Experiences in Designing and Operating the Latest 1,050-MW Coal-Fired Boiler

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OVERVIEW: In the fossil-fuel power utility area, the large capacity coal-fired boiler has been developed for higher efficiencies. The Tachibana-Wan Thermal Power Station's No. 2 Unit (1,050 MW) was completed for the Electric Power Development Co., Ltd. (EPDC) in December of 2000. It has the advanced steam parameters of 25.0 MPa and 600/610˚C. The 3,000-t/h coal-fired boiler for the unit was supplied by Babcock-Hitachi K.K. (BHK), who confirmed, during the commissioning period, that the boiler meets all of its performance specifications. To achieve these high-level steam parameters, newly developed high-strength materials were used in the high-temperature areas, and the latest combustion technology was used for environmental protection as well as for high levels of efficiency and reliability. This article focuses on the latest boiler technologies and operating experience during the commissioning process.

INTRODUCTION

THE strength of demands for Japanese utility companies to reduce emissions of air pollutants and, in particular, of CO_2, has led to a dramatic improvement in the steam conditions of thermal power plants in Japan, and thus to higher plant efficiencies.[1) As shown in Fig. 1, steam conditions started to improve dramatically from 1995 and Babcock-Hitachi K.K. achieved the 600˚C level of steam conditions for the Electric Power Development Co., Ltd. (EPDC) in 1997[2) at the No. 2 unit of the Matsuura Thermal Power Station and for the Tohoku Electric Power Co., Inc. in 1998 at the No. 2 unit of the Haramachi Thermal Power Station[3).

The EPDC has been paying particular attention to environmental issues and decided to apply an advanced steam condition, 25.0 MPa/600˚C/610˚C, to the No. 2 boiler at Tachibana-Wan (see Fig. 2). This 3,000 t/h coal-fired boiler was supplied by Babcock-Hitachi K.K..

Table 1 gives the principal specifications of the boiler. This plant successfully entered commercial operation in December 2000 and its advanced steam conditions represent the highest level in Japan. This

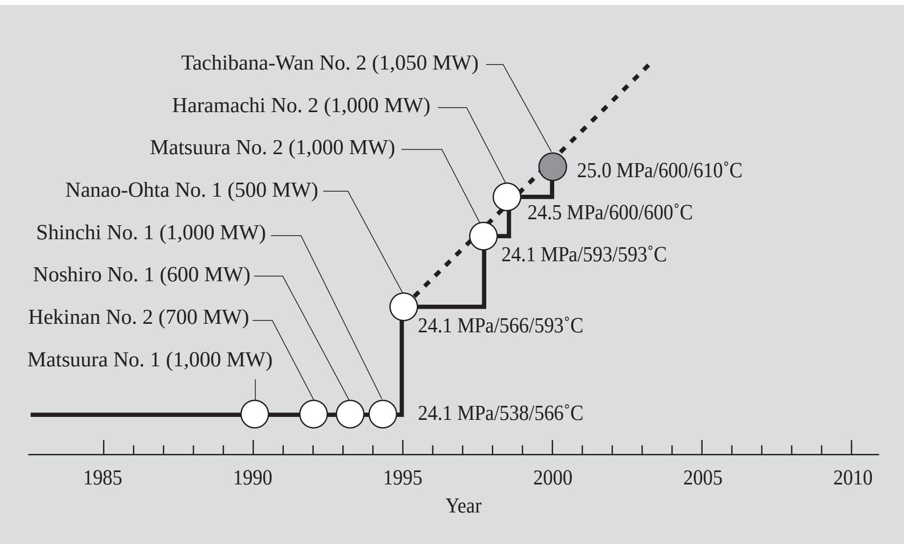

Fig. 1— Improvements in Steam Conditions of Babcock-Hitachi Boilers.
In recent years, steam conditions of coal-fired boilers in Japan have dramatically improved.

article describes the main design features of the No. 2 boiler at Tachibana-Wan, highlighting the use of the advanced steam temperature of 600/610˚C.

MAIN DESIGN FEATURES OF THE BOILER

Fig. 3 is a cross-sectional schematic view of the Tachibana-Wan No. 2 boiler. As this is a medium-load plant burning coals with a wide range of grades, various factors were considered in designing the boiler for sliding-pressure operation with advanced steam parameters.

Fig. 2— Tachibana-Wan Thermal Power Station.
The No. 2 unit is at right.

To achieve high steam temperatures, the numbers of superheaters and reheaters are marginally greater than would conventionally be used. However, the increase in the heating surfaces is kept to a minimum by optimizing the furnace in terms of combustion performance and the slagging potential of the coals the furnace is designed to use, so that the boiler's dynamic response is improved. Furthermore, a three-stage superheater spray system was used to control the temperature of the main flow of steam, while gas-recirculation and gas-biasing dampers were installed to overcome the performance differences encountered in the firing of various imported coals.

