

Design Features and Commissioning of the 700 MW Coal-Fired Boiler at the Tsuruga Thermal Power Station No. 2

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The 700 MW coal-fired supercritical sliding pressure boiler at Hokuriku Electric Power Co., Inc., Tsuruga Thermal Power Station No.2 was designed based on the high-performance and reliable 500 MW boiler at the same Power Station No.1. Applying elevated steam of 593/593 °C, our state-of-the-art low-NOx combustion A-PM burner, A-MACT and MRS pulverizer technology, this boiler has achieved the highest combustion performance with extremely low NOx emission and unburnt carbon together with outstanding boiler operation. This paper reports the design features and operation results of the boiler, e.g., (1) extremely low NOx and unburnt carbon due to cutting-edge combustion and (2) superior boiler operating performance and minimum 15% load in exclusive coal firing.

1. Introduction

The 700 MW boiler at Hokuriku Electric Power Co., Inc., Tsuruga Thermal Power Station No.2, planned and installed as a latest coal-fired supercritical sliding pressure operation once-through boiler for various kinds of coal, started commercial operation on Sept. 28, 2000, after smooth commissioning. This boiler not only utilizes experience gained in the installation and operation of the existent 500 MW boiler⁽¹⁾ at the Power Station No.1, but also employs advanced technology developed by Mitsubishi Heavy Industry Ltd. (MHI) so as to operate at high-efficiency with various coals, under intermediate load operation, and possess the environmental protection, etc. required for coal-fired power generation in the new century. This report introduces the features and the operational data of this boiler.

The major features in the design are as follows:

- (1) Ensured reliability by following the basic design concepts of the existent 500 MW boiler which has demonstrated high-performance and reliability
- (2) High temperature steam conditions (24.1 MPa X 593/593°C) and high efficiencies over the whole load range by using sliding pressure operation
- (3) High reliability in the high temperature steam condition boiler by applying new materials (Ka-SUS310J1TB, Ka-SUS304J1HTB, Ka-SUS410J3TB/TP⁽²⁾, Ka-STBA24J1⁽²⁾) with excellent in anti-high temperature corrosion, anti-steam oxidation, and high temperature strength properties
- (4) Usable with various kinds of coal (128 kinds of design coals)
- (5) Extremely low NOx (less than 150 ppm) combustion by employing A-PM (Advanced-Pollution Mini-

- num) burners⁽³⁾ and a new A-MACT (Advanced-Mitsubishi Advanced Combustion Technology)
- (6) Reduced unburnt carbon in fly ash (less than 5%) and minimum load in exclusive coal firing (15% ECR) by employing an MRS (Mitsubishi Rotary Separator) pulverizer equipped with a two-stage separator consisting of rotary and fixed type.
- (7) Simplified facility and reduced auxiliary power

