Completion of SCR System for Ninghai Power Plant Unit 4 in China

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OVERVIEW: The SCR system installed on Ninghai Power Plant Unit 4 of the Beijing Guohua Electric Power Corporation — one of China's most influential power utilities — is the first NO_x removal system implemented on the Chinese mainland through Chinese capital investment. This SCR system was implemented as a project set up between Babcock-Hitachi K.K. with Hitachi, Ltd. as the main contractor and Zhejiang University Energy Technology Co., Ltd. as a local partner. An order for the SCR system was accepted in January 2005, all items in the contract specifications (including $DeNO_x$ performance) were satisfied, and trial operation was completed in November 2006. In response to growth in the Chinese SCR business, Babcock-Hitachi has transferred SCR technology to three Chinese manufacturers. At the end of September 2008, the Hitachi Group took the lead in the Chinese SCR market with orders received for SCR system — based on that installed at Ninghai Power Plant Unit 4 — for 38 power plants (with a total capacity of about 23,000 MW) combining SCR system and catalysts.

INTRODUCTION

SINCE introducing a commercial SCR (selective catalytic reduction) system on Kainan Power Station Unit 1 of Kansai Electric Power Co., Inc. in 1977, Hitachi, Ltd. and Babcock-Hitachi K.K. have delivered NO_x (nitrogen oxide)-removal system designed for various boiler types and fuels and introduced catalysts at a total of more than 600 plants in Japan and overseas.

Nowadays, dealing with environmental pollution in China is drawing a lot of attention. In line with the strengthening of ambient pollution control around the world, China's GB 13271-2001 standard "Emission Standard of Air Pollutants for Coal-burning Oil-burning Gas-fired Boilers" was introduced in China in 2002. In addition to the above standard, GB 13223-2003, "Emission Standard of Air Pollutants for Thermal Power Plants," took effect in 2004, resulting in further strengthening of flue gas emissions.

Under these circumstances, taking the lead from other Chinese power companies, Beijing Guohua

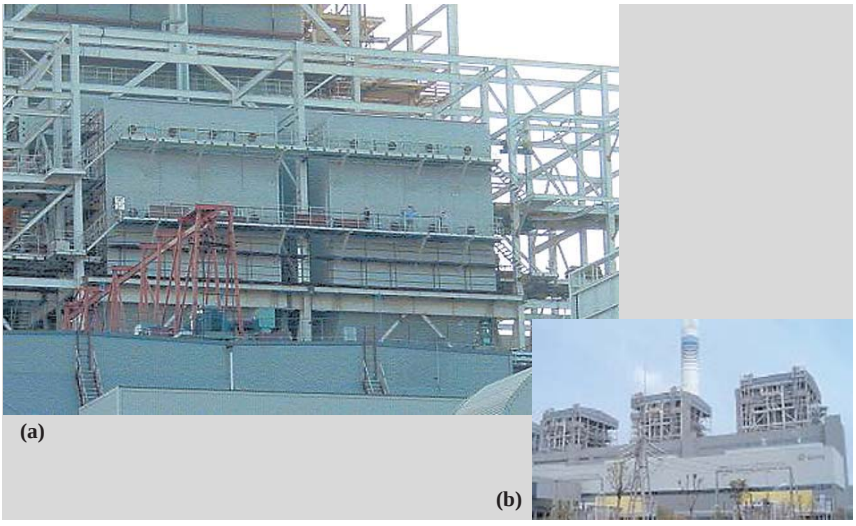

Fig. 1—External Appearance of the SCR System on Beijing Guohua Electric Power Corporation Ninghai Power Plant Unit 4. The external appearance of the SCR (selective catalytic reduction) system of Ninghai Power Plant Unit 4 is shown in photo (a). This is the first international tender from China for an SCR system. System commissioning was completed in November 2006, and the plant is currently running smoothly. The boiler for Unit 4 is shown on the far right in photo (b), and orders for SCR systems for planned installation on adjacent Units 5 and 6 (each with rated power output of 1,000 MW) have also been received by Hitachi, Ltd. and Babcock-Hitachi K.K.

