

Retrofitting of Mitsubishi Low NOx System

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Mitsubishi Heavy Industries, Ltd. (MHI) has long been engaged in low NOx combustion R & D and put them into practical use. Recently, MHI has developed the compact advanced-pollution minimum (A-PM) burner for coal firing boilers, which has excellent compactness and improved combustion performance. By combining this burner with our in-furnace NOx reduction Mitsubishi advanced combustion technology (A-MACT) and the Mitsubishi rotary separator (MRS) pulverizer, we have completed an excellent coal combustion system that, for instance, enables the existing boiler to be retrofitted to make up for installation limited space. This technology was applied to the 300MW coal-fired boiler of the Talin Power Station, Taiwan Power Company and excellent combustion performance was confirmed. Improved operability and maintenance were simultaneously also confirmed.

1. Introduction

In Japan, the requirements for environmental protection are extremely strict especially for thermal power stations, therefore, to reduce NOx emission, many techniques and systems have already been applied not only to new boilers but also to existing boilers. However, in applying these techniques and systems to existing boilers, there are many problems to be considered, such as space restrictions, changes in steam temperature characteristics, etc., and especially for overseas aging coal-fired boilers operated for a long period; these problems have been large obstacles to retrofitting.

Both domestically and overseas, measures for energy diversification and global environmental conservation have recently been being seriously considered. Therefore, in order to solve such space restrictions, MHI successfully developed the compact A-PM (advanced-pollution minimum) burner with a remarkably simplified structure as well as excellent

low NOx characteristics and high combustion performance, and retrofitted the burners to three existing coal-fired boilers (300 MW) of the Taiwan Power Company to reduce NOx emissions.

Furthermore, the retrofitting work implemented this time for reducing NOx emissions was subsequently applied to two 375 MW oil-fired boilers and a 500 MW gas-fired boiler, the first retrofitting work on overseas boilers. This means that MHI's low NOx combustion system is applicable to all fossil fuels including coal, oil and gas used by typical thermal power stations and greatly contributes to improving international environmental problems.

This report explains the outline of these retrofitting works and their operating data (Table 1).

2. Retrofitting for low NOx coal-fired boiler

2.1 Outline of the retrofitting work for Talin No.2 boiler (300MW)

Table 2 shows the major specifications of the Tai-

Table 1 Low NOx retrofitting to existing boilers for Taiwan Power Company

Unit	Output (MW)	Fuel	Year of commercial operation	Year of retrofitting	Contents of retrofitting
Talin No. 1	300	Coal	1968	July, 2000	Replacement by A-PM burner Pulverizer modification to MRS Application of in-furnace NOx removal system, A-MACT Improvement of steam temperature characteristics
Talin No. 2	300	Coal	1968	January, 2001	The contents are the same as those of the Talin No. 1 Unit.
Talin No. 3	375	Oil	1971	March, 2000	Replacement by oil-fired PM burner Adoption of OFA system Addition of GM system
Talin No. 4	375	Oil	1972	March, 2001	The contents are the same as those of the Talin No. 3 Unit.
Talin No. 5	500	Gas	1973	May, 1999	Replacement by gas-fired PM burner Adoption of OFA system Addition of GM system Improvement of steam temperature characteristics
Linkou No. 2	300	Coal	1971	May, 1999	Replacement by A-PM burner Application of in-furnace NOx removal system, A-MACT Improvement of steam temperature characteristics

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Table 2 Major specifications of Talin No. 2 boiler

Type of boiler	Mitsubishi Forced Circulation Steam Generator, Radiant Reheat Type
Maximum evaporation rate	1 000 t/h
Steam conditions	169 kgf/cm ² G X 542/542 °C (Superheater outlet/reheater outlet)
Steam temperature control system	Main steam: superheater spray Reheated steam: burner angle adjustment
Others	Fuel: coal Firing system: vortex firing Drafting system: balanced draft system Number of burners: 20

