UDC 621.181.656-52 : 621.316.79

INSTRUMENTATION FOR BOILER PLANT (II)
(Benson Boiler)

By Takao Komatsu &
Mitsuru Watanabe
Central Technical Dep't.

I. PREFACE

Since our company delivered the first domestically produced automatic control equipment for Yokoyama-VKW Benson boiler (90 t/hr, 110 kg/cm²g, 540°C), Amagasaki Iron Works, Ltd., in 1957, the attention of the industrial world has been focused on this control equipment. As a result, our company has contracted the instrumentation for practically every Benson boiler in Japan ; up to this date instrumentation for nearly thirty boilers has been completed and the actual operation of the control equipment found to be excellent. In the meantime, the TELEPERM system itself has been improved greatly in many respects. In the following paragraphs, we will introduce the automatic control equipment for Benson boilers which uses the newest TELEPERM system.

II. INSTRUMENTATION FOR BENSON BOILER

1. Outline of Benson Boiler

Today's boilers can be classified roughly into drum boilers with drain separators and mono-tube boilers without drums. A Benson boiler is a mono-tube boiler in which the feed water is preheated, evaporated and superheated by its single passage through the piping system. (Refer to *Figs. 1* and *2*)

Since the Benson boiler has no drum, it has no definite water level. Based on the concept of its inventor, Mark Benson, the boiler is designed to

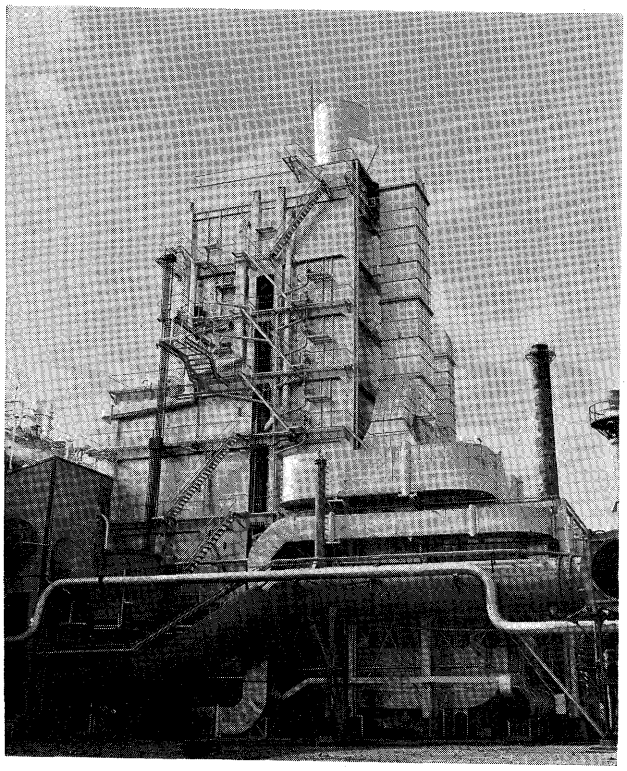

Fig. 1 Outer view of 130 t/hr Benson boiler for Nadahama Factory, Kobe Steel Works Ltd.