Electric Power Corporation set out to implement measures against NO_x emissions. Accordingly, they submitted an international tender for an NO_x-removal, namely, SCR project targeting Ninghai Power Plant Unit 4. This project represented the first NO_x-removal system funded with Chinese investment. After performing strict evaluation from both technical and commercial aspects, Hitachi, Ltd. and Babcock-Hitachi K.K. accepted an order under this international tender in January 2005.

The rest of this report describes the SCR system installed on Ninghai Power Plant Unit 4 of Beijing Guohua Electric Power Corporation (see Fig. 1).

OVERVIEW OF SCR SYSTEM FOR NINGHAI POWER PLANT UNIT 4

The design specifications of the SCR system are listed in Table 1. Under a condition of slip NH_3 of 3 ppm, a high $DeNO_x$-efficiency of over 80% is required.

The SCR reactor and ducts are shown schematically in Fig. 2. The SCR system adopts a "high-dust system" in which the SCR reactor is fitted to the boiler economizer outlet.

The ammonia-injection equipment is fitted in the vertical inlet duct of the SCR reactor considering allowable space. The SCR reactor is designed as a self-supporting external casing structure adopted as standard design of Babcock-Hitachi.

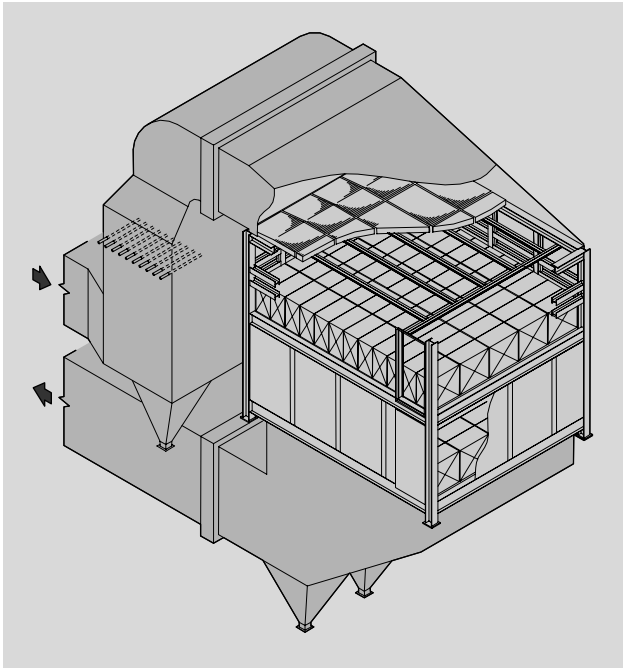

Fig. 2—Bird's-eye View of SCR Reactor and Duct. Flow-model testing and flow analysis were performed in order to devise measures for popcorn ash, exhaust-gas rectification, and layout compactization.

TABLE 1. Design Parameters for SCR System
The design parameters for the inlet and outlet of the SCR system of Ninghai Power Plant Unit 4 are listed.

System inlet

Item	Unit	Design value
Flue gas flow rate	m^3N/h-wet	1,924,795
Temperature	°C	365
O_2	Vol%-dry	3.55
H_2O	Vol%-wet	8.46
Dust	g/m^3N-dry, act O_2	14.0
NO_x	ppmvd, 6% O_2	251.5
SO_2	ppmvd, 6% O_2	659.9
SO_3	ppmvd, 6% O_2	15.3

System outlet

Item	Unit	Design value
NO_x removal efficiency	%	≥ 80
NO_x	ppmvd, 6% O_2	≤ 50.3
Slip NH_3	ppmvd, 6% O_2	≤ 3.0
SO_2 oxidation rate	%	≤ 1.0
System pressure loss	Pa	≤ 800

A unique plate-type catalyst manufactured by Babcock-Hitachi is fitted in the SCR reactor. The catalyst layer in SCR reactor is designed as two stages and initial catalyst is installed at each stage evenly. The future catalyst is designed to install directly on each initial catalyst. By this scheme, the independent future catalyst stage is eliminated and the height of SCR reactor is reduced.

