Experimental Study on Optimized Adjustment of Ammonia Spraying in 300MW Unit

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Abstract. The experimental study on the optimization of ammonia injection in the denitration system of a 300MW coal-fired unit in a power plant. Under the premise of meeting the ultra-low emission standards of environmental protection requirements, the ammonia injection amount of the denitration device can be reasonably adjusted by adjusting the opening degree of the manual ammonia valve. It significantly improves the uniformity of the NOx concentration distribution in the denitration system. It eliminates local ammonia slip peaks and reduces ammonia slip rate. The deviation of the NOx concentration distribution at the outlet of the denitration system decreased by 70.1% and 46.7%, respectively. The ammonia slip concentration decreased by an average of 0.80 mg/m3 and 1.05 mg/m3. Ammonia consumption decreased by 8 kg/h and 15 kg/h, respectively.

Keywords: Ammonia optimization; NOx concentration; ammonia slip concentration; valve opening.

1. Introduction
Nitrogen oxides is an important cause of photochemical smog and acid rain [1-2]. Coal-fired power plants are one of the sources of NOx emissions [3]. According to the requirements of ultra-low emission retrofit, the NOx concentration of the modified boiler flue gas is not more than 50mg/m$^3$. After the denitration ultra-low emission reform of a 300MW unit in a power plant, it is found that the implementation of ultra-low emission standards has brought some outstanding problems to the long-term, safe, reliable and economic operation of the unit [4], such as unstable NOx emission from the chimney outlet and the air preheater (air preheater) frequently appears to block the ammonium hydrogen sulfate[5].

In view of the above problems, this paper starts from the problem of uniformity of NOx concentration distribution in the denitration reactor. By adjusting the ammonia injection amount of the denitration device, the uniformity of NOx distribution and the uniformity of ammonia utilization at the outlet of the denitration device are improved, and the local ammonia escape peak is eliminated. It is of great significance to improve the economic and safety of the unit operation.
2. Overview of denitration test

The unit adopts the selective catalytic reduction method for flue gas denitration. The flue gas denitration device is installed between the boiler economizer outlet and the air preheater inlet. Two SCR reactors are installed in each boiler and are arranged symmetrically along the centerline of the boiler. Guide vanes are respectively arranged at the economizer outlet flue flare, the inlet and outlet turns of the vertical flue, and the top inlet of the reactor. The reactor is arranged in a "2+1" mode. Within the normal load range of the boiler, the NOx concentration at the inlet of the denitration device under design conditions is 650mg/m$^3$ (standard, dry basis, 6%O$_2$), and the outlet NOx concentration is not higher than 50mg/m$^3$ (standard, dry basis, 6%O$_2$).

2.1. Test conditions

The ammonia-smelting optimization test of this denitration device is carried out according to GB/T16157-1996 "determination of particulates and sampling methods of gaseous pollutants emitted from exhaust gas of stationary source". According to the current unit operating conditions of the power plant and the above test standards, the test conditions are arranged as follows: 100% load rate working condition test 1 day, 100% load rate working condition adjustment test 4 days, 100% load rate working condition comparison test 1 day.

2.2. Test Project

(1) The preliminary test contents include the NOx concentration at the inlet of the denitration device, the inlet O$_2$ concentration, the outlet NOx concentration, the outlet O$_2$ concentration, and the outlet ammonia escape. Through the preliminary test, the actual performance of the current denitration device and the ammonia escape condition are grasped in detail, which lays a foundation for the adjustment and optimization test.

(2) After the preliminary test, the optimization test of the ammonia injection system is carried out. The main test contents are inlet NOx concentration, inlet O$_2$ concentration, outlet NOx concentration, outlet O$_2$ concentration, export ammonia escaping, test by ammonia spray, coarse adjustment At the stage of fine tuning, etc., the uniform distribution of the outlet NOx concentration is finally achieved.

(3) After the adjustment, the comparison test is carried out. The main test contents include the NOx concentration at the inlet of the denitration device, the inlet O$_2$ concentration, the outlet NOx concentration, the outlet O$_2$ concentration, and the outlet ammonia escape.

3. Test results

3.1. Preliminary test

3.1.1. NOX concentration test of the flue gas at the inlet of the denitrification device. The width direction "A1" of the A side is the outermost side of the reactor. The "A6" is the center line side of the boiler. The width direction "B6" of the B side is the outermost side of the reactor. The "B1" is the center line side of the boiler. Depth 1 is a shallow depth position. Depth 2 is a position with a large depth.