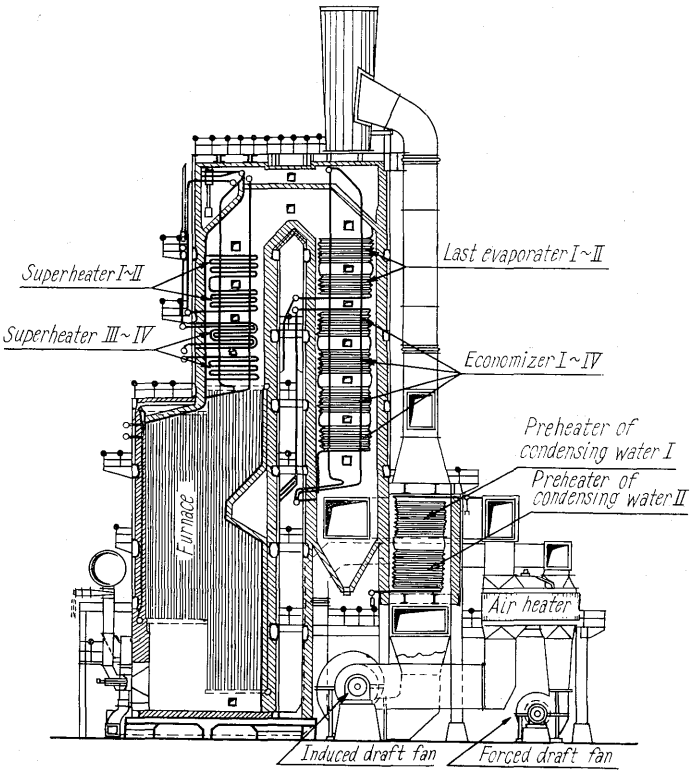

Fig. 2 Sectional diagram 130 t/hr Benson boiler for Nadahama Factory, Kobe Steel Works Ltd.

withstand critical pressure. At critical and super critical pressures, the temperature of water rises continuously and the water changes into the steam without boiling phenomenon when heat is applied, the heat of evaporation is not required. This evaporating process is explained in detail in *Fig. 3*.

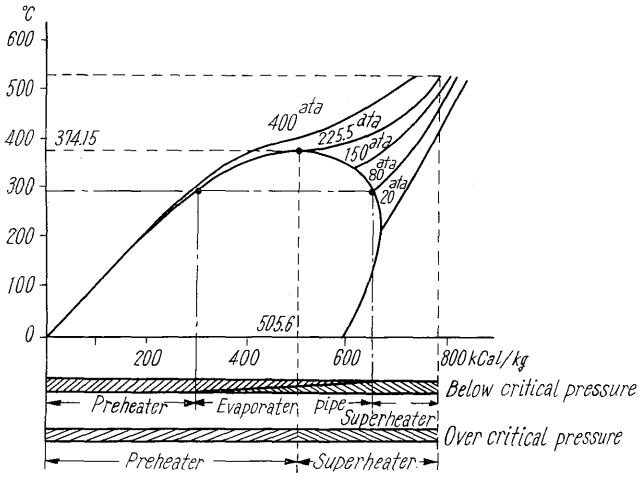

Fig. 3 Process of evaporation at Benson boiler

The patent rights for the Benson boiler are owned by the Siemens-Schuckertwerke AG ; at present, 37 companies in 19 countries are manufacturing this boiler. Siemens statistics as of July 30, 1961, show that since 1926, 347 Benson boilers have been manufactured which have produced 75,272,000 t/hr of steam.

2. Outline of Benson Boiler from The Standpoint of Instrumentation

It should be noted that a Benson boiler does not use a special control system (compared to a drum boiler), just because it is a Benson boiler. At first, the characteristics of the Benson boiler were not fully understood : for safety, as control equipment, delay circuit element was used for the feed water control line, sub-heat surface effect was utilized for the fuel control line and tendency element was used for the steam temperature control line. Thus the equipment was heavy and cumbersome. Later research and experience has eliminated superfluous devices, streamlining the control system.

A description of the control equipment for Benson boiler using BFG (blast furnace gas) as the main fuel and heavy oil as auxiliary fuel will be made in the following order :

(1) Master control equipment
(2) Fuel control equipment
(3) Air control equipment
(4) Feed water control equipment
(5) Steam temperature control equipment

Besides the above, there are sub-machinery and control devices ; however, since these do not specifically belong to the Benson boiler, their description will be omitted.

3. Master Control Equipment

Generally, the boiler time constant for a Benson boiler is very short. (At the time when the amount of generated steam falls short of steam consumption, the deficient steam is supplied by the ability of the boiler ; when excess steam is to be returned, the supply or return of the stored steam causes temporary drop or rise of the steam temperature. If a boiler which is loaded with a standard pressure, P_M is assumed to be in a condition to supply, from its capacity, the entire steam output D_M at these values, its time dimension is defined as the boiler time constant). When the standard pressure control $\rho_P = T_S/T_F$ (see Note 1) is small, (see Note 2) if the load variation is taken on directly, pressure control is thought to be impossible. For this reason, devices such as before pressure control equipment and limited pressure control equipment were attached, using a constant power output operation that determines the output of a turbine and the boiler. However, later research showed that the Benson boiler can be operated by a frequency control system in which pressure is controlled by combustion and feed water by steam flow. The principle of this control cannot be applied to all Benson boilers to obtain the same result ; it cannot be used when the control value of pressure by combustion is small. In cases like this, the pressure of a Benson boiler is controlled with water and its temperature is controlled by combustion. These methods are used only in Benson boilers because these boilers do not have a definite water level. The instrumentation diagram of a Benson boiler in *Fig. 4* shows an example of pressure control by combustion and feed water control of steam flow.

