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INSTRUMENTATION FOR BOILER PLANT (I) (Drum Boiler)

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I. PREFACE

The automatic control of boiler plants is the oldest on all process controls; it developed from the first ACC (Automatic Combustion Control) to ABC Automatic Boiler Control), then to APC (Automatic Plant Control) and now it is progressing to a computer control.

Our company was the first to produce automatic control systems for boiler plants; to date, it has automated the controls for several hundred boiler plants ranging from a few hundred kg/hr to the large boilers of several hundred t/hr capacity for industrial power supply.

With recent perfection of the TELEPERM-TELEPNEU system, a wider combination of control instruments and selection of a suitable control system for any boiler plant are possible. Moreover, the connection of these controls to the data and computing loggers is very easily accomplished.

In the following paragraphs, the author will describe the automatic control of boilers in general and typical applications of the TELEPERM-TELEPNEU system.

II. AUTOMATIC CONTROL OF BOILERS

1. Boiler and Instrument Control Device

Since it is called a steam generator, the boiler is an airtight container in which water is heated to generate steam of specified pressure; it is composed of a furnace to generate heat, the boiler proper which transfers the heat generated in the furnace to the water in the closed container and other incidental equipment.

Consequently, there are many control functions such as the fuel and steam pressure, temperature, excess air factor, furnace draft and drum water level, etc.: these are the control systems with several control functions which do not exist independently but interfere with each other.

The load side of a boiler demands steam with constant pressure and temperature. On the other hand, on the boiler, to avoid a circulation obstruction, priming and foaming at a pressure lower than the limit pressure, it is necessary that the steam pressure not be lowered below the specified pressure and that the steam pressure not be lowered to a speed greater than the specified speed.

With today's high pressure and high temperature boilers, manual operation is impossible and the automatic control becomes indispensable. General advantages of the automatic control are the saving of fuel, production of steam of good quality, prolongation of plant life and decreased manpower for operation, etc.

2. Dynamics of Boiler

Since steam is taken out of a boiler, it is necessary that the boiler maintain a weight balance of the water inside the drum; next, since the heat is carried out by the steam, it is also necessary to maintain an energy balance.

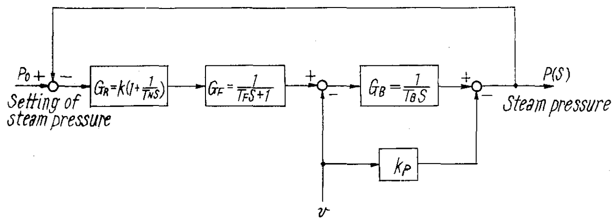
The control of the water weight balance is done as a feed water flow control; with a drum boiler, since the ratio between the amount of steam and feed water flow appears as a drum water level variation, the controlling is done indirectly as a drum water level control.

The energy balance control, to maintain the pressure of generated steam constant, is done as a combustion output control and a boiler's output is determined by this combustion output.

These two basic control systems interfere with each other and other controls are incidental to these two control systems.

Generally, the thermal capacity of a boiler in respect to combustion can be regarded approximately as a concentrating type process of two capacities; the first is the first order system $\frac{1}{T_F S+1}$ which is due to the delayed heat transfer caused by the combustion in the furnace and drum body; the second is the integral system $\frac{1}{T_B S}$ which is due to the thermal capacity of the water in the drum and drum body.

A block diagram of a basic steam pressure control utilizing these transfer functions from which the effect of the feed water is omitted is shown in *Fig. 1*.



G_R : Transfer function of steam pressure controller (PI)
G_F : Transfer function of furnace
G_B : Transfer function of boiler
K_P : Coefficient of pressure drop due to friction
v : Load variation

Fig. 1 Block diagram of boiler ACC

When the time constants for these are known, computation is done easily.

However, in practice, besides the effect of combustion, there is the effect of feed water, air and furnace draft, etc; with the modern high pressure and high temperature boilers, the effect of feed water can never be ignored.