FEATURES OF MAIN EQUIPMENT

SCR Catalyst

In order to decide the catalyst specifications, various tests have been conducted by using samples of Chinese coal and ash. The catalyst performance is greatly affected by deterioration element in the flue gas. In particular, its performance is significantly affected by dust components. The coal ash used in the investigations is marked by very high concentrations of CaO (calcium oxide) and Fe_2O_3 (ferric oxide). Since the CaO content in ash is very high, namely more than 20%, several influences were expected such as, masking by calcium on the catalyst surface and

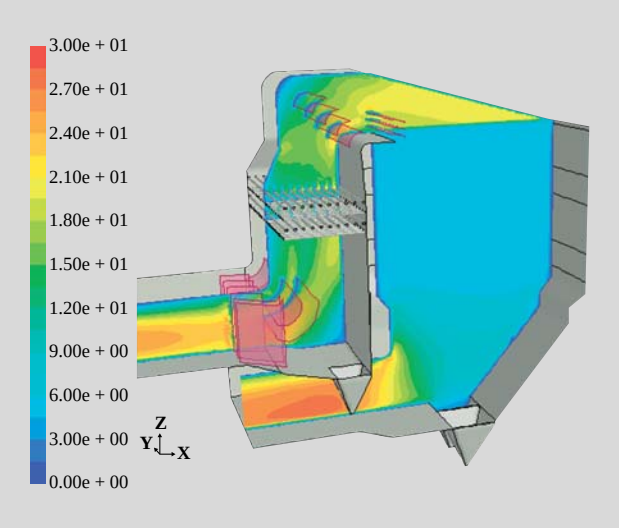

Fig. 3—Distribution of Flue Gas Flow in SCR Reactor Simulated by CFD (computational fluid dynamics). Based on the CFD results, the flow model test was also conducted to verify the final results.

Fig. 4—External View of Ammonia Facility. The made-in-China facility was manufactured according to Chinese standard based on a Japanese proved design.

deterioration of the catalyst activity, and plugging of catalyst. Further, the Fe_2O_3 in ash is one of the factors of increasing SO_2 oxidation rate.

Given these factors, on selecting the specification for the catalyst, we adopted a new catalyst that verified good anti-CaO performance and low SO_2 oxidation rate, in light of its good performance record when used with similar types of coal in the USA. In a "parallel-plate" form, the catalyst has the characteristic that it is highly resistant to dust plugging. Furthermore, in this project, regarding the pitch of the SCR catalyst, anti-blockage measures were strengthened by adopting a larger catalyst pitch than that conventionally used (7 mm compared to 6 mm). As mentioned below, the effectiveness of these high plugging resistant measures was verified. And further effect of widening the catalyst pitch was to decrease the pressure loss. The pressure loss across the catalyst layers was decreased by 30% in comparison with that of a conventional catalyst. As a result, the power consumption of flue gas fan could be reduced.

SCR Reactor and Flue Gas Duct

When larger particle dust generated in the boiler furnace (that is, popcorn ash) flows over the SCR catalyst, ash accumulates on the catalyst layers, causing problems such as decreased catalyst performance, increased pressure loss, and erosion of the catalyst due to local increases in gas flow velocity. In this SCR project, we implemented a countermeasure against this popcorn ash. That is to say, the cross-section of inlet upward duct was expanded in order to decrease gas flow velocity, popcorn ash was collected in a hopper at the bottom of the duct, and popcorn ash inflow into the reactor was prevented.

To confirm the effect of this countermeasure and to study the uniform distribution of the flue gas velocity in the entire SCR system, CFD (computational fluid dynamics) was carried out. The CFD results are shown in Fig. 3. These CFD results were positively verified by a flow-model test using a physical model.

Ammonia Facility

As for the ammonia facility, although it had shown good performance in China at ammonia synthesis plants, refrigeration stations, and so on, the ammonia facility developed by this project represented the first facility, which had been used for an SCR system. Given that fact, a proposal to design the facility, based on a proved Japanese design, to meet Chinese design standards was put forward and built by local manufacturers. Consisting of a compressor for intake, a storage tank, a vaporizer, an accumulator, and so on, the ammonia facility is a dual system in compliance with customer specifications (see Fig. 4).