Note 1. (T_B=boiler time constant, T_F=combustion time constant) combustion time constant T_F is the time lag, from issuance of instruction to the combustion line until a matching steam output is created, caused by fuel carrying, atomization, combustion and heating inertia to the pipe line.

Note 2. It is said when the value of ρ_P is less than 1, control is difficult ; at the value of 1~10, control is normal ; when the value exceeds 10, control is extremely easy.

4. Fuel Control Equipment

As shown in *Fig. 5*, the fuel control system controls the fuel by detecting the main steam flow (with compensating pressure and temperature) by giving instruction to the fuel with a proportional action P (in accordance with the flow) and at the same time by integral action I which corresponds to the deviation from the pressure setter and pressure offset. The fuel control equipment must be designed so that

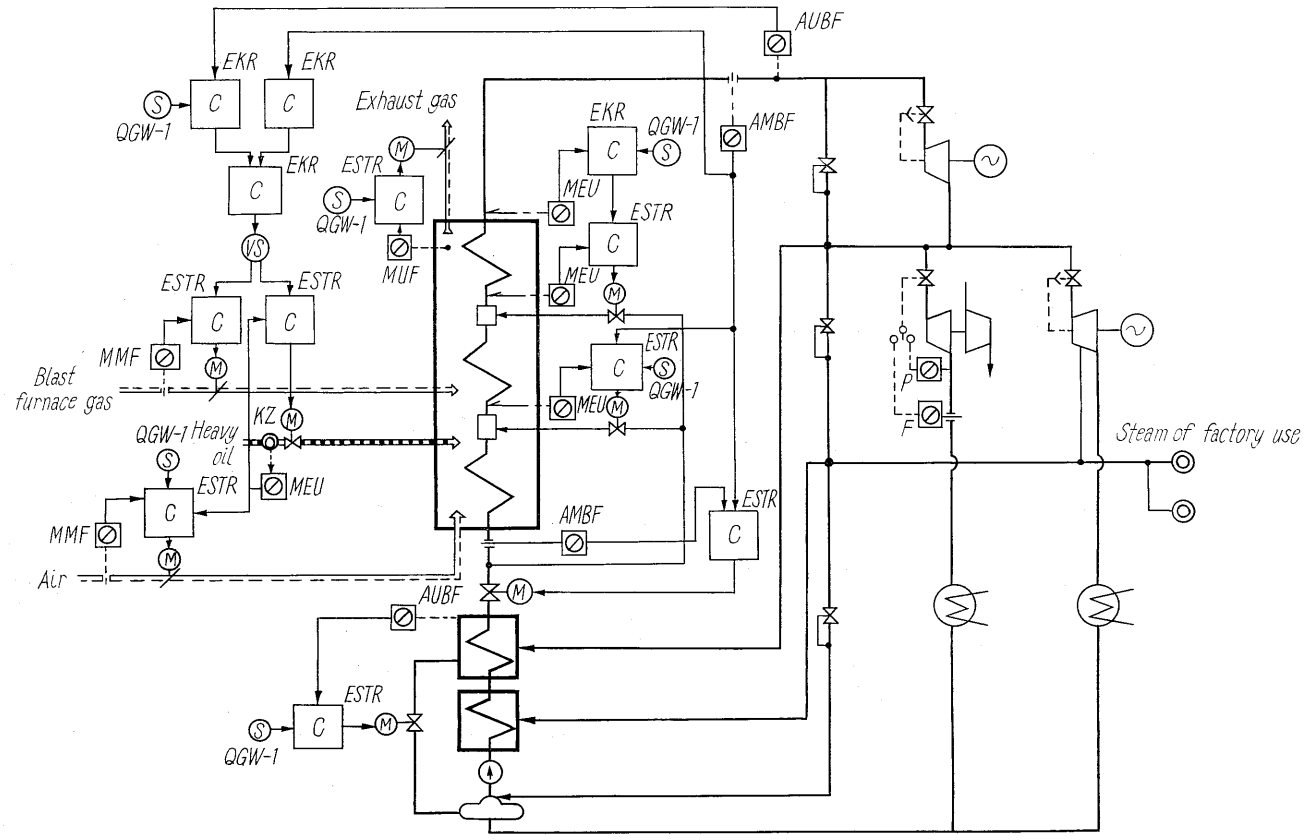

Fig. 4 Instrumentation diagram of Benson boiler

it can determine the proportion of B gas and heavy oil. If the boiler plant has a gas preheater, it is neccessary to feed back the B gas flow to the B gas flow controller with a device to compensate the error which is due to the change of the temperature and the pressure.

