Analysis of Leakage and Corrosion of Air Preheater in Coal-Fired Power Plant

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Abstract. A unit of a coal-fired power plant (300MW) in North China was selected to study. The flue gas parameters (NH₃, O₂ and flue gas temperature) at the outlet of denitration system, oxygen content at the inlet and outlet of air preheater, and composition of combustion coal were tested. Then, the air leakage and corrosion of air preheater were evaluated from the operation of denitration system, air preheater leakage detection, and acid dew point calculation of flue gas. The influence of ammonium hydrogen sulfate from denitration system on the downstream air preheater is limited due to the low ammonia escaping. The air leakage rates of the air preheater at the side A and B were 8.45% and 3.01%, which are higher than the normal value (< 3%). Due to the air leakage of air preheater on side B, the cold end temperature of air preheater is significantly lower than the acid dew point of flue gas, resulting in the condensation of sulfuric acid mist in flue gas on the air preheater and the sulfuric 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]. Since the regenerative element of air preheater is a rotating body, there must be a certain gap between the dynamic and static bodies inevitably; at the same time, in order to prevent the expansion of the regenerative element after heating, there must also be a certain gap between the dynamic and static bodies; thus, the air and flue gas are not tight. Air leakage of air preheater increases power consumption of forced draft fan and induced draft fan. In serious cases, the boiler is forced to operate due to limited fan output. Air leakage increases heat loss of exhaust gas and reduces thermal efficiency of boiler [2-3]. Air leakage also reduces the temperature of hot air, leading to corrosion and ash blocking of the low temperature section of the heating surface [4-5]. Therefore, the detection and study of air leakage and corrosion of air preheater plays an important role in the safe and economic operation of coal-fired power plants.

This paper chooses a unit of a coal-fired power plant in North China to study. The flue gas parameters (NH₃, O₂ and flue gas temperature) at the outlet of denitration system, oxygen content at the inlet and outlet of air preheater, and composition of combustion coal were tested. The air leakage and corrosion of air preheater were evaluated from the operation of denitration system, air preheater self detection, and acid dew point calculation of flue gas. Based on the above test results and analysis, some suggestions are put forward for the normal operation and corresponding transformation of the air preheater of the unit.
2. Experiment and method

2.1. Flue gas denitrification system and air preheater
The unit is a 300MW circulating fluidized bed unit, and selective non-catalytic reduction (SNCR) denitrification technology is adopted in denitrification system. The flue of denitrification device is relatively wide, so it needs to be measured on the opposite side to ensure the test depth (both sides of flue were called east side and west side respectively), and the side holes on each side are numbered from south to north. The flue after denitrification system is divided into two parts, each of which contains an air preheater, so it contains two air preheaters (called A and B respectively).

2.2. Test scheme
The oxygen content of denitrification system and air preheaters were measured by flue gas analyser (NOVA 4000), the flue gas temperature was measured by thermocouple and electronic thermometer, and the ammonia escape was measured by LDAS-3000 portable ammonia escape analyser [6]. The calculation formula of acid dew point temperature of flue gas referred to the new Russian standard method for boiler thermal calculation [7].

3. Results and discussions

3.1. Flue gas denitrification system testing
The test results of ammonia escape at denitrification outlet are shown in Table 1: the measured ammonia escape concentration at the west side of denitrification system outlet is 2.50 mg/m³ (standard state, dry basis, 6% oxygen content); the measured ammonia escape concentration at the east side is 1.51 mg/m³ (standard state, dry basis, 6% oxygen content), and the average ammonia escape concentration at denitrification system outlet is 2.00 mg/m³ (standard state, dry basis, 6% oxygen content). During the test, ammonia escape from the outlet of denitrification system was not serious, thus ammonium bisulfate (ABS) blocked the downstream air preheater and the effect of ammonium salt corrosion was limited.

Figure 1 and Figure 2 are the oxygen content distribution diagram at the west and east measuring points of denitrification system outlet respectively. There are variable diameter slope flues at the south and north flues, and the oxygen content at the measuring points (hole 1-3, hole 10-12) at the east and west sides of the variable diameter is significantly higher than that at the middle measuring hole (hole 4-hole 9), indicating that there is serious air leakage at the variable diameter flues, and the air leakage at the east side of the variable diameter is more serious than that at the west side (Figure 1, Figure 2). The low oxygen content measurement point in the middle part of the flue at the east side of the denitrification system outlet cannot be tested for oxygen content due to the gap between continuous emission monitoring system (CEMS) control room (hole 4-hole 7), so the average oxygen content of the flue at the east side cannot be accurately evaluated. The actual average oxygen content of the flue at the east side is higher than the actual average oxygen content.

