UPDATED LOW NOx COMBUSTION TECHNOLOGIES FOR BOILERS, 2003

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OUTLINE

Hitachi Group has been dedicating a great effort to research and development of low NOx combustion technologies in response to global environment protection. For pulverized coal combustion, we firstly developed a unique low-NOx burner, HT-NR, based on the theory of "In-Flame NOx reduction". For this sophisticated and proven design, and our continuous contribution to low-NOx combustion technology, we were awarded the JSME (Japan Society of Mechanical Engineers) Medal as well as the highest prize from Director-General of the Environment Agency. Our further effort has led to the development of the second-generation low-NOx burner, HT-NR2, which enhances NOx decomposition capability. The HR-NR2 burner system has been applied to both domestic and foreign boilers, and has received high reputation from all users. Complying with the increasing need of higher efficiency, easier maintenance, and lower cost, the third generation low-NOx burner, HT-NR3 with more simplified structure, was developed to realize the concept of a wider and shorter flame for extremely low NOx combustion. Its excellent performance was confirmed in an actual plant

1. INTRODUCTION

Pulverized coal fired boilers have been significant in thermal power stations and industrial plants as well as gas and oil fired boilers. In pulverized coal combustion, the boiler outlet NOx level is much higher than that of gas and oil boiler, as coal contains much organic nitrogen. Japan's low NOx combustion technology has been applied since 1970's. In the case of conventional pulverized coal low NOx burners, which lengthen the flame by means of delayed combustion, it becomes difficult to recover the "trade-off" defect between NOx reduction and increasing unburned carbon (UBC) in fly ash.

The Hitachi group has employed a new concept of "IN-Flame" NOx Reduction to the first generation burner "HT-NR" and the second-generation burner "HT-NR2". NOx emissions have been remarkably reduced through acceleration of NOx decomposition in high temperature fuel rich conditions. By using this "IN-Flame NOx Reduction" technique, NOx can be reduced without increasing UBC.

Now, the third generation burner "HT-NR3" by enhancing the reaction of "In-Flame NOx Reduction" has been developed according to the needs of high efficiency and low NOx combustion.

2. DEVELOPMENT STEPS OF HT-NR3

The development of a newly designed, extremely low-NOx burner has been promoted since 1992 in order to further study the fundamental technologies of enhanced reactions in "In-Flame" NOx reduction that had been already formed in basic research (Fig.1). The basic theory of a low-NOx flame was formed after elemental and technical research on both chemical reactions and fluid dynamics. The basic concept of the new burner is "Widen and Shorten the Flame". Key devices for this newly designed burner were invented as a result of this approach.

By screening tests using a 500kg/h combustion test furnace and same-scale flow characteristics in our test facility, we established parameters for the design of this new burner.

Preceding application to the actual boiler, burner scale-up factors and reliability confirmation of each device was studied using a large-capacity combustion test facility.

The HT-NR3 has been applied to actual existing boilers since August 1997.

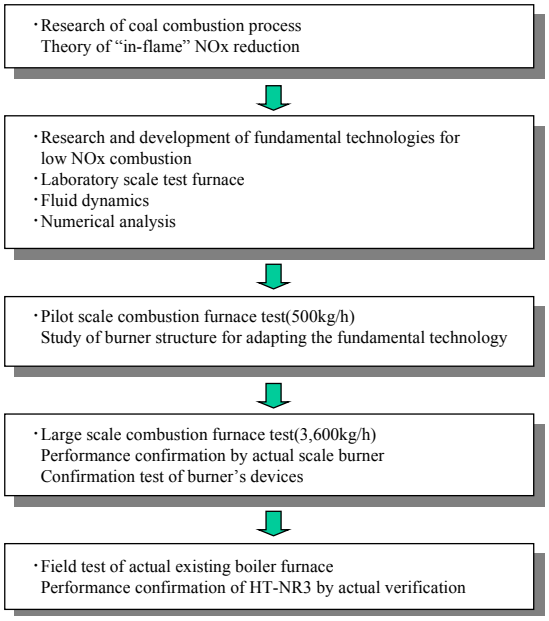


Fig.1 Development Steps of HT-NR3

3.FEATURE OF HT-NR3

To achieve extremely low-NOx combustion using the basic concept of "Wider and Shorter the Flame" the third generation burner HT-NR3 has the following features (Fig.2) that aim to:

(1) Expand the recirculation region around the flame stabilizing ring

Pulverized coal is concentrated around the flame-stabilizing ring by the P.C. (Pulverized Coal) concentrator, so that the flame can be maintained at high temperature as well as that of HT-NR2. The important factor of P.C. is optimum angles at inlet and outlet of P.C. concentrator. As a new device, baffle plate was attached to the flame-stabilizing ring in order to magnify the recirculation region. Ignitability around the flame-stabilizing ring is accelerated because the recirculation zone returns a high temperature flue gas after ignited to the flame-stabilizing ring. Due to the expansion of the recirculation zone of high temperature flue gas, combustion rates in the reducing zone are improved and the chemical reaction of "In-Flame NOx reduction" has been enhanced.

(2) Optimize the implementation of outer air

To achieve low-NOx combustion, it is important to separate tertiary air from the high-temperature reducing zone formed near the burner throat.

The HT-NR3 effectively separates the tertiary air by a simple guide-sleeve structure. Extremely low-NOx combustion with a "Wide and Short Flame" has been obtained by optimizing the supply method of the tertiary air. Fig.3 shows a result of combustion simulation for HT-NR2 and HT-NR3 burners. By enlarging the reducing zone, the HT-NR3 burner has a wider space of low oxygen condition compared with the HT-NR2 burner.