In the instrumentation of a boiler plant, it is necessary to grasp all these boiler characteristics and select automatic control equipment that fully matches the boiler. Furthermore, it is necessary to design a boiler so that its controls can be automated easily.

III. APPLICATION EXAMPLES OF AUTOMATIC CONTROL EQUIPMENT FOR DRUM BOILERS

1. General

Fig. 2 is a systematic diagram of ABC for a boiler for power generation. The description to follow will focus around the special features of this control system.

In this instrumentation, the system used an all electrical one from the detecting unit to the controller and TELEPERM-TELEPNEU system where electro-pneumatic transducing is used at the operating end. The detecting unit which transduces directly in a direct current is a new system using none of the conventional resistance transmitters; the controller is the continuous type TELEPERM controller (EKR type).

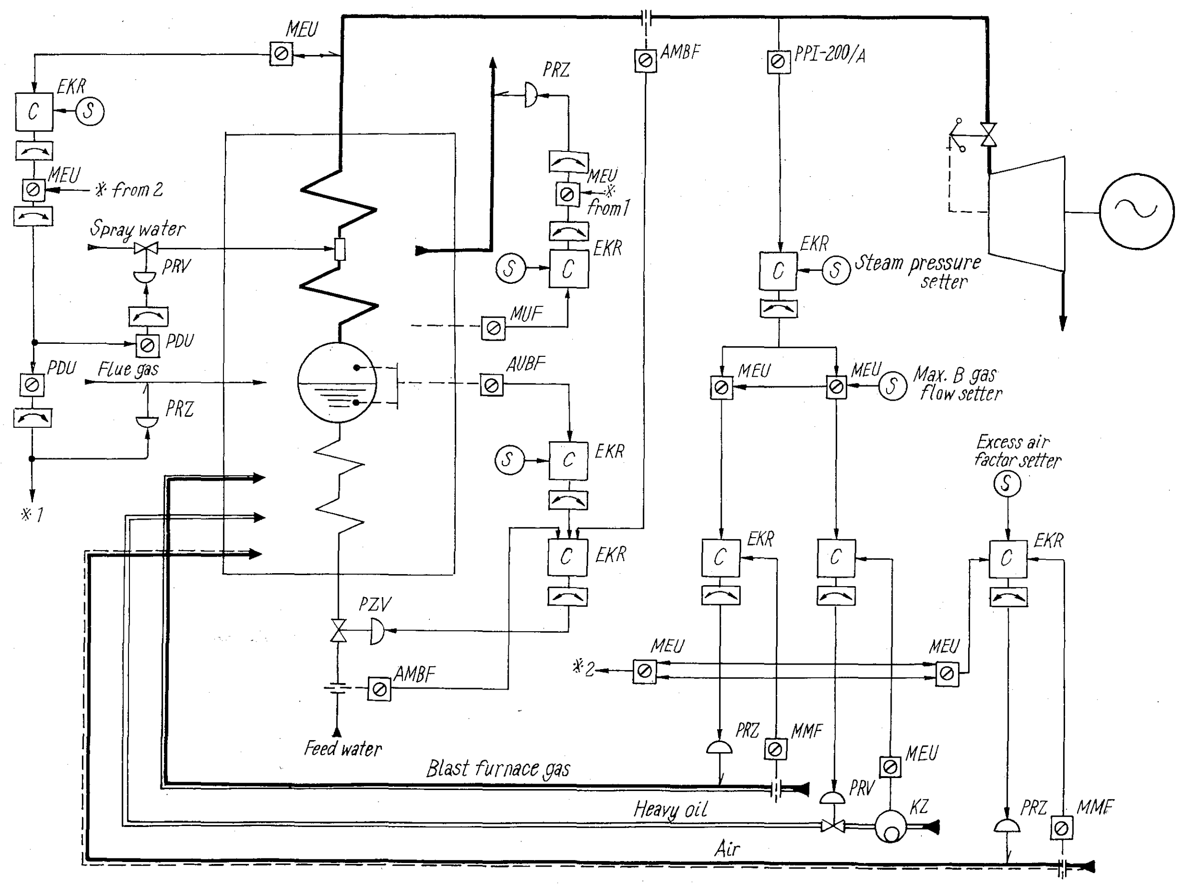


Fig. 2 Instrumentation diagram of boiler control

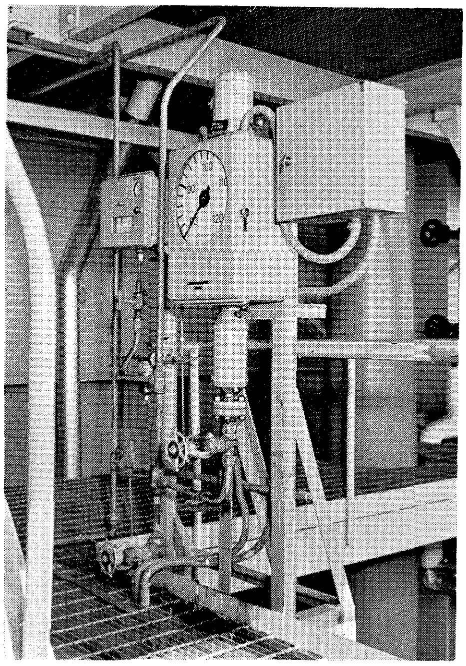


Fig. 3 Main steam pressure transmitter

This system controls the amount of fuel so the steam pressure is specified pressure; it controls the air and furnace draft and also controls the feed water and steam temperature.

2. Master Control Equipment

The main steam pressure is detected with a conventional piston type precision pressure gauge (Model PPI–200) equipped with a TELEPERM Apgriff; the pressure is transduced directly into a direct current ($0\sim50$ ma) (*Fig. 3*).

The principal fuel is B gas and as an auxiliary fuel, heavy oil is used. The control of these fuels is shown in *Fig. 4*. The setting of the maximum combustion output of B gas is done manually; when the fuel needed is in excess of this setting value, the deficiency is filled with heavy oil; when the fuel required is less than the setting value, the heavy oil is held to a minimum and B gas is controlled. The minimum supply of heavy oil is maintained, regardless of the load, to prevent the oil burners from going out. (When the number of the burners is changed, the minimum amount of heavy oil is changed)

This controlling is accomplished easily by combining two TELEPERM insulating type transducers. The principle is shown in *Fig. 5*. At the transducer of I, when I_1 is connected to the positive direction and I_S to the negative direction, because of the diode on the output side, I_2 is 0 when $I_1 \leqq I_S$ and $I_2 = I_1$ when $I_1 > I_S$. If this I_2 is put in the negative direction to the transducer of II and is calculation-transduced with I_1, when $I_1 \leqq I_S$, $I_3 = I_1$ and $I_3 = I_S$ when $I_1 > I_S$. If heavy oil is controlled with I_2 and B gas is controlled with I_3, the control shown in *Fig. 4* is possible. These two signals become the setting values of the fuel controllers and each fuel is controlled to attain the above.