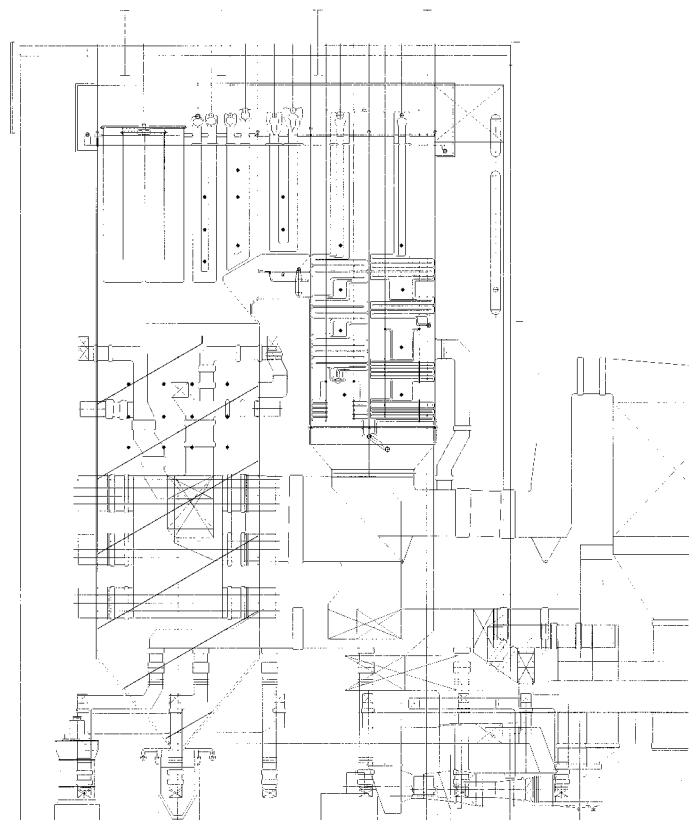


Fig. 1 Boiler general arrangement side view
 Arrangement of heating tubes, major auxiliaries, burners, draft air duct and flue gas duct are shown.

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consumption by using a secondary pass distribution damper as a reheater steam temperature control system

- (8) Improved control functions by employing the latest overall control system; DIASYS-SEP (Digital Intelligent Automation System-Software Enriched Processor), such as the boiler automatic control, mill/burner automatic control, etc.
- (9) Reduced construction period by applying the SBS (Steel Structure Boiler Simultaneous Construction) construction method suitable for small area

2. Measures for use of various kinds of coal and for elevated steam temperature conditions

The major specifications of this boiler are shown

in **Table 1**. The side view is shown in **Fig. 1**.

Four kinds of coal shown in **Table 2** were used during commissioning. The furnace size was designed to be basically similar to the No.1 boiler, taking into consideration firing the various coals (128 kinds) and enabling mixed firing with sub-bituminous coal.

In order to cope with a high steam temperature up to 593/593°C, high temperature strength materials were adopted for the pressure parts to ensure reliability. The following new materials were chosen: 18Cr steel (Ka-SUS304J1HTB) and 25Cr steel (Ka-SUS310J1TB) for the high temperature heating tubes of the superheater and reheater, 2Cr steel (Ka-STBA24J1) and 12Cr steel (Ka-SUS410J3TB) for the high temperature non-heating tubes, and 12Cr steel

Table 1 Boiler major specifications

Boiler type	Mitsubishi supercritical sliding pressure operation once-through boiler radiant reheat type (indoor type)		
Furnace type	Spiral tube type hopper bottom single furnace		
At maximum continuous load (MCR)	Steam flow rate	Main steam	2 120 000 kg/h
	Steam pressure	Superheater outlet	25.0 MPa
	Steam temperature	Superheater outlet Reheater outlet	597°C 595°C
Fuel	Coal, A-oil (25% MCR capacity)		
Combustion system (NO _x -reduction method)	Circular firing system (A-PM burner + new A-MACT method)		
Pulverized coal-firing system	Unit direct pressurizing method		
Draft system	Balanced draft system		
Primary air draft system	Cold primary air fan method		
Heat recovery method for start	Boiler water circulation pump system		
Steam temperature control range	Main steam	From MCR up to 30% load	
	Reheat steam	From MCR up to 50% load	
Steam temperature control system	Main steam Reheat steam	Feed water/fuel ratio, spray Gas distributing damper, excess air ratio, spray (at load change, for emergency)	
Major auxiliaries	Coal pulverizer	Mitsubishi MRS: 6 sets	
	Forced draft fan	Variable blade pitch axial flow type: 2 sets	
	Primary air draft fan	Variable blade pitch axial flow type: 2 sets	
	Induced draft fan	Variable blade pitch axial flow type: 2 sets	
	Air preheater	Regenerative type: 2 sets	
	DeNO _x system	Dry catalytic NO _x removal system: 2 sets	