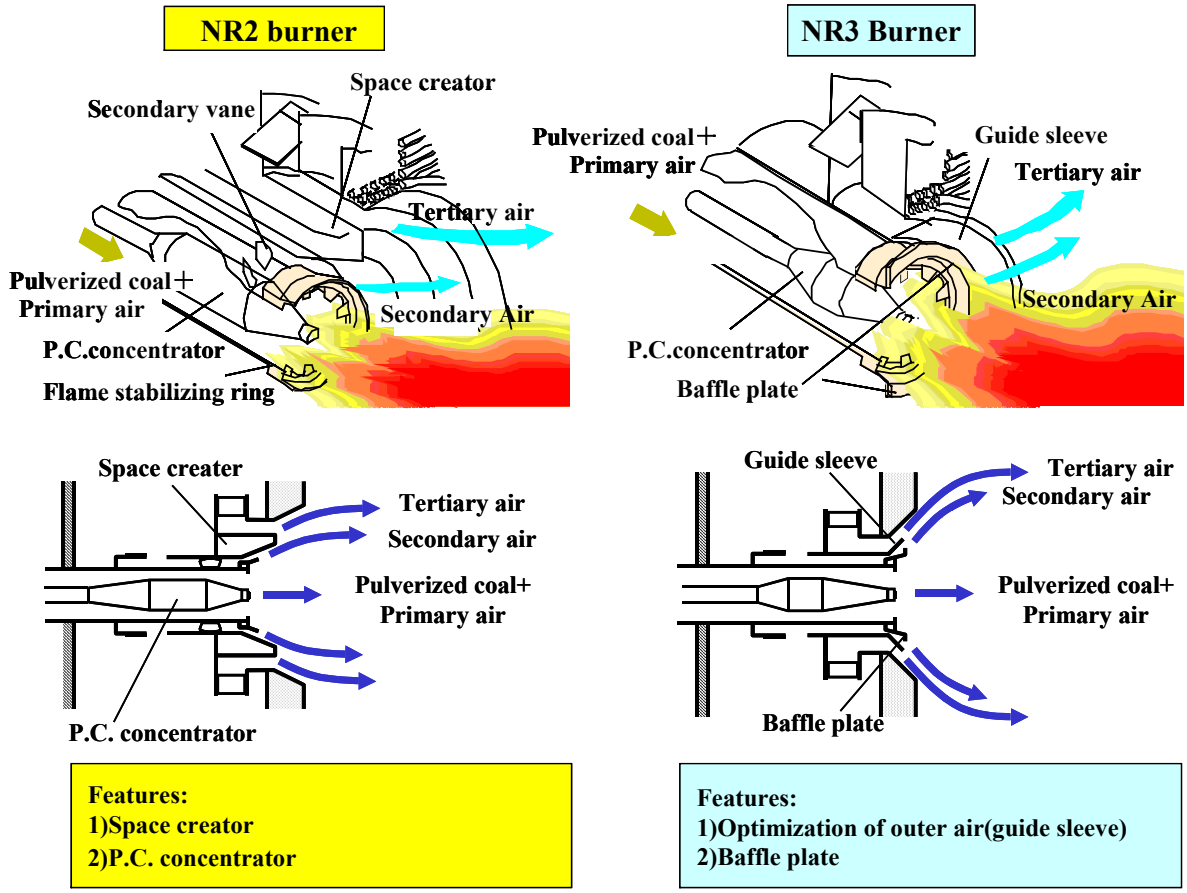
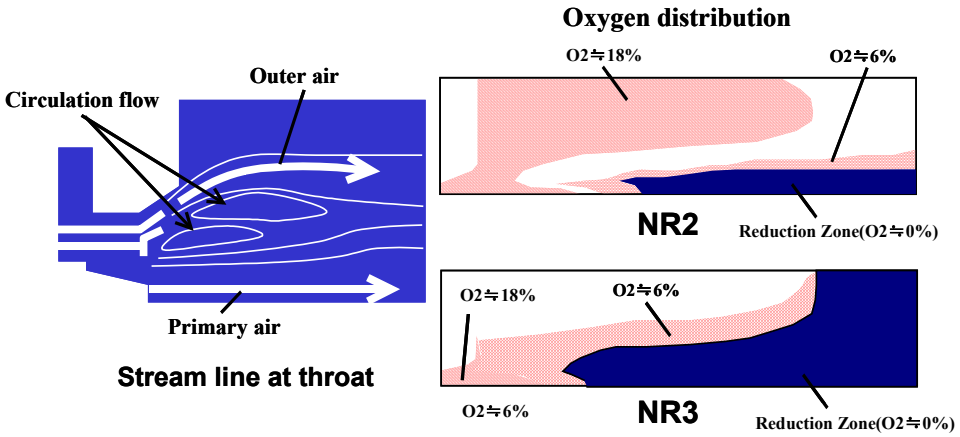


Fig.2 Features of HT-NR3.



Numerical analysis condition ; Cylindrical coordinates , SIMPLE method ,
6-Flux method , Burner Stoichiometric ratio 0.8

Effective separation of outer air→Increasing reduction zone

Fig.3 Optimization of supply method of outer air

4.PRACTICAL USE EXPERIMENT

A 3,600 kg/h actual scale HT-NR3 was produced in a trial experiment. We applied this burner to large scale combustion test facilities, and combustion tests have been carried out using Saxonveil coal whose fuel ratio (=fixed carbon/volatile matter) is 1.7. The combustion performance of HT-NR3 was improved in comparison to HT-NR2 (Fig.4). It was confirmed that high temperatures and a stable flame was kept from the burner root, and that the flame itself was short and wide.

