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Operation Condition Evaluation and Risk Prediction of Air Preheater in Coal-fired Power Plant

Long Jiang¹, Lei Du¹ and Qing Li^{1*}

¹ North China Electric Power Research Institute Co Ltd. Beijing, 100045, China

*Corresponding author's e-mail: kaveykikiy@163.com

Abstract. Air preheater is an important flue gas heat exchanger in tail flue for coal-fired power plant. In this paper, the operation of air preheater was evaluated from three aspects: the influence of denitrification system on the operation of air preheater, the calculation of air leakage rate of air preheater and the evaluation of low temperature corrosion for air preheater. The results shown that: the corrosion of downstream air preheater caused by ammonium bisulfate was limited due to the low ammonia escape rate; The air leakage rate is higher than the normal value of the air leakage rate; the temperature in the cold end of B-side for air preheater is lower than acid dew point of flue gas due to air leakage, which results in sulphuric acid fog condensation and sulphuric acid corrosion on the air preheater.

1. Introduction

Air preheater is a kind of equipment used to improve the heat exchange performance of boiler and reduce energy consumption [1]. The normal operation of the air preheater has a vital influence on the safe operation of the whole power plant. With the implement of ultra-low emission in China, the new denitrification reactor (selective catalytic reduction, SCR) installed in the front of air preheater is used to control the emission of nitrogen oxides (NO_x) [2-3]. At the same time, the reductant ammonia used in SCR can react with sulphur trioxide (SO₃) in the flue gas to produce ammonium bisulfate (ABS), and the adhesion of ABS to the cold end of air preheater will cause a significant increase in air preheater resistance [4-5]. In addition, air leakage, wear and tear of air preheater and corrosion of air preheater will also affect the safe operation of air preheater [6]. In this paper, the operation of air preheater was evaluated from three aspects: the influence of denitrification system on the operation of air preheater, the calculation of air leakage rate of air preheater and the evaluation of low temperature corrosion for air preheater.

2. Experiment and method

Under the unit load of 300 MW, the concentrations of NH₃, O₂, NO_x and flue gas temperature were measured by pull grids in the exit flue of denitrification system, and then the correlative calculation and analysis were carried out. On this basis, by analysing the influence of denitrification reactor on the operation of air preheater, air leakage rate of air preheater and corrosion of air preheater, the main problems affecting the operation of air preheater are found. During the experiment period, the boiler and the denitrification system operated normally and steadily without disturbance such as soot blowing, which met the relevant requirements of the experiment.

Table 1. Experimental contents and experimental instruments.

Items	Contents
Experimental load	300MW

Experimental instruments	Flue gas analyser, temperature tester, thermocouple, ammonia escape tester
Experimental content	NH ₃ concentration, O ₂ concentration, NO _x concentration and temperature

3. Results and discussions

3.1. Effect Analysis of denitrification on air preheater

The experimental concentration distribution of NO_x on the east and west sides of SCR outlet are shown in figure 1 and figure 2 respectively.

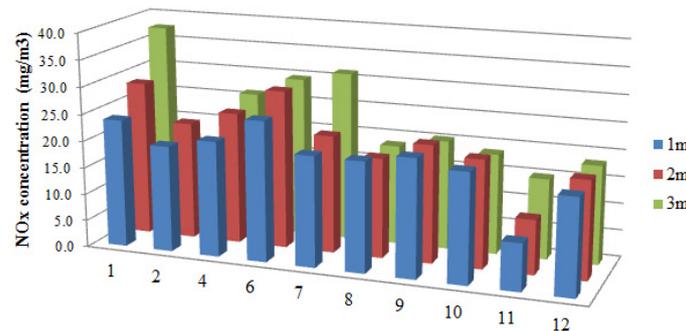


Figure 1. Concentration distribution of NO_x on the west side of SCR outlet

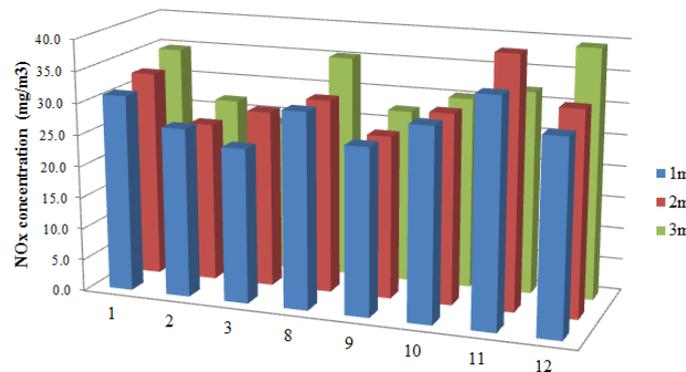


Figure 2. Concentration distribution of NO_x on the east side of SCR outlet

Under 300 MW load condition, the experimental results show that: (1) the measured NO_x concentration at the west side of the SCR outlet is 21.0 mg/Nm³ (standard state, dry base, 6% oxygen content), the relative standard deviation of NO_x concentration distribution is 28.59%, which is large; (2) the measured NO_x concentration at the east side is 30.5 mg/Nm³ (standard state, dry base, 6% oxygen content), the relative standard deviation of NO_x concentration distribution is 14.29%; (3) the average NO_x concentration at SCR outlet is 25.8 mg/Nm³ (standard state, dry base, 6% oxygen content).

The experimental results show that: the ammonia escape rate is 2.50 mg/Nm³ (standard form, dry base, 6% oxygen content) on the West side, 1.51 mg/Nm³ (standard state, dry base, 6% oxygen content) on the east side and 2.00 mg/Nm³ (standard form, dry base, 6% oxygen content) on the outlet of SCR system under 300 MW load condition. During the experimental period, the ammonia escape rate at the outlet of SCR system was not serious, thus, the corrosion of downstream air preheater caused by ammonium bisulfate was limited.