Table 2 Used coal properties

				Lemington coal	Workworth coal	Satui coal	Blair athol coal
Higher heating value		AR (As Received)	kJ/kg	29 220	29 530	28 760	28 470
Total moisture		AR (As Received)	wt %	8.2	9.8	10.0	17.7
Proximate analysis	Inherent moisture	AD (Air Dry)	wt %	2.8	3.5	5.5	6.2
	Fixed carbon	AD (Air Dry)	wt %	49.7	51.9	43.0	57.1
	Volatile matters	AD (Air Dry)	wt %	34.3	34.3	44.5	28.5
	Ash	AD (Air Dry)	wt %	13.2	10.3	7.0	8.2
Fuel ratio				1.45	1.51	0.97	2.00
Ultimate analysis	Carbon	Dry	wt %	72.80	75.14	74.16	74.21
	Oxygen	Dry	wt %	6.69	7.49	10.81	10.51
	Hydrogen	Dry	wt %	4.81	4.98	5.85	4.49
	Nitrogen	Dry	wt %	1.54	1.70	1.30	1.61
	Total sulfur	Dry	wt %	0.36	0.42	0.53	0.42
Grindability			HGI	48	50	40	59

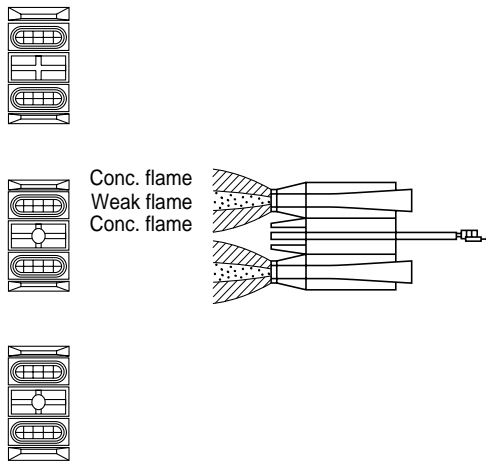


Fig. 2 Outline drawing of A-PM burner

The A-PM burner has low NO_x performance and excellent ignition stability. The burner has excellent maintainability, reliability, and durability because of its simple structure.

(Ka-SUS410J3TP) for the main steam pipes and high temperature reheater steam pipes.

3. Measures for extremely low NO_x combustion and reduction of unburnt carbon in fly ash

The latest low NO_x and low unburnt carbon combustion system combined with an A-PM burner, new A-MACT in-furnace DeNO_x method, and MRS pulverizer with a two-stage separator was adopted. This system was first commercially employed in the 1 000 MW boiler at Chugoku Electric Power Co., Inc. Misumi Thermal Power Station No.1⁽⁴⁾ to reduce NO_x and unburnt carbon in fly ash.

(1) A-PM burner

The A-PM burner is MHI's most advanced low NO_x burner not only realizing an even lower NO_x in comparison to the conventional continuous wind box type PM burner, it also reduces the number of the wind box dampers and improves the accessibility to the burner part by making the wind box a split type, and therefore a simple structure with excellent maintainability, reliability, and durability (**Fig. 2**).

Although a PM burner reduces NO_x by separating the flames into the conc. flames with a high coal-air ratio and weak flames with a low coal-air ratio, the A-PM burner reduces NO_x by forming a single flame coaxially composed of a conc. peripheral part and a weak core part simultaneously maintaining ignition stability by the peripheral conc. part. In other words, it is intended to improve the ignition performance as a whole burner, form a NO_x reducing zone having a low air ratio at a higher temperature, and realize an extremely low NO_x combustion by utilizing both the burner by itself, and the whole furnace in combination with additional air described later.