OPERATIONAL STATUS

Performance-test Results

After 168-h continuous operation test, performance testing was conducted from May to June 2007 under the charge of the Zhejiang Electric Power Test & Research Institute. However, there are no local vender

TABLE 2. Performance Test Results
By adopting the proved design, all the guaranteed values were satisfied.

No.	Item	Unit	Guaranteed value	Test results A-line	Test results B-line	Result
1	NO_x removal efficiency	%	≥ 83.0	84.3	84.3	Passed
2	Slip NH_3	ppmvd, 6% O_2	≤ 3.0	0.25	0.22	Passed
3	System pressure loss	Pa	≤ 800	640	700	Passed
4	Catalyst pressure loss	Pa	≤ 360	340	350	Passed
5	SO_2 oxidation ratio	%	≤ 1.0	0.68	0.56	Passed
6	NH_3 consumption	kg/h	≤ 360	308		Passed
7	Electricity consumption	kW·h/h	≤ 37	20		Passed

Catalyst-layer top surface **Close-up view of catalyst-layer top surface** **Close-up of catalyst interior**

Fig. 5—Catalyst Inspection Results after Operation for Seven Months.
Regardless of the presence of ash (with high blockage characteristics), on the top surface of the catalyst, and within the catalyst as well, ash blockage cannot be seen, and an extremely good condition is maintained.

with proven records in performance testing of SCR systems, so commissioning supervisors and designers were dispatched from Japan and the testing methods used were verified during the performance testing.

The performance testing results are listed in Table 2. Although the coal properties were conditionally crucial, through design with regard to actual performance, all guaranteed values (such as $DeNO_x$ efficiency, pressure loss, and SO_2 oxidation rate) were satisfied.

Internal-inspection Results

Inspection of duct and reactor interior components was conducted in May 2007. First flue gas was introduced through the SCR system from October 2006, and after an operation period of about seven months, the catalyst layers were inspected (see Fig. 5). According to results of the internal inspection, the overall interior of the duct and reactor was in much cleaner condition than a similar plant. In particular, regarding the catalyst layers, no deposition or blockage that might cause a problem was observed. The popcorn ash that was the cause of much concern was not observed either. The inspection results verify the effectiveness of measures for uniform distribution of flue-gas flow as intended by design and prevention of blockage of the catalyst layers. Accordingly, stable and highly reliable operation of the SCR system can be expected from now onwards.

Future Activities Aimed at the Chinese SCR Market

With Ninghai Power Plant Unit 4 as a cornerstone of our efforts, Hitachi is the leading player in the Chinese market and, as of the end of September 2008, we have already received orders for 38 systems combining SCR system and catalysts to handle power plants with a total capacity of about 23,000 MW.

According to the "Eleventh Five-year Plan of the People's Republic of China," the capacity of China's thermal power plants is forecast to grow rapidly. To put that concretely, specialists are forecasting that in comparison with China's total thermal-power capacity in 2005, i.e. 390 GW, total capacity will reach 731

GW in 2010, and 980 GW by 2020. Around 80% or 90% of these plants will be coal-fired types, and from 2010 onwards, environmental regulations will become even stricter. Accordingly, the market for SCR system is expected to grow rapidly.

In response to this growth of the Chinese SCR market, Babcock-Hitachi has signed technical transfer contracts for NO_x-removal technology with three Chinese manufacturers. From here on after, through cooperation with local partners, we will continue our efforts to supply products of the highest reliability while expanding our sales in the Chinese market.

CONCLUSIONS

This report described the SCR system installed on Ninghai Power Plant Unit 4 of Beijing Guohua Electric Power Corporation. The SCR system described here is the first of its kind to enter the Chinese SCR market. Implementing projects with a Chinese local partner, namely, Zhejiang University Energy Technology Co., Ltd., Hitachi, Ltd. and Babcock-Hitachi K.K. have been able to satisfy all the contract items (including performance) and hand over the system operation to our Chinese customers. Moreover, in regard to the Chinese SCR market, by successfully completing the SCR project, we have substantiated the effectiveness of the advanced NO_x-removal technology of the Hitachi Group. In partnerships with Chinese manufacturers, we will continue to take the lead in the Chinese SCR market.

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