Design and Operating Experience of the Latest 1,000-MW Coal-Fired Boiler

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ABSTRACT: The Matsuura Power Station No. 2 Unit (1,000 MW) for Electric Power Development Co., Ltd. (EPDC), which was completed in July 1997, has advanced steam parameters of 24.1 MPa and 593°C/593°C for the first time in Japan. The 2,950-t/h coal-fired boiler for the unit was supplied by Babcock-Hitachi K.K. (BHK), who confirmed that the boiler met all performance specifications during the commissioning period. To achieve these high steam parameters, new high-strength materials were used in the high-temperature areas, and the latest combustion technology was used not only for high efficiency and reliability but also for environmental protection. Furthermore, a sophisticated control system STARTS (self-tuning ART system) was incorporated into the design to improve control when various coals are burned. This paper summarizes the boiler design and operating experience during the commissioning.

INTRODUCTION

WITH the strong demands for Japanese utility companies to reduce air pollutant emissions, particularly CO_2, there has been a drastic improvement in steam conditions of thermal power plants in Japan.[1)] Electric Power Development Co., Ltd. (EPDC) has been paying special attention to environmental issues and decided to apply an advanced steam condition of 593°C/593°C to Matsuura Power Station No. 2 Unit, which resulted in a significant improvement in plant efficiency. A bird's-eye view of Matsuura Power Station is shown in Fig. 1.

The Matsuura No. 2 Unit, whose steam parameters are 24.1 MPa/593°C/593°C, achieved the highest live

Fig. 1—Bird's-Eye View of the Matsuura Power Station.
Both coal-fired boilers (1,000-MW output each) were supplied by Babcock-Hitachi K.K.

steam temperature in Japan and started commercial operation in July 1997. Furthermore, subsequent units to be completed after 1997 will have 600°C-level steam conditions, as shown in Fig. 2.

This paper describes the main design features of the Matsuura No. 2 boiler, highlighting the use of an advanced steam temperature of 593°C/593°C.

MAIN DESIGN FEATURES OF THE BOILER

A side view of the Matsuura No. 2 boiler is shown in Fig. 3 . As it is a medium-load plant burning a wide range of coals, various factors were considered in designing the boiler for sliding pressure operation with advanced steam parameters.

The area of the heating surfaces of the superheaters and reheaters was increased to achieve a high steam temperature, but the increase was limited by optimizing furnace size considering combustion performance and the slagging potential of the coals designed to use. The result was an improvement in boiler dynamic response. Furthermore, a three-stage superheater spray system was used for the main steam temperature control, while gas recirculation and gas biasing dampers were installed to overcome the performance difference when firing various coals.

Use of High-Strength Materials

When high steam conditions are selected, it is essential to use high-strength materials in order to reduce the wall thickness of pressure parts, resulting in a low thermal stress and pressure drop.

For pendant superheaters, the austenitic steel SUS304J1HTB (18Cr9Ni3CuNbN), which has a very high creep strength at high temperatures, was selected after extensive testing of its performance.

For pendant reheaters, another high-strength austenitic steel, SUS321J1HTB (18Cr10NiTiNb), was selected.

Reliable ferritic piping of KA-STPA28 (9Cr1MoVNb) was selected for the main steam piping and high-temperature superheater headers, and welded

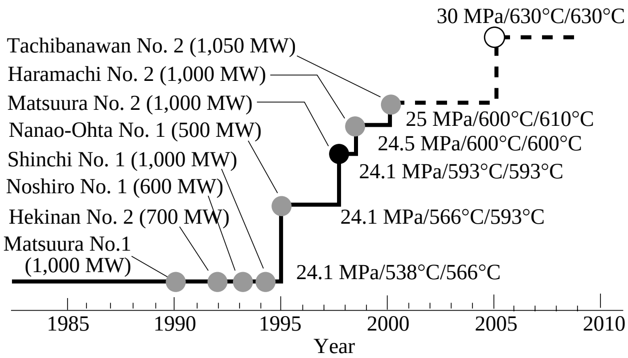


Fig. 2—Improvements in Steam Conditions of Babcock-Hitachi Boilers.
Main steam temperature of 600°C is now the standard in Japan.