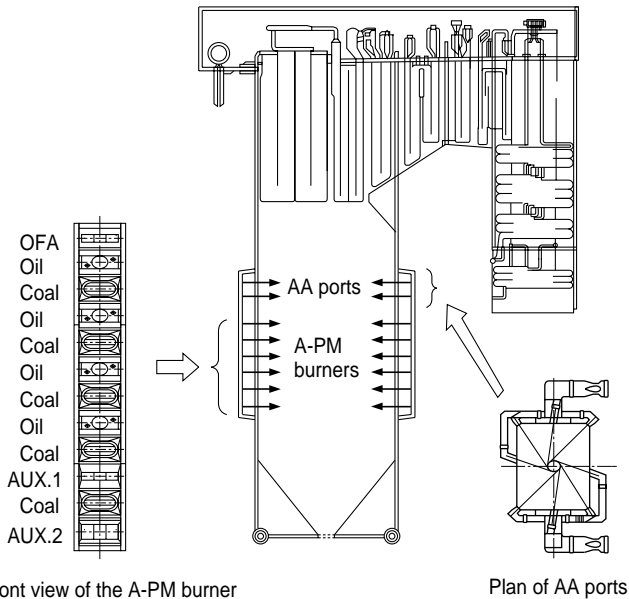


Fig. 1 Cross-sectional view of boiler modification
Modification outline of the Talin No. 2 boiler, A-PM burners, and AA ports (A-MACT) are shown.

wan Power Company Talin Power Station No. 2 boiler applying the retrofitting work for reducing NO_x emissions.

The main modifications for reducing NO_x emissions consists of the following three points:

- A-PM (Advanced-Pollution Minimum) burner modification (replacement of conventional burners)
- A-MACT (Mitsubishi Advanced Combustion Technology) system modification (installation of additional air ports (AA))
- MRS (Mitsubishi Rotary Separator) modification (installation of rotary separator)

Fig. 1 shows the side view of the modified boiler. The main burner nozzles and wind boxes with dampers installed at each corner of the furnace were replaced. Simultaneously, the pressure parts, pulverized coal piping, backstay, air duct, instruments and controls, etc. were also partially modified in accordance with the burner modification.

Also, as a part of the A-MACT, the AA ports were additionally installed, separated into two stages, i.e. at the corners of the furnace for the lower stage and

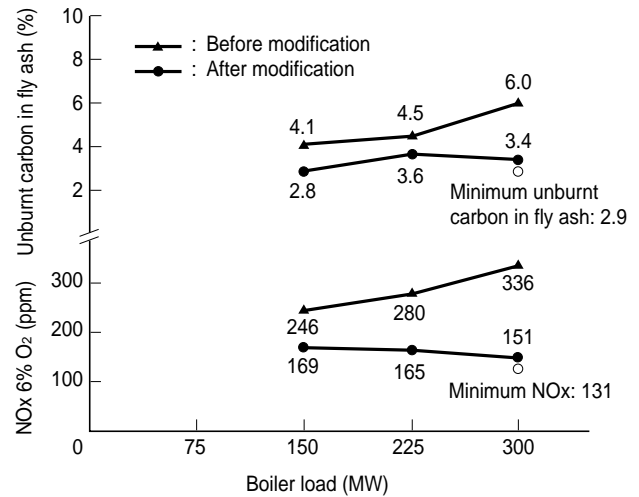


Fig. 2 Combustion test results (economizer outlet NO_x and unburnt carbon in fly ash)

Combustion test results of the Talin No. 2 boiler are shown.

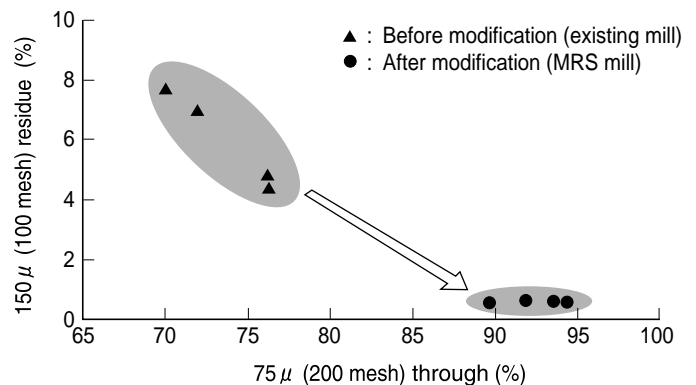


Fig. 3 Combustion test results (fineness of pulverized coal)
Combustion test results (fineness) of the Talin No. 2 boiler are shown.

near the centers of the furnace for the upper.

For the pulverizer, in order to reduce unburnt carbon in fly ash, the existing fixed vane separator was removed and an MRS was newly installed.

Table 3 shows the actual schedule for the retrofitting work. The total period was about 140 days including the removal of the existing components, the restoration work, and the commissioning operation.

