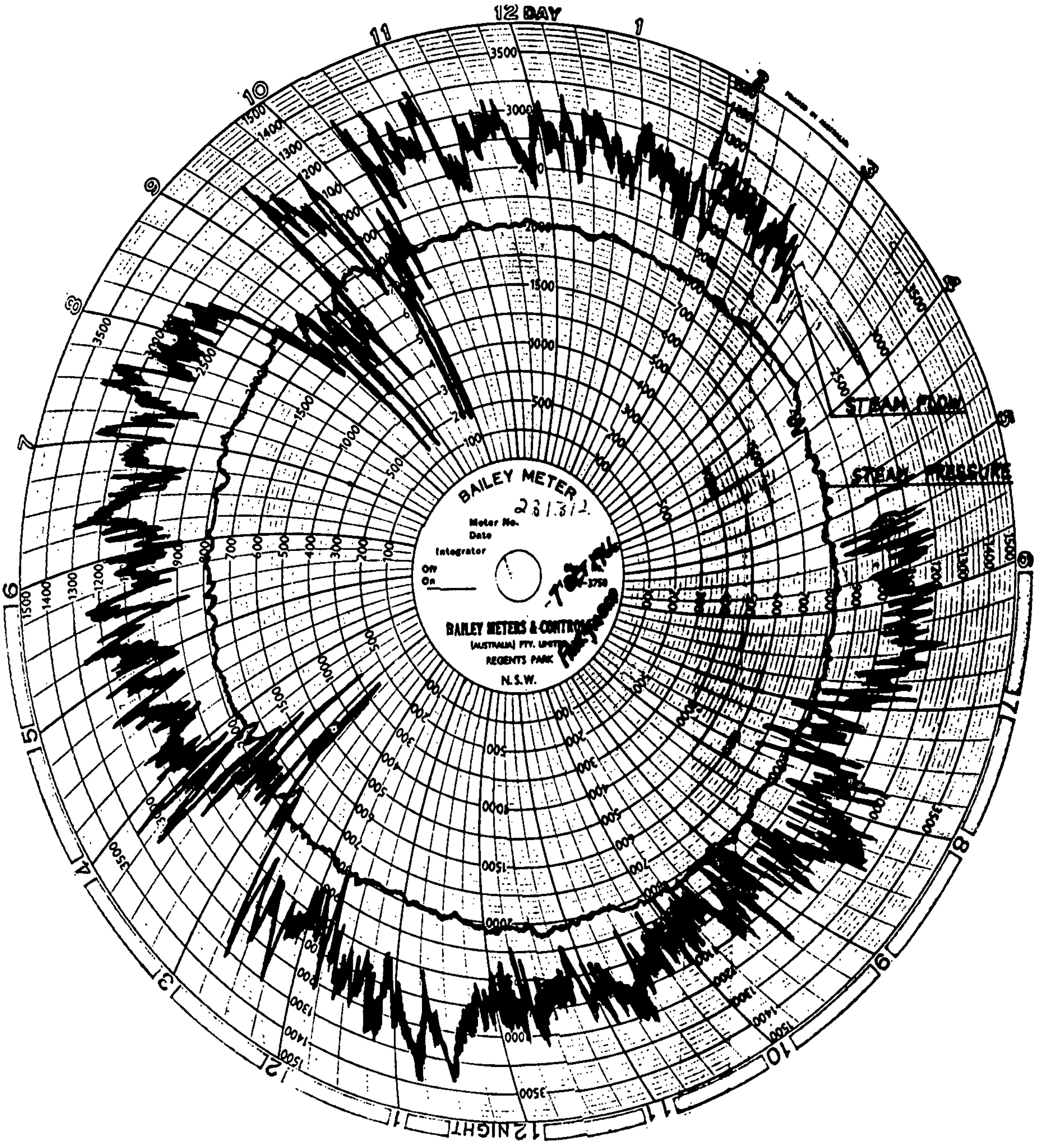

FIGURE 9: Steam Flow/Pressure Chart—Fairymead Sugar Co. Ltd., Australia. Note effect of mill stoppages, hence interrupted bagasse supply on boiler pressure. Plant comprises one 100,000 p.p.h boiler fitted with pneumatic suspension firing equipment, three element feedwater control, master pressure controller coupled to fuel/air ratio control loop and furnace pressure control. The boiler operates in parallel with a number of older units fitted with hearth type furnaces which are manually controlled.

Discussion

Mr. Allan: At Umfolozi some years ago we installed two bigger units and got charts similar to those shown in Figure 2.

We suffered from the same load swings and it was probably because we had too many boilers on range resulting in low unit loads.

By taking two boilers off we got the flow line to steady out much as happened at Noodsberg.

From the flow rate depicted in Figure 2 I estimate the boiler was steaming at about 40,000 pounds per hour, or slightly less than half its capacity.

In Figure 7 the boiler is steaming much closer to its true capacity and very likely the additional load related to the pressure drop at the feed valves would have had a lot to do with the trouble being experienced at the time.

Mr. Magasiner: Yes, if one operates at 40% load, the feed valves are throttled in and the pressure drop across the valves in the case of Noodsberg must have been close to from 150 to 180 p.s.i. instead of the designed 25 p.s.i. which would have given this effect. But I think the main reason was that the valves had not been set up properly as the boiler had only just begun operating. At Umfolozi by increasing the load on the system the feed valves were opened further to give better control.

Mr. Andrews: As regards Figure 2, I think that at this time Noodsberg had only one turbine in commission.