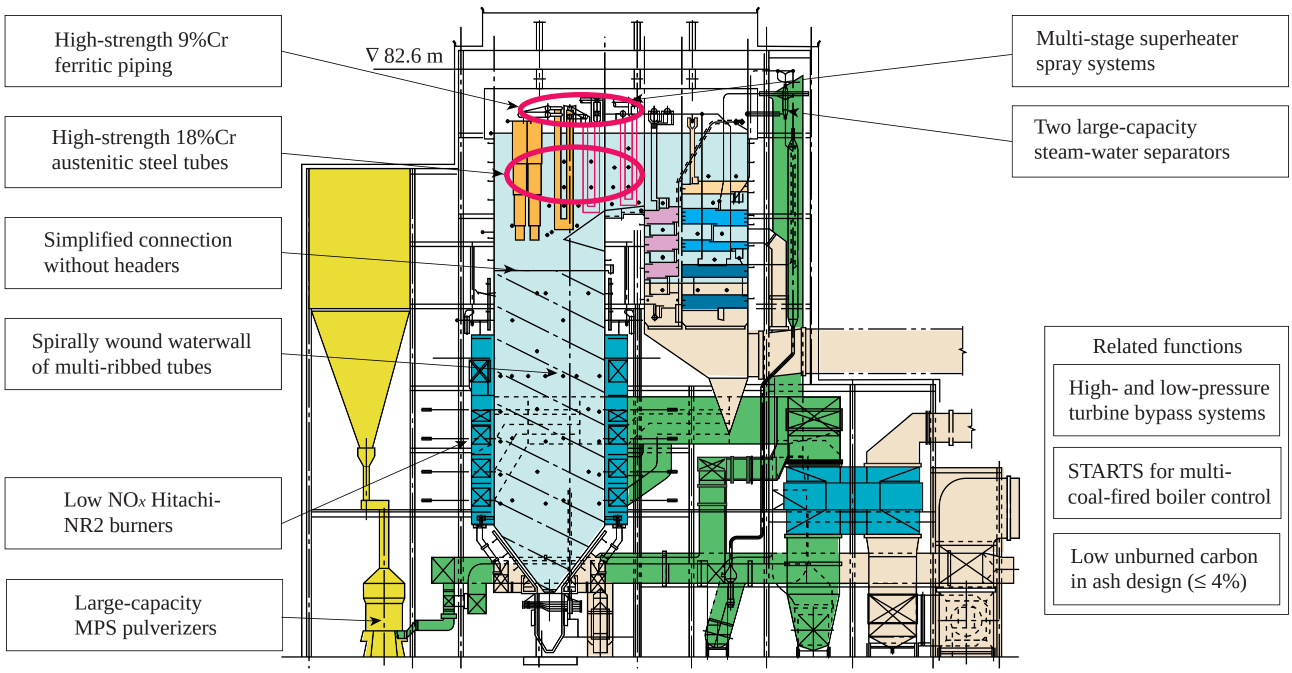


Fig. 3 — Technologies Applied to Matsuura No. 2 Boiler.
The design is rationalized for efficient, reliable, and economical operations.

piping of the same steel was used for the reheater outlet header and hot reheat piping.

Using these materials enabled the wall thickness in high-temperature zones to be kept similar to that of conventional boilers. The strengths of austenitic steels are compared in Fig. 4.

Note that the generation of inner oxidation scale remains minimum up to 700°C when stainless tubes are shotblasted[2] and both of the above-mentioned austenitic steels were internally shotblasted when manufactured.