In case of the pressure atomizing system with oil return pipe, the flow actually supplied to the boiler is measured by the difference of flow between supply and return ; then the measurement of the heavy oil return flow is done before the heavy oil flow control valve to eliminate the error due to the formation of

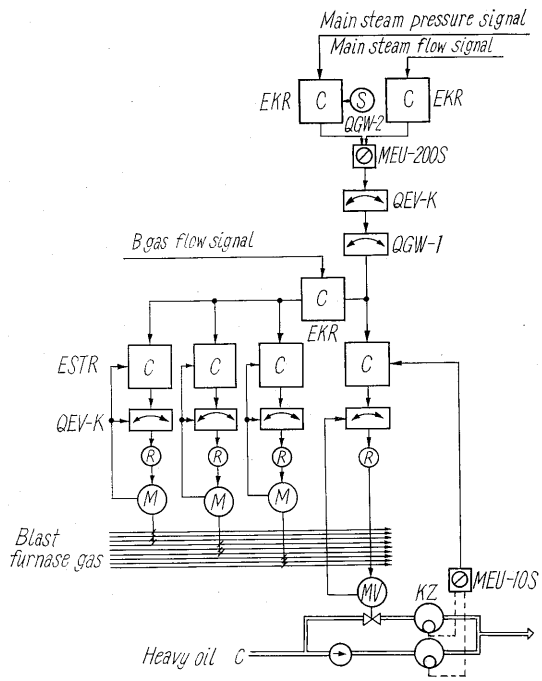

Fig. 5 Instrumentation diagram of fuel control

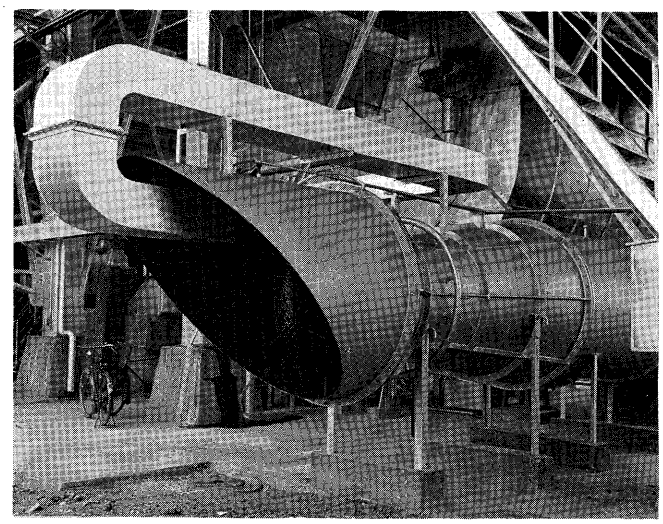

Fig. 6 Venturi for air measurement

foam caused by throttling of the control valve. Return heavy oil is then fed back to the flow controller.

One damper driver (Model K-50/w, w_2) drives three dampers of horizontal row (total of nine dampers: three tiers of three horizontal dampers); to place three vertical tiers in the same position, a position feedback is done to eliminate position deviation.

5. Air Control Equipment

Air required for combustion is controlled with FDF vane by measuring B gas and C class heavy oil flows (as described in item 4); air flow after the air preheater is measured (if necessary) after pressure-temperature compensation and then the signals of the two are compared in the controller.