3.2. Calculation and analysis of air leakage in air preheater

The experimental oxygen content distribution on the east and west sides of SCR outlet are shown in figure 3 and figure 4 respectively.

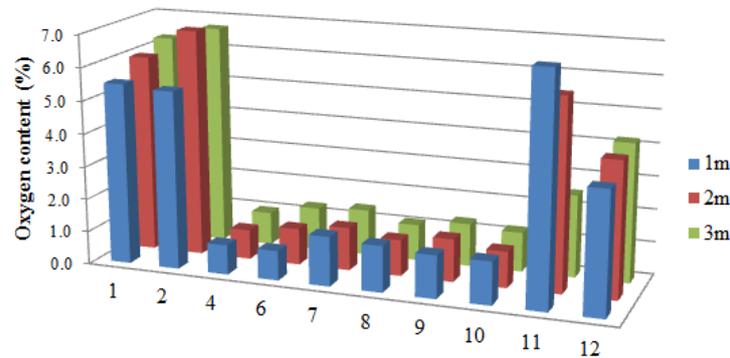


Figure 3. Oxygen content distribution on the west side of the air preheater inlet

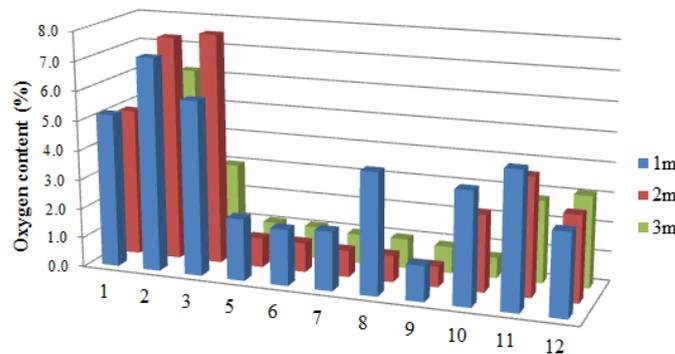


Figure 4. Oxygen content distribution on the east side of the air preheater inlet

For the air preheater inlet, the oxygen contents at East and west sides (hole 1-3, hole 10-12) are significantly higher than that at the middle orifice (hole 4-9), which indicates that there is a serious air leakage at the sidepiece of the air preheater, especially the east side.

According to the measured average oxygen content at the inlet of the air preheater and the outlet of the air preheater shown on the dial, the air leakage rate of the A side is 8.45% and the B side is 6.24% (Table 2), which are larger than the normal value of the air leakage rate of the tube type air preheater (less than 3%).

Table 2. Calculation table for the air leakage rate of air preheater.

Items	Unit	A	B
Oxygen content at the inlet of air preheater	%	2.7	3.1
Oxygen content at the outlet of air preheater	%	4.27	4.26
Inlet Excess air coefficient	—	1.14	1.17
Outlet Excess air coefficient	—	1.26	1.25
Leakage rate of air preheater	%	8.45	6.24

3.3. Acid dew point calculation of flue gas and analysis of air preheater corrosion

The amount of coal fired by the boiler is 180t/h during the experimental period with the load of 300MW. The coal quantity combusted in the boiler is high, indicating that the coal is rich in water and ash which has low calorific value. Coal quality test data are shown in Table 3. According to the coal

quality data, the moisture content of flue gas at the inlet of air preheater is 8.28%, which is in normal level.

According to the calculation formula of the acid dew point temperature of the flue gas in the new Russian edition of "boiler thermodynamic calculation standard method" [7], the acid dew point temperature of the flue gas is 366.45 K at the entrance of the air preheater. The exit temperature of A side for air preheater is 376.48 K and B side is 350.75 K. The temperature in the cold end of B-side for air preheater is obviously lower than the acid dew point due to the air leakage, which causes the condensation of sulphuric acid mist on the air preheater and the sulphuric acid corrosion of the air preheater, aggravating the air preheater leakage furtherly.

Table 3. Coal quality testing data.

Items		Value
	$M_{ar}(\%)$	10.3
Proximate analysis	Aar(%)	32.43
	Var(%)	19.11
	Car(%)	46.36
Ultimate Analysis	Har(%)	2.35
	Nar(%)	0.80
	Sar(%)	0.82
	Oar(%)	5.73
	$Q_{net,ar}(\text{MJ/kg})$	17.06

3.4. Advices

(1) It is suggested that the corrosion on both sides of air preheater (A and B) should be checked to see if the sulfuric acid condensation and acid corrosion on the side B is more serious than that on the side A, because of the lower flue gas temperature at the cold end of B side.

(2) It is suggested that the specific composition of the fouling on the cold end of the air preheater should be detected when the furnace is shut down for overhaul, so as to diagnose the flue gas composition and the cause of the fouling on the air preheater.

(3) The moisture content of flue gas is calculated according to the coal quality test data during the experimental period. It is suggested that the moisture content of flue gas at the exit of SCR system be measured to better evaluate the influence of moisture on ammonia escape rate.

4. Conclusions

(1) Ammonia escape rate at the outlet of SCR system was not serious during the experimental period, thus, the corrosion of downstream air preheater caused by ammonium bisulfate was limited.

(2) The air leakage rate on the A side of the air preheater is 8.45%, and that on the B side is 6.24%, which is higher than the normal value of the air leakage rate of the pipe air preheater (< 3%).

(3) The temperature in the cold end of B-side for air preheater is lower than acid dew point of flue gas due to air leakage, which results in sulphuric acid fog condensation and sulphuric acid corrosion on the air preheater, aggravating the air preheater leakage furtherly.

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