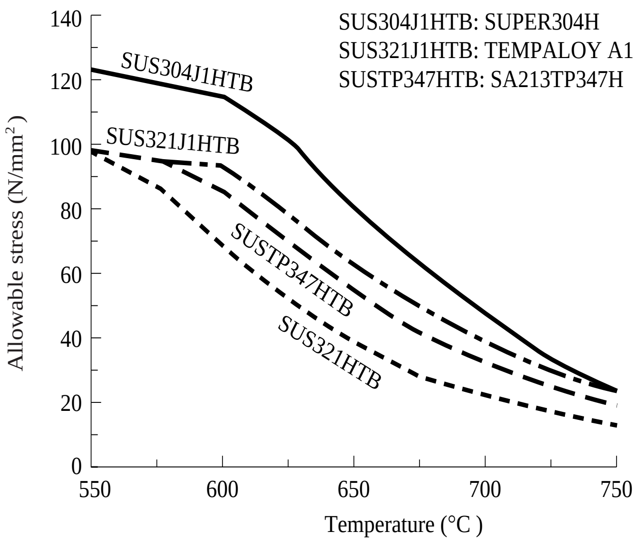


Fig. 4—Allowable Stress Data of High-Strength Austenitic Steels.
High-strength SUS304J1HTB has been widely used for the first time in utility boilers.

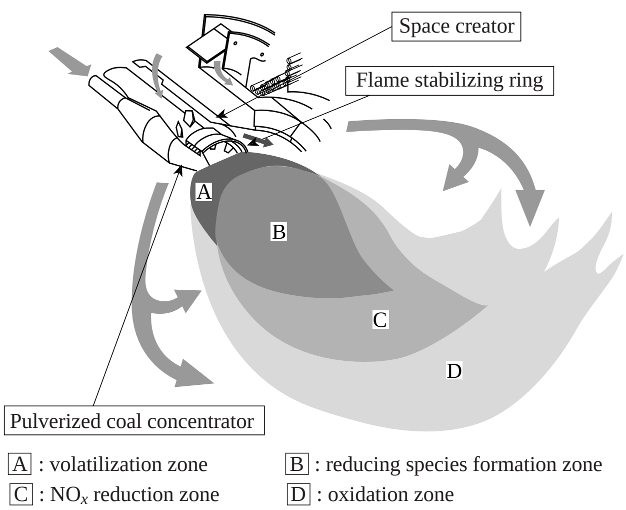


Fig. 5—Flame Structure of Hitachi-NR2 Burners.
Pulverized coal concentrator and space creator accelerate high-temperature in-flame NO_x reduction.

Combustion System

The Hitachi-NR2 burner is based on enhanced in-flame NOx reduction technology, which incorporates two novel devices: a pulverized coal (PC) concentrator and a space creator. The NOx reduction principle is shown in Fig. 5.[3]

Fifty-six Hitachi-NR2 burners are installed in the Matsuura No. 2 boiler together with a two-stage combustion system in a suitably dimensioned furnace. As a result, NO_x emissions could be reduced to 180 ppm (6% O_2) at the boiler outlet and unburned carbon in fly ash to less than 4% even if burning South African coal of low volatile and high nitrogen content.

To fully utilize the burner, it is essential to obtain very fine coal. Matsuura No. 2 boiler has seven large-capacity roller-type pulverizers of MPS 118 type incorporating rotating classifiers.

OPERATING EXPERIENCE

The boiler was first ignited in November 1997 and commissioned with two imported coals until July 4th, 1998. All specifications were met and satisfactory performance was confirmed.

Boiler Performance

Stable operation was confirmed at each load with the advanced steam parameters of 24.1 MPa/593°C/593°C without any alarms. Backend gas temperature, excess air, and unburned carbon in ash (UBC) were well below the design values and boiler efficiency was found to be quite satisfactory across the entire load range.

Combustion Performance

Combustion test results are summarized in Fig. 6 and main coal analysis data is also included. Both coals have a high fuel ratio (fixed carbon to volatile matter) and nitrogen content, which means that simultaneous NO_x and UBC reduction is very difficult. The specified performance was met with both coals, and by raising the rotation speed of the pulverizer rotating classifiers, NOx and UBC could be effectively reduced by NR2 burners.