A theoretical air flow setter should be provided so that the change of theoretical air flow which is due to the variation of fuel calories can be set manually. (Theoretically, it is desirable to measure the calories; however, in practice it is not necessary.) Design the control equipment so that the percentage of execss air can be set up manually by the controller.

The furnace draft control maintains the boiler combustion chamber draft slightly lower than the atmospheric pressure. Thus the air that enters through the chink of the furnace is held to a minimum to maintain boiler efficiency and to prevent the combustion gas from blowing out the boiler. When the detection of the furnace draft is made at the furnace outlet and, as shown in *Fig. 7*, when one controller controls two drivers (K-50 type) which in turn drive two vanes of IDF suction, a position feedback is done to eliminate the deviation of the angle of the vanes.

When the driver is pneumatic, in contrast to an electric driver, it does not have an integrating characteristic and position control is not necessary.

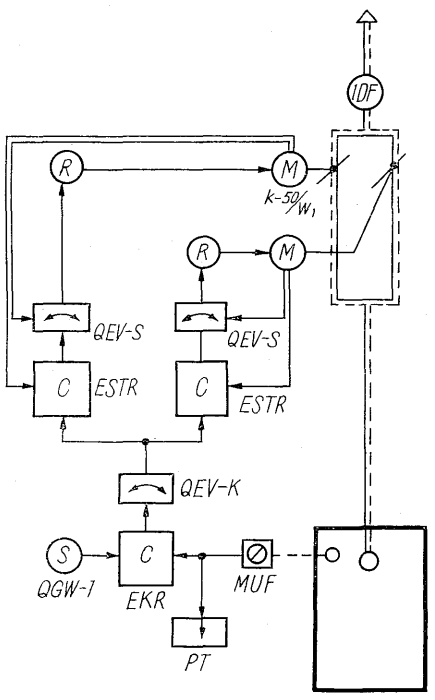

Fig. 7 Instrumentation diagram of furnace draft control

6. Feed Water Flow Control Equipment

The feed water control which affects the final temperature of steam is usually done directly with the steam flow at the boiler outlet. (Refer to II. 3.) In this control, it is controlled so that the per cent of feed water flow is a little less than that of the steam flow: the difference becomes the spray water for steam temperature control. (Refer to *Fig. 8*) For this reason, the spray water must be deflected before the measuring point of feed water flow.

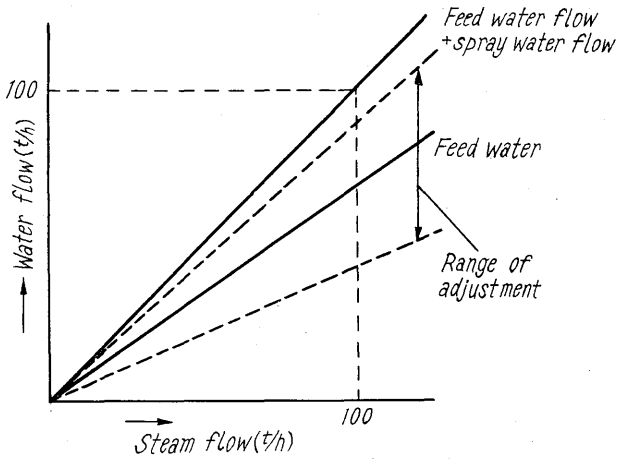

Fig. 8 Ratio of steam flow to feed water flow

This is an important point for the feed water control of a Benson boiler; the method of controlling the feed water flow with steam flow has the advantage in that the feed water flow corresponds to the combustion output of any specific time. Also, since the feed water flow is set always a few per cent less than the steam flow, it is possible to maintain the feed water-spray water ratio constant under all kinds of loads.

Provisions should be made so that the ratio of steam-feed water can be set manually by means of a ratio setter. (Normally, steam: feed water flow = 100 : 95)

When feed water flow is controlled in this manner, if a disturbance occurs, the point of last evaporation moves automatically to a suitable position according to the load at the specific time.

The signal of the steam flow is same signal that was supplied to the fuel line; slight variation of the steam flow is eliminated with attachment of a filter.