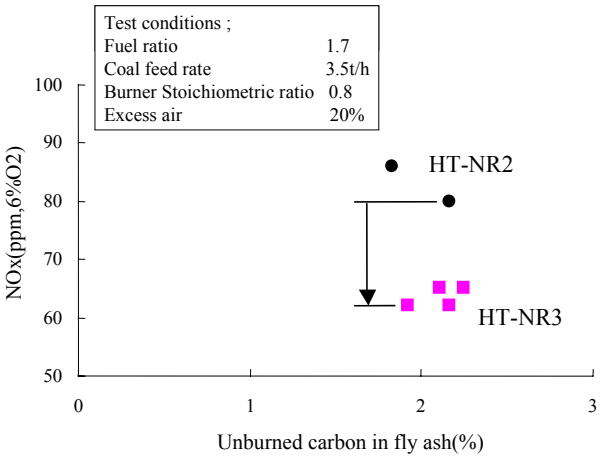


Fig.4 Results of Practical Use experiment.

5.RESULT OF ACTUAL VERIFICATION

5.1 Retrofit Case, Plant IN

The performance of HT-NR3 has been verified at thermal power plant IN in Finland. The modification to HT-NR3 and commissioning was carried out in summer, 1997, by Enprima, the licensee of the HT-NR technology.
This power station consists of 4×265MW pulverized coal-fired boilers with the same specific subcritical sliding pressure stood in a line (Table 1).
The burners were arranged four rows on the rear wall.
Each row has four burners and totally sixteen burners are installed as shown in Fig.5. Before retrofit, circular burners were installed with single stage combustion.
In unit No.4, after air ports were installed in 1990, retrofitting was carried out to replace circular burners with HT-NRs and a successful combustion performance was achieved. In units 1 and 2, retrofitting was carried out to replace circular burners with HT-NR2 in 1992 and 1994 respectively. The newly developed HT-NR3 burners were applied to unit 3 in 1997.

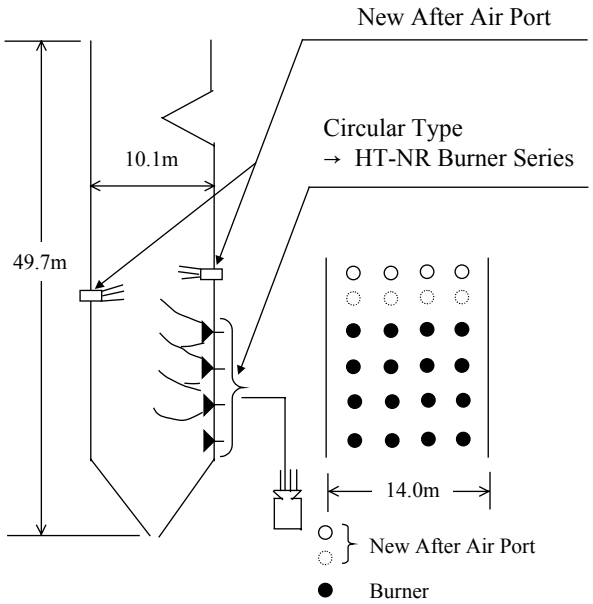


Fig.5 Retrofit Item

Two-stage combustion was also applied to Units 1 to 4 in their retrofits (Same after air ports). HT-NR series burners have been applied to the Inkoo Thermal Power Station, and these technologies attained greatly reduced NOx levels (Fig.6). For both HT-NR3 and two-stage combustion, there was a reduction of 75% (before and after) more NOx than before the retrofit under conditions employing the same UBC in unit 3 (HT-NR series burners reduced UBC by improving combustion rates in flame). It was also confirmed that the HT-NR3 had an approximately 25% (relative value) lower NOx level than HT-NR2.

Table1 (Inkoo Power Station)

Plant	#4	#1,2	#3
Boiler Type	Once-Through Type, Sliding Pressure Operation		
Plant Output	265MW		
Steam Condition	20.6MPa 530/540℃		
Original Type	Circular		
Applied Type	NR	NR2	NR3
Year of Retrofit	1990	1992(#1),1994(#2)	1997
Burner Number	16		
Burner Arrangement	4 x 4 Rear Wall Firing		
Burner	10t/h/Burner ($214x10^6$ kJ/h)		