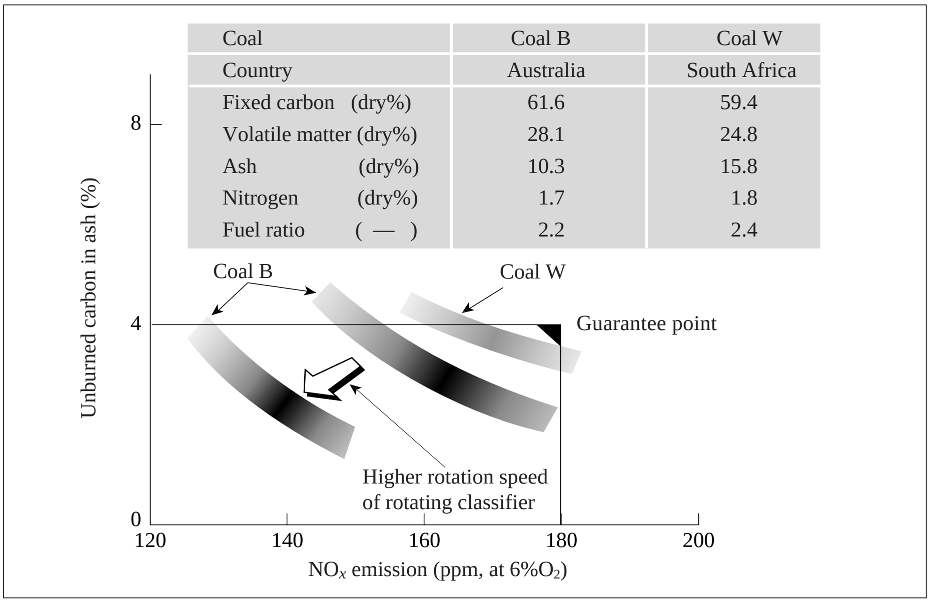
Dynamic Performance

Dynamic performance was also tested during the commissioning period. With a load changing rate of 4%/min between 500 MW and 1,000 MW, variations in steam pressure and temperatures were within the allowable values. A high- and low-pressure turbine bypass system enabled the boiler to achieve smooth and quick start-up (Fig. 7) and shutdown and the boiler met the medium-load operating conditions.

STARTS: ADAPTIVE CONTROLLER FOR BOILERS

Recently, utility boilers have been required to burn various kinds of coals having heavy slagging or slow-burning profiles. In the prior art of boiler control shown at the bottom of Fig. 8, where coal characteristics are regarded as an averaged value specified by the coal code, further characteristic dispersion from the average is compensated by output feedback of certain differences from the set points in steam pressure and temperature. On the other hand, STARTS is designed to compensate for drift of the plant dynamics before certain differences occur in the pressure and temperature. It has been developed under cooperation between EPDC and BHK.[4)]

STARTS consists of a pulverizer and furnace controlling subsystems, where drifted-dynamics-influenced state variables estimated by observers, are fed back to manipulations such as the pulverizer inlet coal flow and furthermore, the identified parameters dominating the dynamics are reflected on the subsystems. In short, the strategy of the controller is to refer to parameters and control state variables, which change faster than the steam pressure and temperature. STARTS was applied to this No. 2 boiler for the first



Coal	Coal B	Coal W
Country	Australia	South Africa
Fixed carbon (dry%)	61.6	59.4
Volatile matter (dry%)	28.1	24.8
Ash (dry%)	10.3	15.8
Nitrogen (dry%)	1.7	1.8
Fuel ratio (—)	2.2	2.4

Fig. 6—Combustion Test Results at Rated Load.
NOx emissions can be greatly reduced by improving coal fineness when the rotation speed of the rotating classifier is raised.