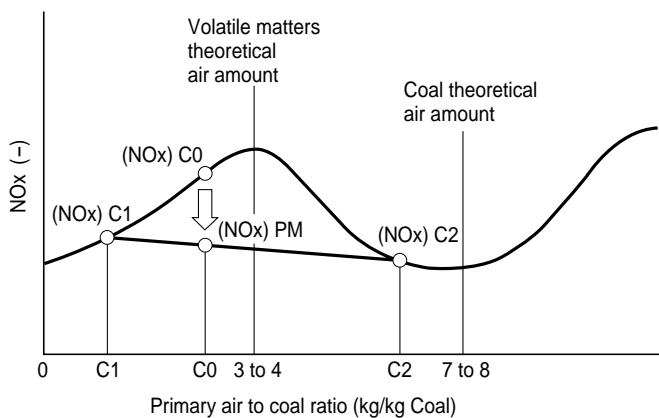
2.2 Combustion test results of Talin No.2 boiler

In order to compare the boiler performance before and after the modification, the combustion test was carried out using Australian coal (a fuel ratio of 1.6 and an ash content of 16.3%). **Fig. 2** shows the levels of emitted NO_x and unburnt carbon in the fly ash before and after the modification, respectively. NO_x emissions were reduced to 150 ppm under normal operating conditions, a reduction of 55%, and NO_x emissions as low as 131 ppm were recorded during the minimum NO_x test simultaneously carried out.

Also, for the pulverized coal fineness before and after the modification by the MRS, a remarkable modification effect was obtained as shown in **Fig. 3**. Consequently, unburnt carbon in fly ash could be re-

Table 3 Modification schedule of Talin No. 2 boiler

Item	2000				2001
	Sep.	Oct.	Nov.	Dec.	Jan.
Key schedule	Shut down			Hydro-static test	Ignition
1. Temporary construction work	Setting	Removal work	Carrying-in, positioning, welding		
2. Wind box and burner equipment			Removal work		
3. Steel structure			Installing, welding		
4. Pressure parts		Removal, carrying-in, positioning, welding			
5. Duct	Removal work		Carrying-in, positioning, welding		
6. MRS	Removal work	Installing, restoring			
7. Piping	Removal work			Carrying-in, installing	

**Fig. 4 Concept of the A-PM burner (NO_x formation characteristics)**

Relationship between the ratio of primary air to coal-burning amount and the NO_x formation is shown. The concentrated and weak combustion reduces NO_x emissions.

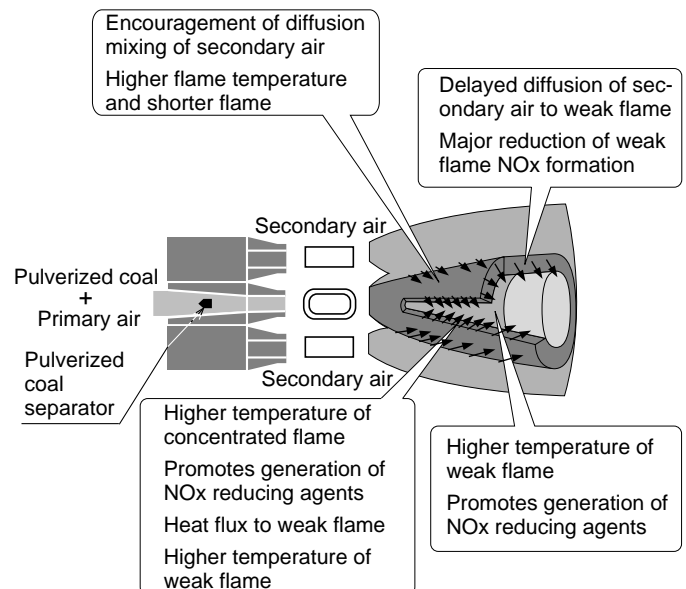
duced by 40 to 50%. In this retrofitting work, furthermore, the heating surfaces were also adjusted for both the superheater (SH) and the reheater (RH). As a result, the steam temperature characteristics could be greatly improved in comparison to the performance before the retrofitting work, so that the overall plant efficiency was improved by about 3.0%.

2.3 Technical features of the coal-fired boiler low NO_x system

2.3.1 Coal-fired A-PM burner

Fig. 4 shows the NO_x formation characteristic curve of the pulverized coal-fired PM burner. NO_x emissions can be controlled to be low by the combination of two kinds of flames obtained by dividing the flame into a concentrated flame (rich fuel concentration) and a weak flame (lean fuel concentration).