(2) New A-MACT in-furnace DeNO_x process

The new A-MACT process shown in **Fig. 3** is in-

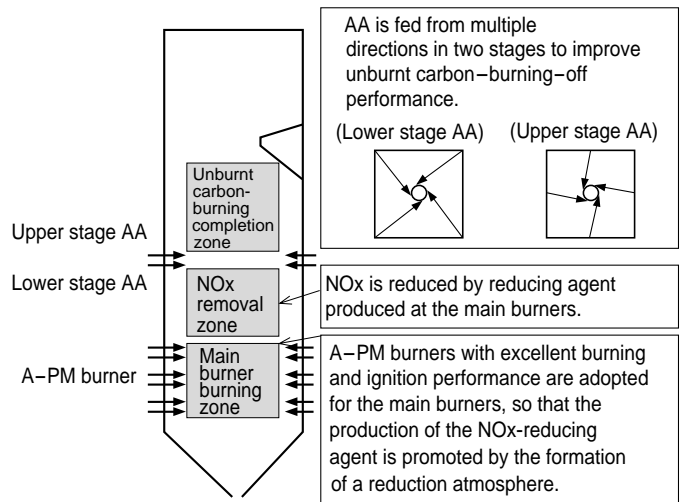


Fig. 3 New A-MACT in-furnace DeNO_x system

Additional air (AA) is fed from multiple directions in two stages to improve the unburnt carbon-burning-off performance and reduce NO_x emissions.

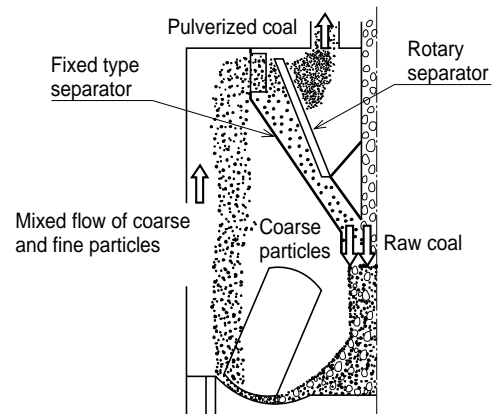


Fig. 4 MRS pulverizer

Coarse particles after separation are uniformly mixed with raw coal by the two-stage separator consisting of both rotary and fixed type separators, so that mill vibration at the high fineness zone is reduced.

tended to further reduce NO_x by the same amount as unburnt carbon. It employs the multi-additional air (AA) feeding method having air ports provided at two stages, in each furnace corner for the lower stage and each wall center for the upper stage, to complete burning, and therefore the mixing of the AA and flames is promoted and the burning-off performance of unburnt carbon is improved in comparison to the conventional single stage AA feeding.

(3) MRS pulverizer

This boiler is provided with a MRS pulverizer realizing stable production of even finer pulverized coal by two-stage separator having fixed type separator integrated with a conventional MRS pulverizer⁽⁵⁾ realizing a greater fineness by rotary separator alone and demonstrating a high performance in the No. 1 boiler. (**Fig. 4**.)

As shown in **Fig. 5**, the MRS pulverizer can remarkably reduce coarse particles of 100 mesh (149 μm) or

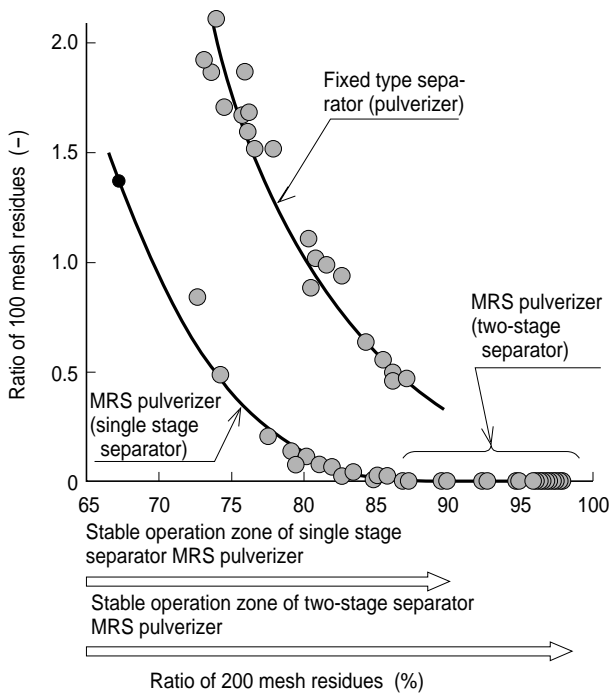


Fig. 5 Fineness of pulverized coal
The MRS pulverizer with the two-stage separator is capable of stable operation at a high fineness zone.