Table 1. Ammonia escape at denitrification outlet (mg/m³, standard state, dry basis, 6% oxygen content).

| Hole | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | Average |
|------|----|----|----|----|----|----|----|----|----|----|---------|
| West | 3.26 | /  | /  | 2.21 | 2.00 | 1.78 | 2.38 | 2.43 | 2.56 | 3.39 | 2.50 |
| East | /  | 2.56 | 1.91 | /  | /  | /  | 0.87 | 1.04 | 1.23 | 1.46 | 1.51 |

3.2. Air leakage of air preheater

According to the measured average oxygen content in the flue at the east and west sides of the denitration system outlet and the oxygen content at the outlet of two air preheaters (A and B), the...
calculated air leakage rate of air preheaters at side A and side B is 8.45% and 3.01% respectively (Table 2), both of which are higher than the normal value of tubular air preheater (<3%). However, as the measured average oxygen content in the east flue of denitration outlet is higher than the actual average oxygen content, the air leakage rate in the B side of the actual air preheater is higher than 3.01%. All of the above indicate that there is serious air leakage in the air preheater.

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

| Items                                      | Unit | A   | B   |
|--------------------------------------------|------|-----|-----|
| Oxygen content at the inlet of air preheater | %    | 2.7 | 3.7 |
| Oxygen content at the outlet of air preheater | %    | 4.27| 4.26|
| Excess air coefficient at inlet            |      | 1.14| 1.21|
| Excess air coefficient at outlet           |      | 1.26| 1.25|
| Air leakage rate of air preheater          | %    | 8.45| 3.01|

3.3 Calculation of acid dew point of flue gas

Under 300MW load, the operation panel of the unit shows that the coal consumption of the boiler is 180t/h, and the coal consumption of the boiler is on the high side, which indicates that the coal used is rich in moisture and ash and has low calorific value. The test data of coal quality during the test is shown in Table 3. According to the calculation of coal quality data, the moisture content of flue gas at the outlet of denitration system is 8.28%, and the moisture content of flue gas at the outlet of denitration system is at normal level.

According to the calculation formula of acid dew point temperature of flue gas in the new Russian standard method for boiler thermal calculation, the acid dew point temperature of flue gas at the inlet of air preheater is 93.3 °C. According to the data of air preheater outlet temperature displayed on the dial, the outlet temperature of a side and B side of air preheater are 103.23 °C and 77.6 °C respectively. Due to air leakage and other reasons, the cold end temperature of air preheater at side B is significantly lower than the acid dew point of flue gas, which causes the condensation of sulfuric acid mist in flue gas on the air preheater and causes sulfuric acid corrosion to the air preheater, further aggravating the air leakage of air preheater.

Table 3. Coal quality test data.

| Items                                      | Values    |
|--------------------------------------------|-----------|
| Total moisture content Maw (%)             | 10.7      |
| General analysis of coal moisture (%)      | 2.80      |
| Ash as received basis (%)                  | 34.83     |
| Volatile matter as received basis (%)      | 18.81     |
| Fixed carbon as received (%)               | 35.66     |
| C (%)                                      | 44.36     |
| H (%)                                      | 2.54      |
| N (%)                                      | 0.72      |
| S (%)                                      | 0.88      |
| O (%)                                      | 5.97      |
| Low calorific value of received basis Qnet,ar (MJ/kg) | 16.60 |

3.4. Air leakage of air preheater

(1) It is recommended to detect the corrosion on both sides of air preheater A and B during shutdown maintenance to see if the sulfuric acid condensation and acid corrosion on side B caused by low smoke temperature at the cold end is more serious than that on side A.
(2) It is suggested to detect the specific components of the scale on the cold end of the air preheater when the boiler is shut down for maintenance, so as to diagnose the specific components and causes of the flue gas fouling of the air preheater.

(3) At present, the moisture content of flue gas is calculated according to the coal quality test data on the day of test. It is suggested to measure the moisture content of flue gas at the outlet of denitration system to better evaluate the impact of moisture in flue gas on ammonia escape test.

(4) The $O_2$ online test instrument at the outlet of denitration system is located in hole 8 (at the low oxygen content test hole) of the west flue. The deviation between the oxygen content at the instrument and the average oxygen content in the flue gas at the outlet of denitration is caused by the serious air leakage at the flue gas reducer, so it is impossible to accurately evaluate the oxygen content in the flue gas at the outlet of denitration. It is suggested to increase $O_2$ at the flue gas with uniform mixing at the inlet of air preheater online test instrument.

4. Conclusions

(1) The phenomenon of ammonia escaping from the outlet of denitration system is not serious, thus the influence of ammonium hydrogen sulfate on the downstream air preheater is limited.

(2) According to the measured average oxygen content in the outlet flue at the east and west sides of the denitration system and the oxygen content at both sides of the air preheater outlet, the air leakage rates of the air preheater at the side A and B can be calculated to be 8.45% and 3.01%, both of which are higher than the normal value (< 3%) of the air leakage rate of the tubular air preheater.

(3) Due to the air leakage of air preheater on side B, the cold end temperature of air preheater is significantly lower than the acid dew point of flue gas, resulting in the condensation of sulfuric acid mist in flue gas on the air preheater and the sulfuric acid corrosion on the air preheater, further aggravating the air leakage of air preheater.

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