7. Steam Temperature Control Equipment

The steam temperature of a Benson boiler is

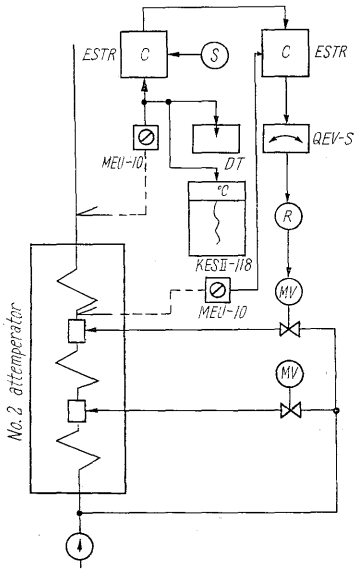

Fig. 9 Instrumentation diagram of No. 2 attemperator control

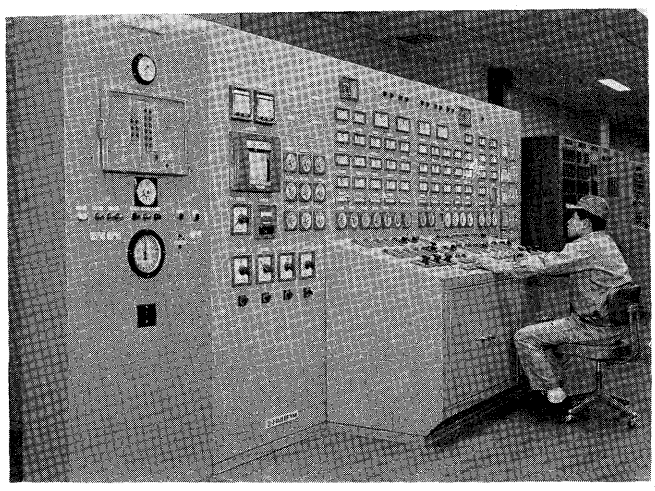

Fig. 10 Instrument panel at control instrumentation room for Nadahama Factory, Kobe Steel Works Ltd.

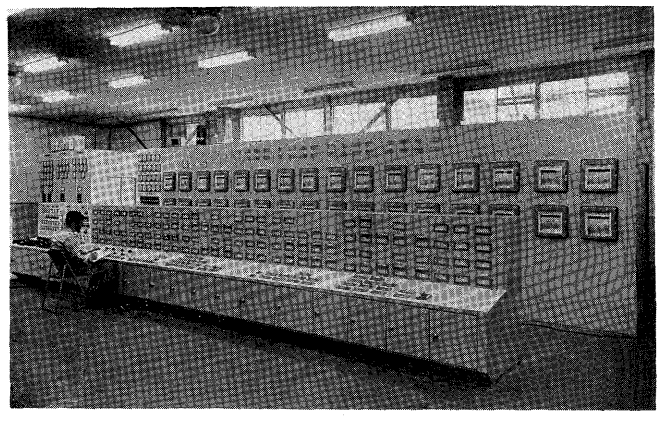

Fig. 11 Instrument panel at central instrumentation room for Tsurumi Iron Works, Nippon Kokan K. K.