Use of High-Strength Materials

When high-level steam conditions are selected, it is essential to use high-strength materials in order to reduce the thicknesses of the walls of parts under pressure, resulting in low level of thermal stress and small pressure drops.

Two austenitic steels, SUS304J1HTB (18Cr-9Ni 3Cu-Nb-N) and SUS321J1HTB (18Cr-10Ni-Ti-Nb), both of which have very high levels of creep strength in the high-temperature region, were selected for use in the pendant superheaters and reheaters. The performance of these materials had been fully confirmed by our earlier experiences with 600˚C-level utility boilers.

Reliable ferritic piping of STPA29 (9Cr-1.8W) and SUS410J3TP (11Cr-2W-0.4Mo) was selected for the superheater headers.

By employing these materials, wall thickness in the high-temperature zone is kept within a similar

Table 1. Main Specifications of the Boiler

Item			Specifications
Boiler type			Babcock-Hitachi supercritical sliding-pressure-operation Benson boiler
MCR	Steam flow	Main	3,000 t/h
		Reheat	2,490 t/h
	Steam pressure	Main	25.0 MPa (g)
	Steam temperature	Main	600˚C
		Reheat	610˚C
	Economizer inlet: feed-water temperature		288˚C
Combustion system			Pulverized-coal fired
Draught system			Balanced draught system
Steam-temperature control system		Main	Water-fuel ratio control and three-stage spray attemperation
		Reheat	Parallel gas dampering and intermediate spray attemperation
Steam-temperature control range		Main	35% ECR – MCR
		Reheat	35% ECR – MCR

MCR: maximum continuous rating
ECR: economical continuous rating

range to that seen in conventional boilers. The strengths of various ferritic steels are compared in Fig. 4.

Combustion System

For environmental protection, the Hitachi NR2 burner has been applied to achieve low levels of emission of NOx (oxides of nitrogen) and high levels of combustion efficiency.

Following on from the development of Hitachi's NR burner in which an innovative concept of in-flame NOx reduction is applied, Babcock-Hitachi K.K. has developed the NR2 burner. This burner features a strengthened flame in terms of high-temperature reduction and achieved extremely low levels of NOx emission and high levels of combustion efficiency[4)].

The Hitachi NR2 burner is based on an improved in-flame NOx-reduction technology, which incorporates two novel devices: a pulverized-coal (PC) concentrator and a space creator. The configuration of the burner is shown in Fig. 5. This burner enables a

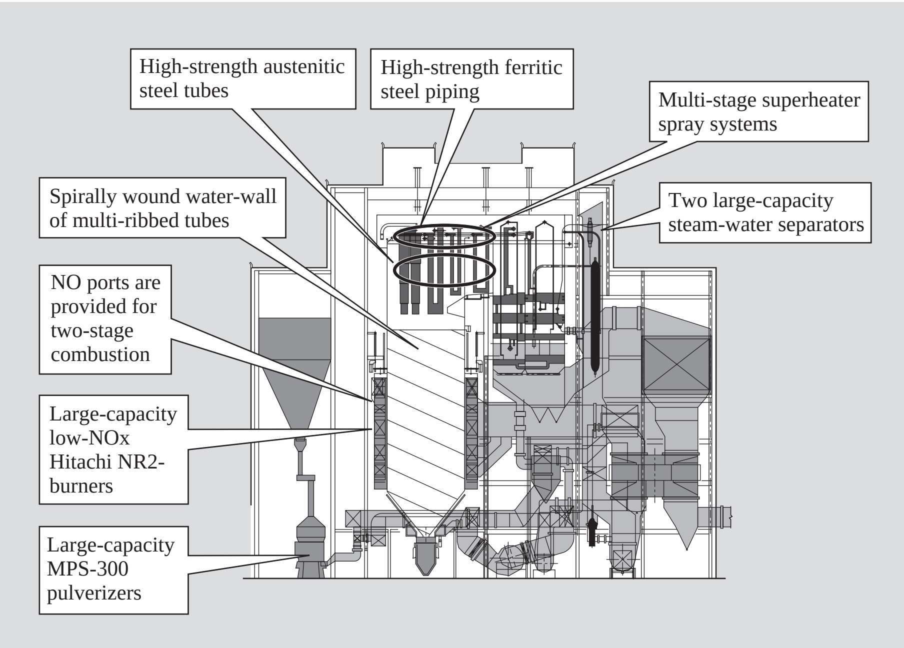

Fig. 3— Technologies Applied in the Tachibana-Wan No. 2 Boiler.
State-of-the-art technologies of not only in terms of combustion technologies and other items, as well as in the steam parameters are incorporated in the design.