Although a conventional PM burner needs separate upper and lower nozzles for the concentrated and the weak flames, the A-PM burner can produce the

**Fig. 5 Illustration of the A-PM burner combustion**
Principles of the A-PM burner are shown.

concentrated and the weak flame parts, from a single nozzle by adopting a built-in type concentrated and weak flame separator, making its structure compact.

The burner is designed so that the doughnut shaped concentrated flame surrounds the weak flame as shown in **Fig. 5**, therefore, the concentrated flame part easily receives radiation heat from the furnace, so that the ignition performance is improved and simultaneously slow combustion produced by the delayed diffusion of secondary air into the weak flame part contributes to the reduction of NO_x emissions.

2.3.2 In-furnace NO_x removal system, A-MACT

The A-MACT system achieves low NO_x formation as a whole furnace by means of dividing the furnace into three zones as shown in **Fig. 6**. The principle of low NO_x formation in each zone is as follows:

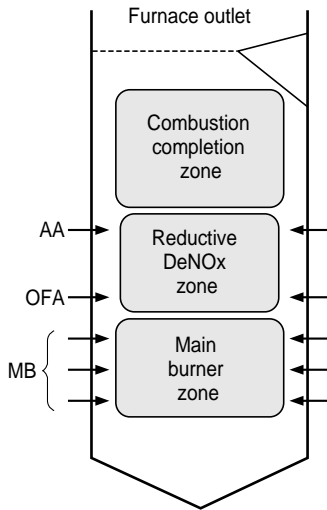


Fig. 6 Concept of A-MACT system

This figure shows the concept of the A-MACT system with the furnace divided into three zones.

(1) Main burner zone

In the main burner zone, the flame is formed by the ignition of volatile matters emitted from the burner by the radiation heat from its surroundings. NO_x produced in this zone results mainly from the volatile matters, and it can be reduced by highly active char as a reducing agent, which is produced by burning the pulverized coal at a high temperature in a reducing atmosphere having an air ratio below 1.

(2) Zone from the main burner to AA (reductive DeNO_x zone)

In the zone from the main burner to AA, NO_x produced in the main burner zone is reduced by being well mixed with the char as a reducing agent and being kept in the reducing atmosphere for sufficient residence time.

In this case, it is important to keep a long residence time in the NO_x-reducing atmosphere. Furthermore, even in a comparatively small furnace, the actual residence time in the NO_x-reducing atmosphere is extended by the flame-shortening effect of the A-PM burner.

(3) Zone after AA (combustion completion zone)

In the zone after feeding AA, the complete combustion of the char is carried out by residual combustion air. In this zone, when the oxygen concentration is uneven in the furnace, high oxygen concentration spots are locally formed producing NO_x, and extremely low concentration spots produce unburnt carbon in fly ash. Therefore, it is essential to keep the air ratio uniform inside the furnace.

Although the conventional AA ports are composed of a single stage at the corners of the furnace, the new AA ports have two stages, i.e. the lower stage ports are located at the corners and the upper stage

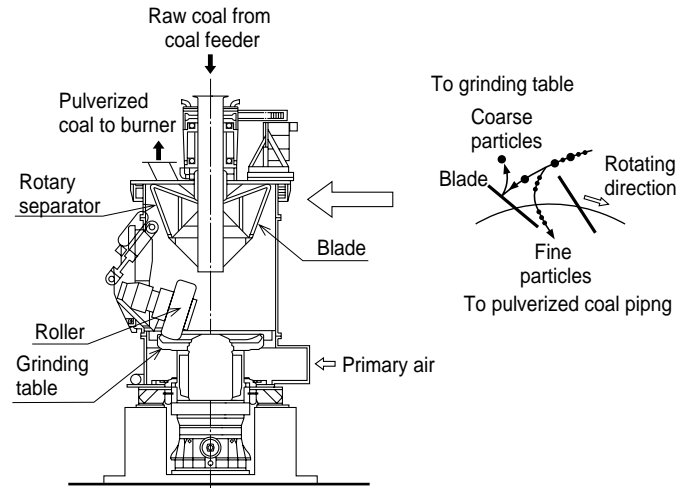


Fig. 7 Structure of MRS pulverizer and image of MRS classification

Rough structure drawing of MRS pulverizer and the concept of the classification system are shown.

ports near the centers, so as to enable further uniform feeding. This method (multi AA system) can simultaneously reduce NO_x, CO, and unburnt carbon in fly ash.