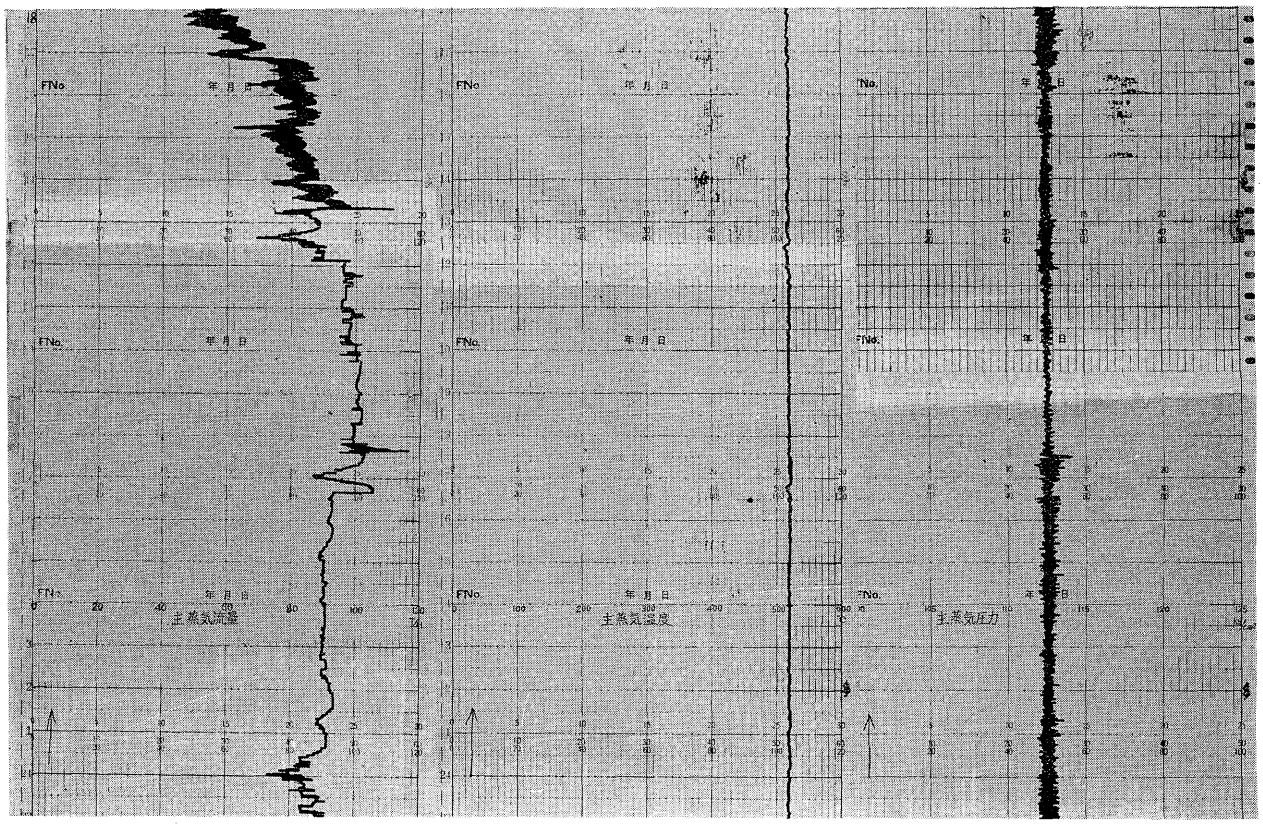

Fig. 12 Recording Chart

determined by the ratio between the combustion output and feed water flow ; if this ratio is changed, the temperature at the boiler outlet becomes a temperature that corresponds to the change. When this ratio is disturbed, it may be thought that control is possible by properly adjusting the feed water flow ; however, since the dead time of this control system is large, it is impossible to bring the steam temperature within the allowable range. To avoid this, a part of feed water is used as spray water to control the temperature, using a method by which the cooling water is sprayed at two stages of No. 1 and end superheaters to control the steam temperature. The water spray device of No. 1 superheater is called No. 1 attemperator and normally sprays 2/3 of the spray water for rough temperature control to maintain the temperature at the end superheater at the boiler design value. With a Benson boiler, however, as the load increases, the temperature of No. 2 superheater usually rises. For this reason, the load factor or the steam flow signal must be cascaded to lower the setting. This is a characteristic of a Benson boiler because the heater of a boiler without drum has no definite heating surface as does a drum boiler.

The water spray device before the end superheater is called No. 2 attemperator ; this system usually has a prolonged dead time : with a fixed set point control, it is not sufficient to compensate disturbances. For this reason, a cascade control is generally used. As shown in *Fig. 9*, the idea is to set the temperature before the end superheater with the temperature of the end superheater outlet in order to hold the end superheater outlet temperature at the specified steam temperature.

III. CONCLUSION

The above is an outline of instrumentation for Benson boiler. Because of its high thermal efficiency and low equipment cost, the number of mono-tube type boilers is increasing and automatic control systems becoming imperative for the safe operation of these boilers.

If this article has been of any help to guide the reader in making plans for the future, we are indeed most grateful.

Assortment of Instrumentation diagram symbols

Thermocouple	
TELEPERM transducer	
Kolben transducer	
Indicator	
Recorder	
TELFEERM controller	C
Setter	S
Operating device	
Diaphragm valve	
Motor valve	M
Damper driver	M