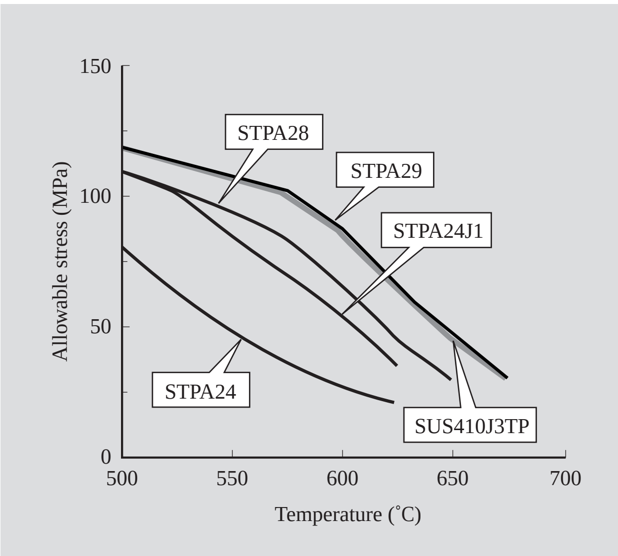

Fig. 4— Allowable-Stress Data on High-Strength Ferritic Steels.
STPA29 and SUS410J3TP are notably strong in the high-temperature region.

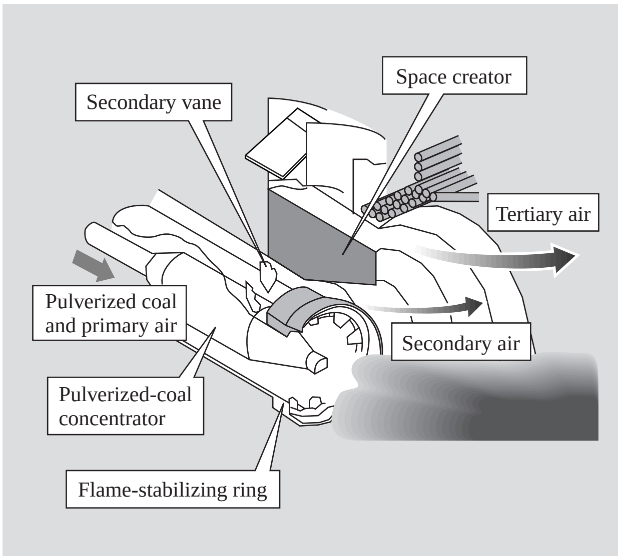

Fig. 5— Configuration of Hitachi NR2 Burners.
The pulverized-coal concentrator and space creator accelerate high-temperature in-flame NOx reduction.

low level of excess air, at only 15%, at the economizer's outlet. This is so when firing any of various kinds of imported coals.

Forty-eight (48) burners are installed, together with a two-stage combustion system, in the Tachibana-Wan No. 2 boiler. These elements are enclosed in a suitably dimensioned furnace.

To fully utilize these burners, obtaining very fine coal is essential. To do so, the No. 2 boiler at Tachibana-Wan has six large-capacity roller-type pulverizers of the MPS300 type, along with rotating classifiers.

ACHIEVEMENTS IN THE COMMISSIONING

Tachibana-Wan No.2 boiler was ignited for the first time in April of 2000. Commissioning continued, with two imported coals being burnt, until December of 2000, when the plant successfully entered commercial operation as had been planned. Stable operation with the advanced steam condition was confirmed in both static and dynamic modes. The main features of the boiler's performance as confirmed during the commissioning process are described below.