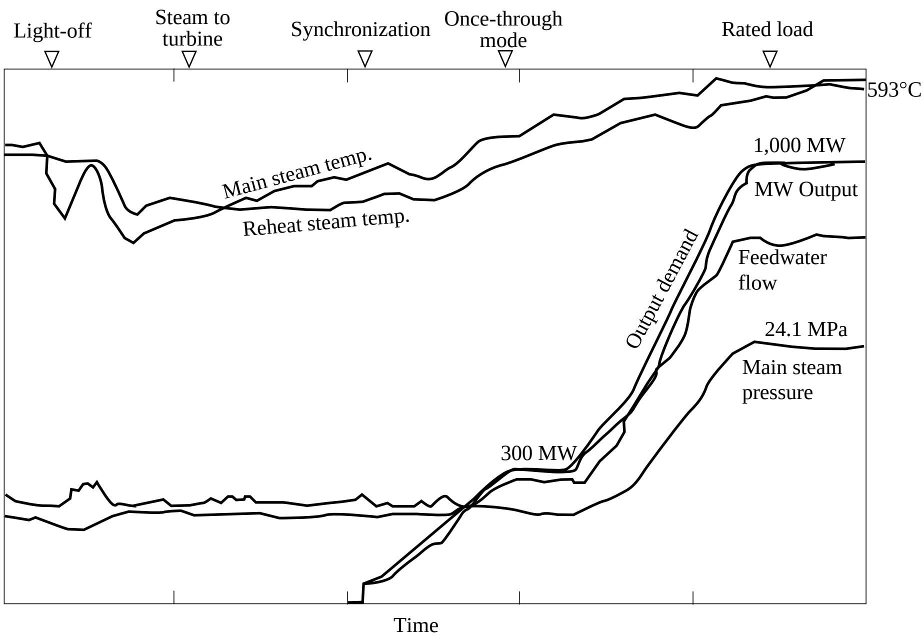
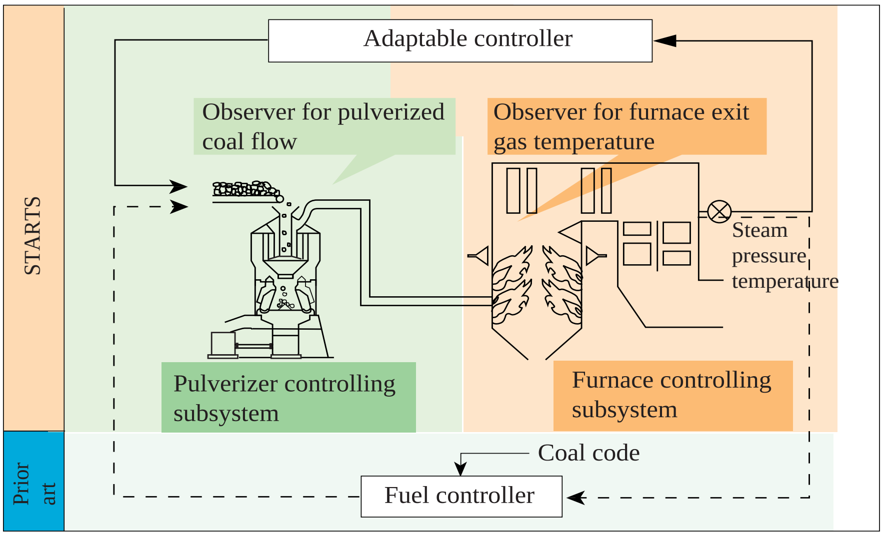


Fig. 7—Hot Start Trend Data.
Stable operation was achieved under not only static but also dynamic conditions.



STARTS: self-tuning art system

Fig. 8—STARTS: Control System for Multi-Coal-Fired Boiler.
STARTS consists of two main sub-systems: the pulverizer and the furnace.

time and was found to be very effective for stable operation under static and dynamic conditions when firing various coals.

CONCLUSIONS

The Matsuura No. 2 boiler, which has the most advanced steam condition of 24.1 MPa/593°C/593°C in Japan, represents an important step towards improved steam conditions. Detailed design is proceeding to apply new ferritic pipings, HCM12A and NF616, to the 1,050-MW coal-fired boiler Tachibanawan No. 2 Unit for EPDC, which has steam conditions of 25 MPa/600°C/610°C. BHK expects to be able to raise steam conditions in power plants to levels such as 30 MPa/630°C/630°C in the near future, and the ultimate target is a 700°C-class plant that can compete with other high-efficiency plants such as IGCC (integrated coal gasification combined cycle). BHK continues to play a key role in the development of advanced steam boilers and contributes to global welfare and environmental protection.

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