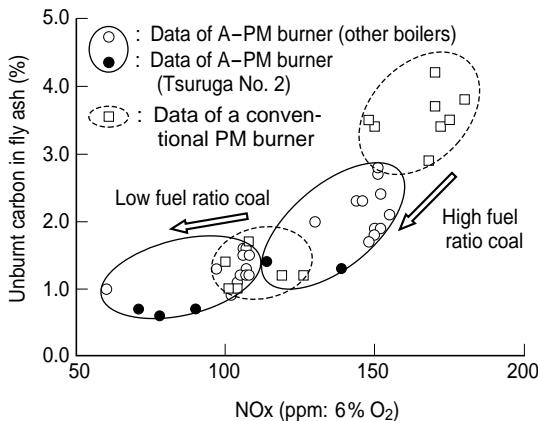


Fig. 6 Measured NOx emissions and unburnt carbon in fly ash
Extremely low NOx emissions and low unburnt carbon in fly ash were demonstrated by the combination of the A-PM burner, new A-MACT, and MRS pulverizer.

larger that plays the dominant role in increasing unburnt carbon. However, because coarse particles separated by the rotary separator pile on the raw coal on the grinding table, slip vibration occurs when the coarse particles are caught between the rollers, causing the stable operation to be hard to maintain at a high fineness. Therefore, the fixed type separator is integrated to return the coarse particles to the center of the table and mix them with raw coal, so that the mill vibration can be controlled to ensure stable operation even at a high fineness containing fine particles with 90% or more passing 200 mesh.

(4) Realization of low NOx and low unburnt carbon in fly ash

The combustion performance of low NOx and low

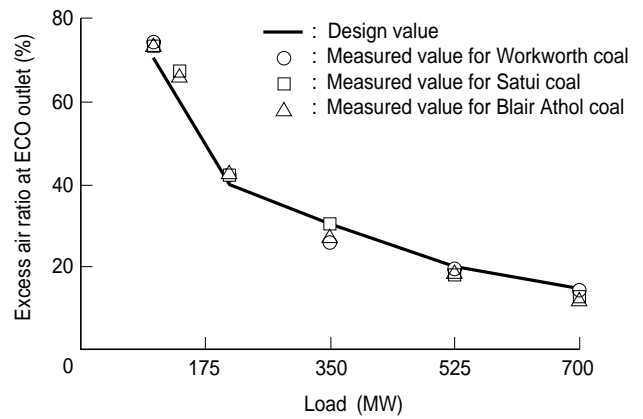


Fig. 7 Low excess air performance
Excellent combustion stability and low excess air combustion were realized.

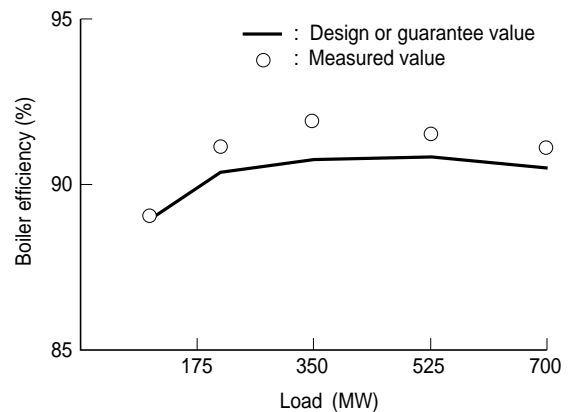


Fig. 8 Boiler efficiency at performance test
High efficiency operation over the whole load range was realized by achieving low excess air ratio and low unburnt carbon.

unburnt carbon in fly ash is remarkably superior to the combination of the conventional PM burner and MRS pulverizer (Fig. 6) and also an excellent low O₂ combustion performance is demonstrated such that low excess air operation of 15% or less (Fig. 7) can be performed at 100% load.