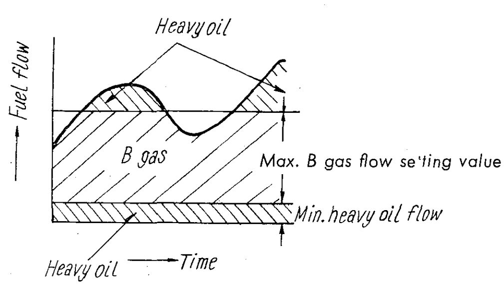


Fig. 4 Character of fuel control

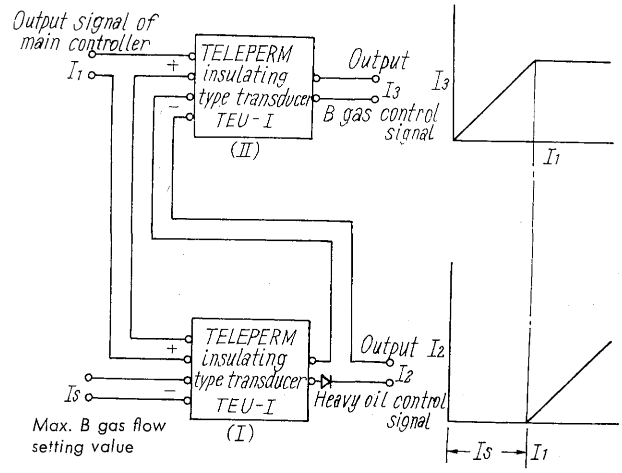


Fig. 5 Limiter circuit

3. Fuel Flow Control Equipment

This equipment controls the fuel according to the instruction of the master control equipment and utilizes a cascade control system.

In order to maintain the minimum flow of heavy oil, aside from the heavy oil flow control signal of the master control equipment, a minimum heavy oil flow setting signal is impressed on the input to attain the above.

B gas is damper controlled and the heavy oil is controlled by a diaphragm valve.

4. Air Flow Control Equipment

This equipment controls the air to match the fuel flow. Theoretical air flow is computed for B gas and heavy oil flows; this is multiplied with a proper excess air factor and the air flow that matches the above is controlled by the forced draft fan inlet vane.

Because of the large size of the boiler, two ducts are provided. These are measured and designed for the proper air flow.

5. Furnace Draft Controller

For safety and increase in combustion efficiency, this controller maintains the furnace draft at a negative pressure of several mmH_2O; it is controlled primarily by an air flow control signal and is corrected by a furnace draft controller. Furthermore, since this boiler's steam temperature control system is a flue gas recirculation system (spray water is spare), the effect of this becomes a distrubance in furnace draft control. To decrease this distrubance, a derivative value of the flue gas recirculation damper control signal is used in the input.

6. Feed Water Flow Control Equipment

This controls the feed water flow that matches the combustion output or the steam flow ; this is a three element control system controlling the drum water level, steam flow and feed water to maintain a specified drum water level.

The transmitters for the above are the double bellows type differential pressure transmitters to which TELEPERM Apgriff has been added and directly transmits signals as direct current (0~50 ma) (*Fig. 6*). The flow meter, by means of a link mechanism, controls the measuring differential pressure and the relationship between the flow and output is linear.

The feed water valve is a specially constructed cylinder type control valve. (*Fig. 7*)

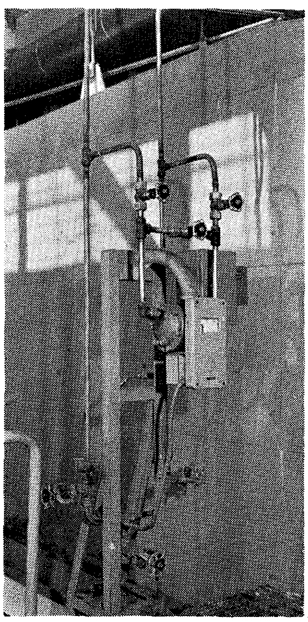


Fig. 6 Double bellows type TELEPERM differential pressure transmitter

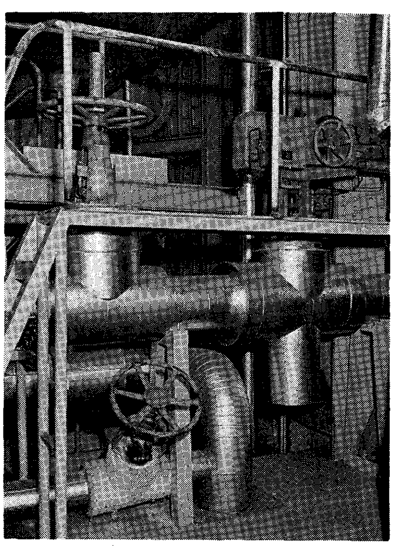


Fig. 7 Power cylinder type feed water flow control valve

7. Superheated Steam Temperature Control Equipment

This equipment returns the combustion gas out of IDF back to the furnace to control the gas temperature to control the steam temperature. As a preliminary control for this, an attemperator is provided.