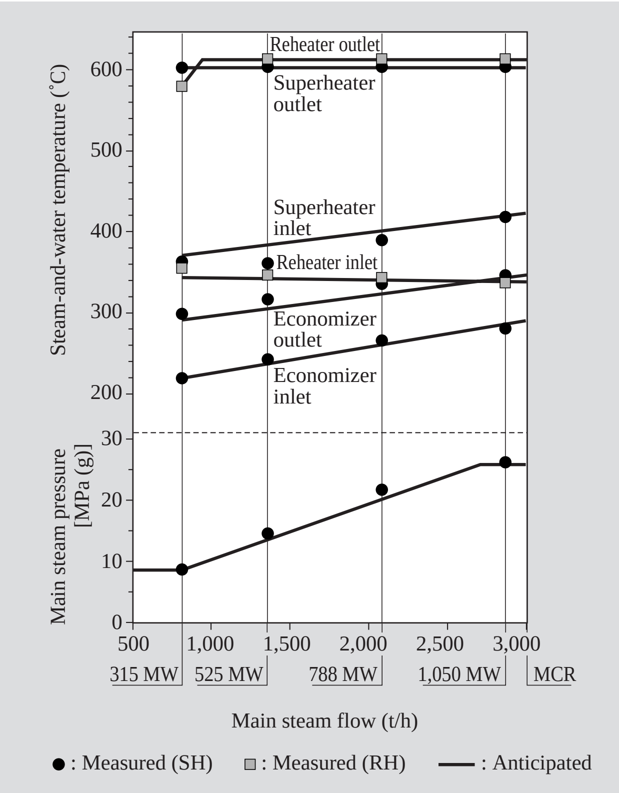

Fig. 6— Steam-and-Water Temperature and Main Steam Pressure Characteristics (Firing A-Type Coal).
The main steam and reheat steam temperatures were at the anticipated values.

Boiler Performance

Fig. 6 shows the steam-and-water characteristics at each turbine load. The main-steam and reheat-steam temperatures were at the anticipated values without causing any alarms. The backend gas temperature and amounts of excess air and unburned carbon in ash (UBC) were well below the designed values. The boiler's level of efficiency was found to be quite satisfactory across the load range.

Combustion Performance

The results of combustion testing are summarized in Fig. 7. The A-type coal has a high fuel ratio (fixed carbon to volatile matter = 2:1) and nitrogen content, which means that the simultaneous reduction of both

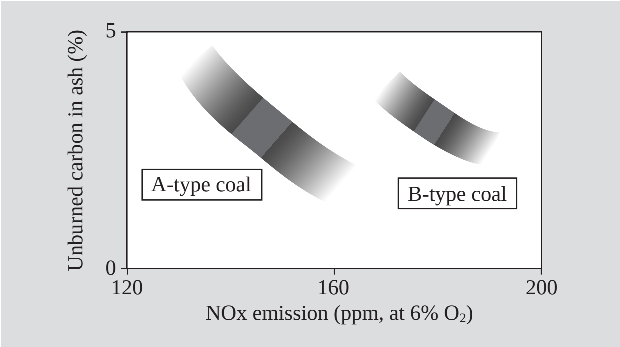

Fig. 7— Combustion Test Results at Rated Load.
The system reduced both UBC and NOx-emission levels.

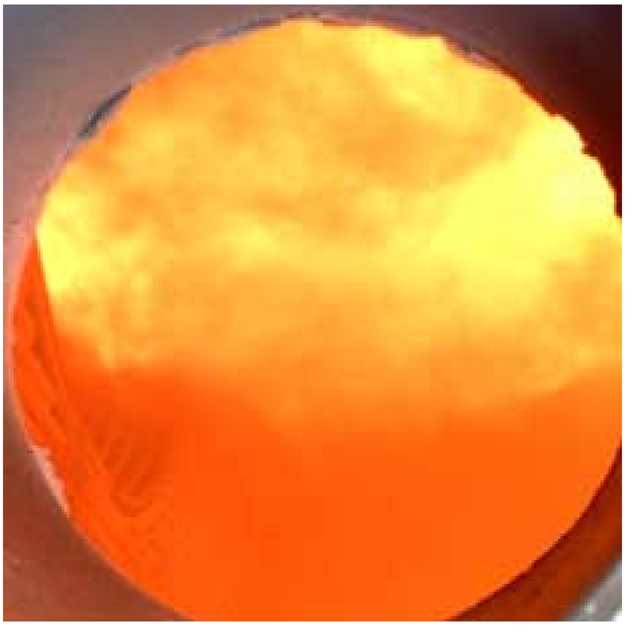

Fig. 8— Flame of Hitachi's NR2 Burner at 35% of ECR.
The burner's flame was very bright and stable during low-load operation.

NOx and UBC is very difficult. In burning the A-type coal, the reduction in UBC was confirmed, as were lower NOx emission levels. The same trend even held when burning the B-type coal, with its higher fuel ratio (= 2.4) and nitrogen content. Fig. 8 shows the flame during burning of the B-type coal at a load of 35% ECR (368 MW). A very bright and stable flame can be maintained at the tip of the fuel nozzle at the low coal-firing load of 35% of ECR, along with stable boiler performance.

CONCLUSIONS

The advanced steam condition of 25.0 MPa/600˚C/610˚C is applied in the Tachibana-Wan No. 2 boiler, which entered service in December of 2000. We confirmed that this latest-model coal-fired boiler, which was designed to work well with a wide range of coal fuels and to have strengthened countermeasures against environmental pollution, met all performance specifications during its commissioning.

We will continue to add improvements in performance and technology, as a contribution to global welfare in the form of better technologies for energy and environmental systems.

ACKNOWLEDGMENTS

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