4. Boiler performance

The boiler efficiencies based on the performance test results are shown in Fig. 8.

The unburnt carbon loss was reduced and the low excess air operation was realized by the combination of the A-PM burner, new A-MACT, and MRS pulverizer. This resulted in excellent measured boiler efficiencies completely exceeding the guarantee or design figures over the whole load range from 100% load up to a minimum load of 15%. These results guaranteed the high efficiency operation of the whole plant.

For the steam temperature characteristics, the predicted main steam and reheat steam temperatures could be maintained over the whole load range for all used coals, within the suitable ranges of controlling parameters for the SH spray and gas distribution damper.

Introducing a new control method⁽⁶⁾ applied to various kinds of coal by fuzzy logic for presuming the furnace conditions and heating surface conditions, an excellent controllability was confirmed during commissioning with four used coals chosen for their widely diverging properties.

It was also confirmed that exclusive coal firing at 15% minimum load can be achieved with operating stably, automatically, and continuously.

5. Load swing and unit start-up characteristics

The APC was adjusted in four load bands (530 MW ↔ 700 MW for Band I, 380MW ↔ 560MW for Band II, 315MW ↔ 420MW for Band III, and 210MW ↔ 315MW for Band IV) and in load changing rate (4%/min for Bands I to III and 2%/min for Band IV). The deviation in the unit outputs, steam pressures, and steam temperatures were controlled within the prescribed figures by the application of the latest overall control system, DIASYS-SEP, so that the good results were obtained.

Also, in the unit start-up tests, the unit could be started up within the planned time for each start-up mode, and also it was confirmed that the unit is capable of hot start-up with stopping BRP (boiler water recirculation pump) without any problem.

6. SBS construction method

Because this boiler needed to be installed in a small area and therefore the large-scale zone module construction⁽⁷⁾ could not be applied, the SBS construction method was adopted. In this method, the main piping, ducts, and pulverized coal piping were installed in parallel with steel structure erections, and then the main ceiling beams and the upper pressurized parts were lifted and installed as one block.

The adoption of this method extended the scope of modules and blocks assembled in shop and enabled the application of "just-in-time" physical distribution management, thereby reducing the marshalling in yard, mitigating traffic jams by reducing in personnel and accommodations, relieving congestion while unloading by reducing of the number of assigned vessels, and leveling the site work, the construction period could be shortened to 22 months, from the first steel structure erection to the initial firing, and simultaneously work safety could be improved by the reduction of elevated work at site.

7. Conclusion

The Tsuruga No. 2 boiler demonstrated its excellent environmental adaptability, boiler static characteristics and combustion performance achieving the lowest levels of O₂ combustion, NO_x, and unburnt carbon. This was achieved by using a design concept similar to the existent No. 1 boiler, which had already demonstrated high performance and reliability and additionally by the effective combination of a elevated steam temperature and the latest technology (such as the A-PM burner, new A-MACT, and MRS pulverizer). Furthermore, from the point of view of operation, excellent middle load operation including excellent capability to fire various coals, the dynamic performance, the start-up performance, and the minimum load operation were verified.

MHI utilizes the previous experience obtained through the completion of the Tsuruga No. 2 boiler to future designs and also intends to work continuously to further develop and improve technology required by the world.

Finally, the authors would like to express our gratitude to the persons concerned of Hokuriku Electric Power Co., Inc. for their courteous guidance and cooperation given to us over the whole period from the basic design through to the commissioning.

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