Generally, a steam temperature control system has an extremely long dead time, the allowable range of variation is narrow and controlling is very difficult. For this reason, since good controlling cannot be expected with the steam temperature signal only, in many instances, other auxiliary elements are added.

In this case, the signal is multiplied with the coefficients of B gas and heavy oil (the coefficients are determined by the actual operation results) for primary controlling and is corrected by the steam temperature controller.

The flue gas recirculation damper is driven by the composite signal of the above two ; if the temperature is still too high, water spraying starts after the damper is completely closed. (*Fig. 8*)

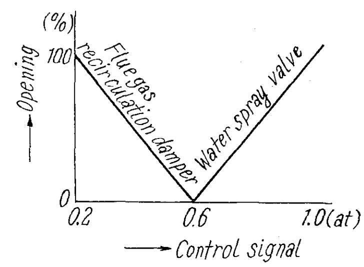


Fig. 8 Character of temperature control

8. Others

Besides the above, there are controls for auxiliary machines and heat control equipment but the explanation of these will be omitted.

IV. TELEPERM-TELEPNEU SYSTEM AND BOILER AUTOMATIC CONTROL EQUIPMENT

In today's high pressure and temperature boilers, the response of pressure, temperature, water level, and etc., is very high, and the allowable range of variation is very small.

Since an automatic control is very difficult, a superior control system and excellent control devices become necessary.

The TELEPERM-TELEPNEU system accomplishes these complicated computations and the connection of loggers which have increasingly wide application