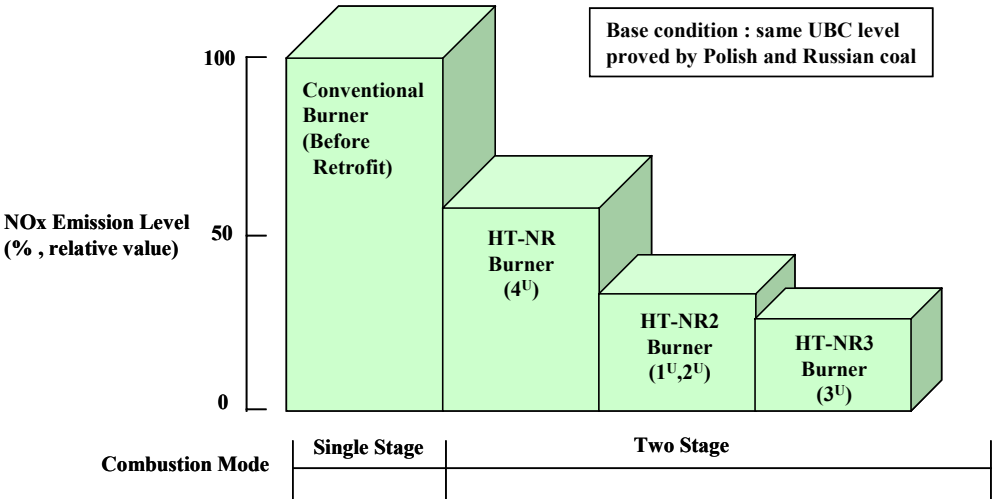


Fig.6 Result of combustion performance test IN

5.2 Retrofit Case, Plant HW

The performance of the HT-NR3 has also been verified at Plant HW, 670MWe unit in the Netherlands. The boiler equips 3 mills at front wall and 3 mills at rear wall. 36 HT-NRs were installed (6 burners fed from the same mill) and these were retrofitted to 36 HT-NR3s. Enprima, the licensee of the HT-NR technology, carried out modification to HT-NR3 and commissioning in 2002. In normal operation, the plant achieves 630 MWe with 5 mills in service and 670 MWe with 6 mills in service. NOx emission measurements were carried out before and after the HT-NR3 modification in order to prove the NOx performance of the new burners. The test before the burner modification was carried out in the end July 2002. The Guaranty measurements were executed after the burner modification and commissioning of the modified burners in the end of November 2002. Measurements before and after the modification were carried out by using the same coal (Fuel Ratio (Fixed Carbon/Volatiles): 1.7 – 1.8, Nitrogen 1.6 – 1.9 %, dry ash free). Guaranty measurements proved that the NOx emission was reduced by approximately 20 % compared to the NOx level before the burner modification and the NOx level after the modification was 240-250 mg/m^{3}N (dry, 6 % O2) maintaining the similar unburned carbon in the fly ash.

