JFE Engineering has developed a new combustion control system that is capable of achieving the stable combustion for various multi-waste-fuels in the circulating fluidized bed boiler (CFB). This system has advanced control functions with a rule-based type multipurpose control. This device is applied to furnace temperature control, exhaust gas stabilization control, and blowing control of slaked lime for the reduction of HCl. The application test was conducted in two CFB plants

(1) High Fuel Adaptability

Because the combustion reaction proceeds in the entire furnace height direction and a circulating circuit for the fuidized particles exists, the CFB boiler has a long reaction time of combustion. For this reason, its adaptability to diverse fuels is high, and mixed combustion of multiple fuels is easy. Its desiccation capacity is also high due to the holding heat quantity of the fuidized particles, enabling direct feed of fuels with a high percentage of moisture content without advance desiccation.

(2) Low Environmental Load

For SOx, dry-type furnace desulfurization is possible by direct injection of limestone into the furnace. Generation of thermal NOx is suppressed due to the comparatively low combustion temperature (850–950°C), and fuel NOx is also reduced by multistage injection of combustion air.

(3) Low Air-Ratio Combustion Possible

The excess air ratio can be set low because the relative velocity between the fuel particles and combustion air is large due to high-speed fuidization, supporting a favorable solid-gaseous reaction.

(4) Economical Equipment (Low Installation Cost)

Because the environmental load is low and special fue gas treatment equipment is not necessary, the equipment composition can be simplifed, reducing equipment costs.

A fowchart of a CFB boiler system is shown in **Fig. 1**.

The combustion chamber comprises a membrane-type water wall, which secures high air tightness and reduces heat loss by radiation. Particles are fluidized by supplying primary combustion air from air nozzles in the bottom of furnace. The fuels are directly thrown into the lower furnace, and that are rapidly stirred and mixed with the fluidized particles in the furnace by this primary combustion air. To realize low NOx combustion, secondary combustion air is injected from the middle of furnace, forming a so-called reduction combusting zone in the space under this stage.

A collecting section (cyclone) which captures fluidized particles and unburned combustible content, and particle recirculation pipe which returns the collecting fluidized particles and other matter to the furnace are provided at the outlet at the furnace top. In the cyclone, these are separated into flue gas and fluidized particles, ash with a comparatively large particle size, etc. The flue-gas which is separated in the collecting section is transported to the convectional heat transfer section together with comparatively small ash, etc. After dedusting by a bag filter, this is released into the atmosphere by way of a chimney. The fluidized particles and relatively large ash recovered by the cyclone are recirculated and returned to the lower furnace as fluidized particles via the seal section and particle recirculation pipe, and the unburned combustible content is after-burned.

Fig. 1 Schematic þow of CFB boiler (KISHU PAPER Co., Ltd.)

3. Features of Control in CFB Boiler

In CFB boilers supplied by JFE, advanced control is realized by adoption of the following control methods in addition to normal boiler control.

3.1 Boiler Master and Fuel Injection Rate Control

Normally, with turbine generators, power generation (or power transmission) control is performed by the demand of power generation (power transmission), and the boiler master performs proportional-integral-derivative control (PID control) of the main steam pressure. In the method adopted here, the output from the boiler master is used as the command value for the fuel input calorie. After assigning the input calorie rates of the respective fuels, which have been set in advance, the charging amounts of the fuels are determined from the unit calorie of each fuel. For the charging systems of each fuels, participation in boiler master pressure control (or not) is selected, and constant input calorie control is performed for the nonparticipating charging systems. With this method, it is possible to maintain a constant total input calorie and suppress fluctuations in boiler output, even when the input calorie ratios of the respective fuels are changed and during backup with another fuel due to troubles in one of the fuel charging systems.

In order to eliminate deviations in boiler master output and the combustion air rate due to changes in the unit calorie of the fuels, calorie compensation control is performed, in which the boiler master output is corrected by a compensation value obtained from the ratio of the predicted main steam flow rate obtained from the fuel charging rate in operation and the actual main steam flow rate.

3.2 Automation of Boiler Operation

In JFE Engineering's CFB boilers, operation of the boiler is automated so that all processes can be per-

The present optimum value is determined so as to satisfy all of these conditions, and this is used as the corrected O_2 concentration value.

4.3 Control of Slaked Lime Blowing Rate for HCl Reduction

In control of the slaked lime blowing rate for HCl reduction, application of feedback control is diffcult because of the large amount of dead time in measurement/control, as well as fuctuations in dead time, due to delays in measurements by the analyzer, time lag in the chemical reaction, the effect of slaked lime deposition in the bag flter, etc. Therefore, the blowing rate is set by a function of the boiler load. Furthermore, due to deviations in the amount of HCl generation, a larger setting value is generally adopted considering the risk of exceeding the regulating value.

In this work, a control system which determines the amount of slaked lime blowing by rule-based control, based on the predicted amount of HCl generated in the future using operational data, was developed in order to optimize slaked lime consumption.

Considering dead time, this control system performs control with a long cycle of 5–15 min.

The concrete control method is outlined below.

(1) Prediction of Future HCl Concentration (**Fig. 4**)

A predictive standard value for the HCl concentration is obtained from the slope of the previous and present HCl sampling values, the previous actual amount of slaked lime, and other information. In cases where the fuel input ratio or the boiler load will change subsequently, between the present sampling and the next sampling, the predictive value is corrected considering these c/consit eC

As the basic concept, the existing control system by distributed control system (DCS) was used as-is, and the Personal computer of the new combustion control system was installed separately from the DCS and made correction calculations in parallel with the DCS. A more optimum operating condition is obtained by giving the results to the existing DCS control system as correction values.

Therefore, the data communication tags and logic for which adds the correction values from the combustion control system was added to the existing DCS. Data communications between the combustion control system and the existing DCS are performed via a newly installed OPC server.

5.3 Test Results and Discussion

(1) Furnace Temperature Optimization Control

An example of the test results at the Iwakuni Power Plant is shown in **Fig. 7**.

In this case, operation using the new combustion control system and operation using only the conventional control were compared for two conditions, these being rough wood : architectural scrap wood ratios of 30 : 70 and 45 : 55. When the architectural scrap ratio was high and the combustion rate was rapid (rough wood : architectural scrap wood ratio = 30 : 70), the effect of the combustion control system in reducing the temperature in the middle of the furnace was clearly apparent.

The effectiveness of the new system in smoothing the furnace temperature and maintaining soundness (<950°C) was also confirmed under the other condition.

In the test as a whole, NOx and CO concentration reduction effects were obtained, and suppression of the other indexes to levels which are not problems could be confrmed. Moreover, the test also confrmed that the new system is effective in reducing fan power consumption because the total amount of combustion air is reduced by the application of this system.

(3) Control of Slaked Lime Blowing for HCl Reduction

The results of the test at the Iwakuni Power Plant are shown in **Fig. 9**.

Control by the combustion control system was performed using 78 mg/Nm^3 as the HCl concentration control target value. The control value for the HCl concentration is 80 mg/Nm^3.

In control of slaked lime blowing, the blowing rate was discretely changed in a relative to the fuctua cystem wor ! twin ihe Hheget ve ue finge ' i vd nn -g 7 fe Htutrol oe ue] o ^ ge ᴀ en M age Hsl ctutuntration