2.3.3 MRS pulverizer

As shown in Fig. 7, the high fineness pulverizer has a rotary separator installed above a grinding table and dryer chamber. The pulverized coal crushed by the grinding table is dried and transferred by hot air. The transferred pulverized coal is classified by the rotary separator passing fine particles only, and coarse particles are separated by centrifugal force and impinging force generated by the rotating blades as shown in Fig. 7. The separated coarse particles fall by gravity to the table to be crushed again, so that only fine particles having the required fineness are transferred in the pulverized coal flow from the outlet port to the pulverized coal piping.

Since this system enables the partial modification of upper pulverizer parts only, it is commonly applicable to retrofitting works.

3. Retrofitting for a low NO_x oil-fired boiler

3.1 Outline of the retrofitting work in Talin No. 3 boiler (375 MW)

Since thermal NO_x is an important factor in oil-fired boilers, a low flame temperature (combustion temperature) and slow combustion are a basic means for reducing NO_x.

The flame temperature can be reduced by combustion divided into the concentrated flame and weak flame on the basis of the PM principle and reduced oxygen concentration in air diluted with the mixture of gas recirculation (GM) into the combustion air. Furthermore, the air ratio reduced at the main burner zone by the OFA system also enables the reduction of

NOx emissions.

The major points of the retrofitting work implemented this time for reducing NOx emissions are as follows:

- Oil fired PM burner modification (replacement of conventional burners)
- OFA system modification (additional installation of Over Fire Air ports)
- SGR system modification (additional installation of SGR burners, a GM fan and duct)

In the retrofitting work, the main burner nozzles and wind boxes with dampers were replaced, and together with this, the pressure parts, fuel piping, backstay, air duct, instruments and controls, etc. were also partially modified, and a GM fan, SGR duct, and GM duct were additionally installed. Since the layout of additionally installed GM fan, the SGR and GM ducts needed to be made in narrow spaces, careful prior examination was required to get the work done smoothly. As a result, the retrofitting work period could be shortened to about 90 days.

3.2 Combustion test results of Talin No.3 boiler

The combustion test carried out after the retrofitting work gave excellent results, and the NOx emissions were reduced from 179 ppm to 102 ppm under normal operating conditions, a 43% reduction. In the minimum NOx test carried out simultaneously, a performance reaching 86 ppm NOx was recorded.

4. Retrofitting for a low NOx of gas-fired boiler

4.1 Outline of the retrofitting work in Talin No. 5 boiler (500 MW)

The concepts for reducing NOx emissions in gas-fired boilers are basically the same as those in oil-fired boilers, therefore, thermal NOx reduction is an important factor.

The major points of the work implemented this time for reducing NOx are as follows:

- Gas fired PM burner modification (replacement of

conventional burners)

- OFA system modification (additional installation of Over Fire Air ports)
- GM system modification (additional installation of a GM fan and duct)

In the retrofitting work, the main burner nozzles and wind boxes with dampers were replaced, and together with this, the pressure parts, fuel piping, backstay, air duct, instruments and controls, etc. were also partially modified, and a GM fan and duct were additionally installed.

This retrofitting work was also completed in about 90 days.

4.2 Combustion test results of Talin No.5 boiler

The combustion test after the retrofitting work gave excellent results, and the NOx emissions were reduced from 167 ppm to 58 ppm under normal operating conditions, a 65% reduction. In the minimum NOx test carried out simultaneously, a performance reaching 45 ppm NOx was recorded.

The steam temperature characteristics were also greatly improved, so that the overall plant efficiency was improved by about 0.5%.

5. Conclusion

The overall low NOx system demonstrated this time by adopting the compact A-PM burner, A-MACT, and MRS for pulverizer to the Taiwan Power Company Talin No. 2 boiler indicates a new direction for the retrofitting work of existing coal-fired boilers.

For retrofitting to reduce NOx emissions in overseas oil and gas-fired boilers, the results obtained in the Talin No.3 and Talin No.5 boilers renew the recognition of the effectiveness having so far been shown by the MHI's low NOx system.

In the future, MHI intends to work to contribute to environmental protection and energy-saving from a global view, through the application of this system to as many overseas plants as possible.