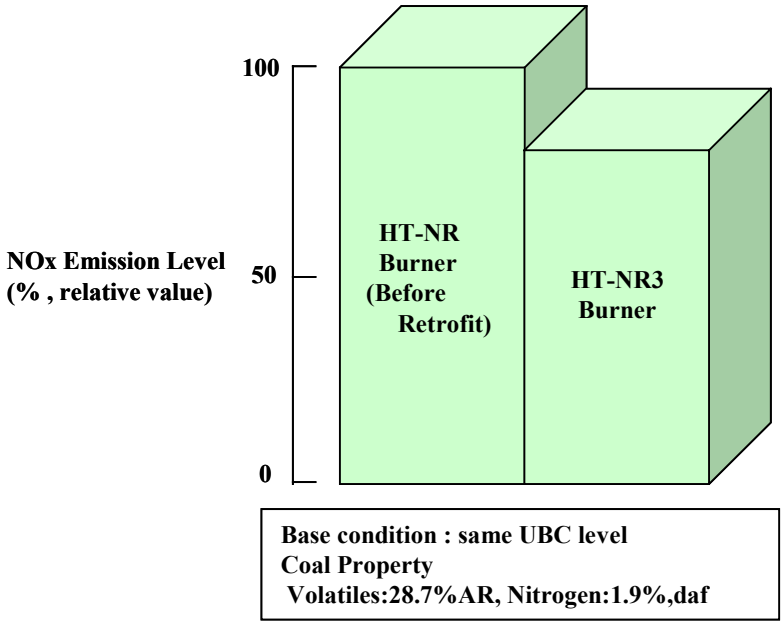


Figure 7 Result of combustion performance test HW

5.3 New Installation Case, Plant HK

The HT-NR3 burners were installed in the new boiler, 1000MWe plant in Japan, after the several retrofitting case of HT-NR3 successfully completed. The boiler equips 3 mills at front wall and 3 mills at rear wall. 36 HT-NRs were installed (6 burners fed from the same mill). The plant achieves 1000MWe with 5 mills, 30 burners in service. Accordingly, the burner capacity is approximately 290 x 10^6 kJ/h. Comparing to our previous experience of 1000MWe boiler, the distance between the top burner row and the After Air Ports has been shorten employing the improved performance of the HT-NR3, even the design NOx emission is slightly lowered. The features of the boiler are presented in the following table. The plant is under commissioning and the preliminary result from the trial is also shown in the following figure.

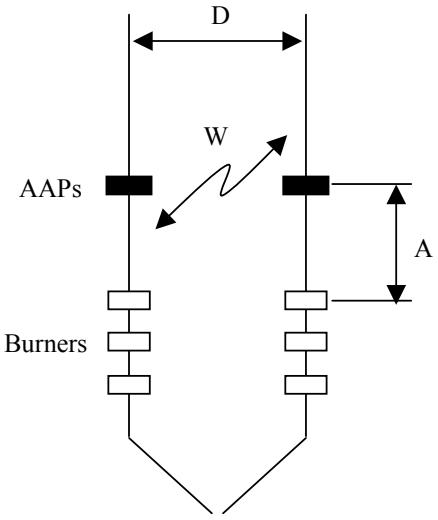


Table 2 Plant feature HK

	Previous Design	Plamt HK
Furnace Width (W)	100	97
Furnace Depth (D)	100	103
AAP Height (A)	100	***85***
Burners in Row	7 burners	***6 burners***
Burner Capacity	250 x 10^6 kJ/h	***290 x 10^6 kJ/h***
Design NOx	180ppm, 6%O_2	***175ppm, 6%O_2***

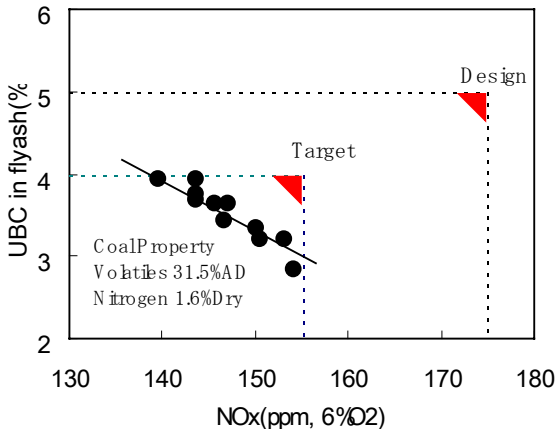


Figure 8 NOx/UBC result HK

6.CONCLUSIONS

The original concept of "In-Flame" NOx reduction has also been achieved in our third generation burner HT-NR3. HT-NR3 can be applied to new boilers and to retrofits of existing burners with reputable reliability in many countries that grope for environmental protection.

The Hitachi group aims to supply the best products with highest performances (higher efficiency and lower NOx) at the lower costs.

REFERENCES

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2. S.Morita, T.Tsumura et al., "Development of Extremely Low NOx Puverized Coal Burners by Using the Concept of 'In-Flame' NOx Reduction," ICOPE93, Vol.2 (1993), pp.325-330.