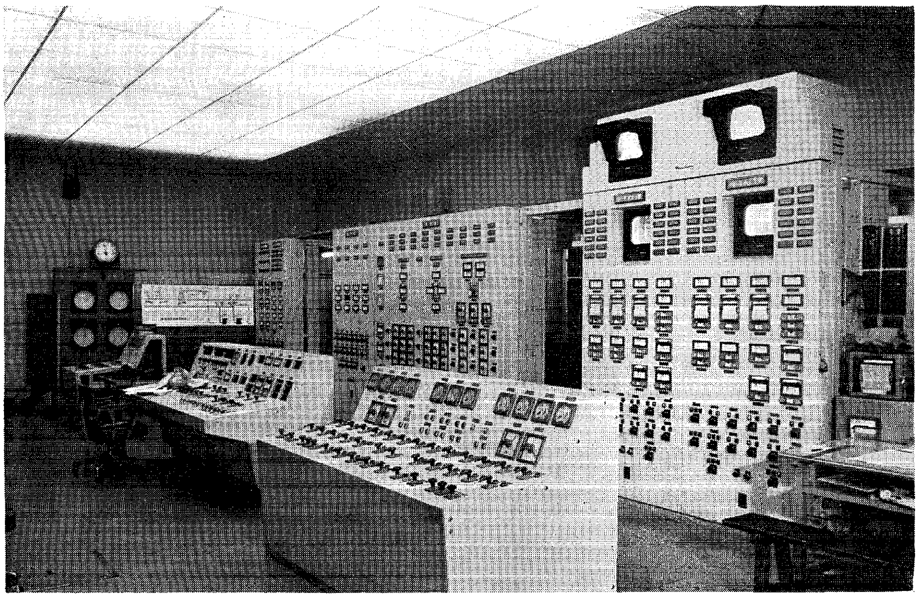


Fig. 9 Instrument panel for boiler ABC by TELEPERM-TELEPNEU

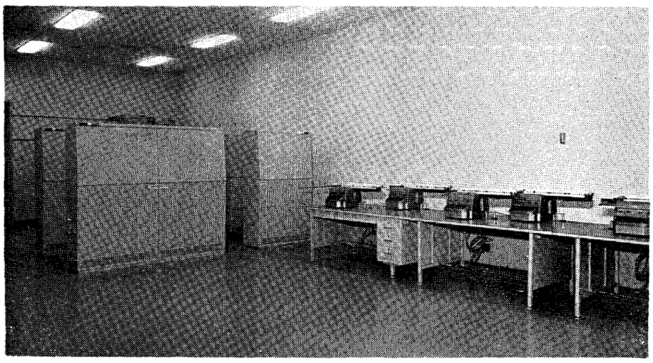


Fig. 10 Data logger

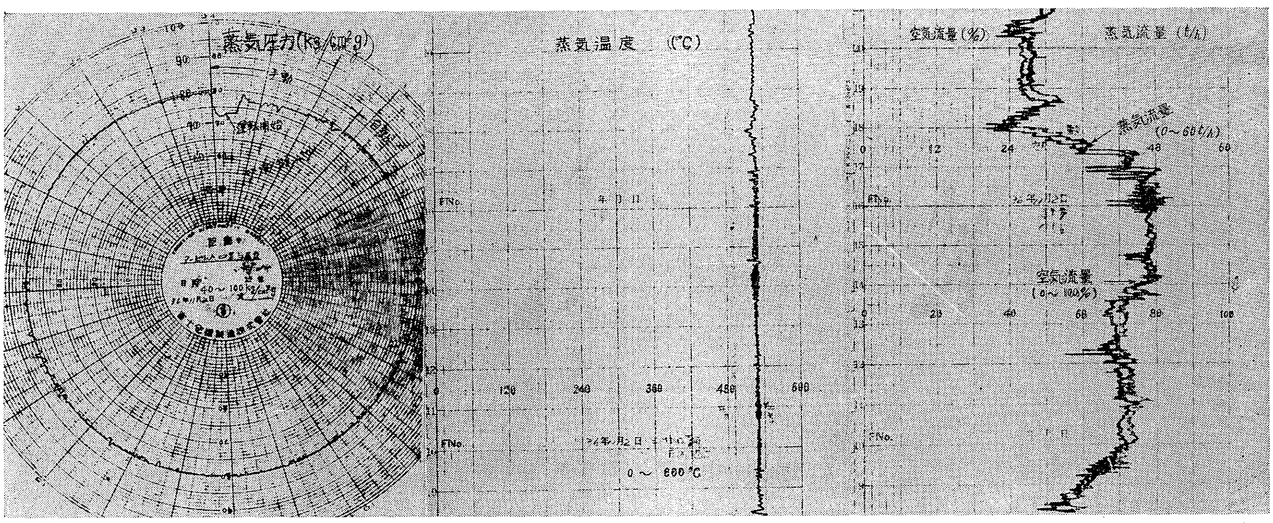
is possible. Its combining range is very wide; unit construction of each component is very convenient in the operation of the system.

Fig. 9 shows an instrument panel for boiler ABC by the TELEPERM-TELEPNEU system; *Fig. 10* shows a data logger and *Fig. 11* shows charts of control results.

V. CONCLUSION

When the TELEPERM-TELEPNEU system was first completed, instrumentation with the conventional large pneumatic type or electro-pneumatic type controller was chiefly used. However, as the advantages of TELEPERM-TELEPNEU became recognized, the instrumentation of boiler plants by this system began to increase.

The instrumentation by the completely electrical genuine TELEPERM system is increasing rapidly. We expect this trend will continue to progress at an amazing rate of speed.



Main steam pressure Scale: 40～100 kg/cm²

Main steam temperature Scale: 0～600 °C

Steam flow Scale: 0～60 t/hr
Air flow Scale: 0～100%

Fig. 11 Charts of boiler ABC