The average NOx concentration at the inlet of the A side was measured to be 709 mg/m$^3$ (standard state, dry basis, 6% O$_2$). The average NOx concentration at the B side inlet was 693 mg/m$^3$ (standard state, dry basis, 6% O$_2$). The relative standard deviations of the NOx concentrations after the conversion of the SCRA side inlet and the SCRB side inlet were 6.4% and 5.4%, respectively. The concentration distribution is relatively uniform.
3.1.2. **SCR outlet flue gas NOx concentration field test.** The width direction "A1" of the A side is the outermost side of the reactor. “A9” is the boiler center line side. The B side width direction "B9" is the outermost side of the reactor. “B1” is the boiler center line side. Depth 1 is a shallow depth position. Depth 2 is a position with a large depth.

Under the predicted conditions, the average NOx concentration of the outlet on the A side was 43 mg/m$^3$ (standard, dry basis, 6% O$_2$), and the average NOx concentration on the B side was 42 mg/m$^3$ (standard, dry basis, 6% O$_2$). The relative standard deviations of the NOx concentrations after the conversion of the SCRA side outlet and the SCRB side outlet are 92.8% and 66.2%, respectively. The concentration distribution is uneven.
3.1.3. Ammonia escape test. The average NOx concentration at the A side inlet is 709 mg/m³ (standard, dry basis, 6% O₂), the average NOx concentration at the outlet is 43 mg/m³ (standard, dry basis, 6% O₂), and the denitration efficiency is 93.96%, and the ammonia escaped 2.27 mg/m³ (standard, dry basis, 6% O₂). The average NOx concentration at the B side inlet is 693 mg/m³ (standard, dry basis, 6% O₂), the average NOx concentration at the outlet is 42 mg/m³ (standard, dry basis, 6% O₂), and the denitration efficiency is 93.89%, and the ammonia escaped 2.31 mg/m³ (standard, dry basis, 6% O₂). The average ammonia slip of the SCR outlet of a single furnace was 2.29 mg/m³. The ammonia escape concentration distribution at the SCR outlet is shown in Figure 5.

**Fig.3** NOx concentration distribution at the outlet of the SCRA side under the bottom condition

**Fig.4** NOx concentration distribution at the outlet of the SCRB side under the bottom condition
3.1.4. Ammonia consumption test. In the time period that meets the test requirements and conditions, according to the measured NOx concentration, ammonia slip, dynamic pressure, static pressure and temperature in the flue gas, the ammonia consumption of the A reactor is calculated to be 148kg/h, and the ammonia of the B reactor is calculated to be 140kg/h. The ammonia consumption of a single furnace is 288kg/h.

3.2. Spraying ammonia optimization adjustment and comparison test

3.2.1. Ammonia branch pipe adjustment door opening adjustment. The relative standard deviation of the NOx concentration after the outlet of the denitration device A side is 92.8%. The relative standard deviation of NOx concentration after the conversion of the B side outlet of the denitration device was 66.2%. The NOx concentration in the intermediate zone of the A reactor and near the centerline of the furnace is significantly higher. The NOx concentration in the B reactor outlet away from the furnace centerline is low.

In view of the above test results, multiple adjustments were made to the manual opening of the ammonia spray branch to maximize the uniformity of the NOx concentration distribution at the outlet of the reactor. Before and after the optimization adjustment, the opening degree of the manual valve of each ammonia branch pipe is shown in Table 1.

| Valve number | A1  | A2  | A3  | A4  | A5  | A6  | A7  | A8  | A9  |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Original opening | 4   | 4   | 4   | 4   | 5   | 5   | 3   | 5   | 4   |
| Adjusted opening | 5   | 4   | 5   | 4   | 4   | 5   | 4   | 4   | 6   |

| Valve number | A10  | A11  | A12  | A13  | A14  | A15  | A16  | A17  | A18  |
|--------------|------|------|------|------|------|------|------|------|------|
| Original opening | 4   | 5   | 6   | 7   | 6   | 8   | 8   | 6   | 6   |
| Adjusted opening | 4   | 5   | 4   | 6   | 5   | 9   | 9   | 6   | 6   |

| Valve number | B1  | B2  | B3  | B4  | B5  | B6  | B7  | B8  | B9  |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Original opening | 5   | 6   | 6   | 6   | 5   | 5   | 6   | 5   | 5   |
| Adjusted opening | 6   | 7   | 7   | 7   | 5   | 5   | 5   | 4   | 6   |

| Valve number | B10  | B11  | B12  | B13  | B14  | B15  | B16  | B17  | B18  |
|--------------|------|------|------|------|------|------|------|------|------|
| Original opening | 5   | 8   | 8   | 5   | 5   | 6   | 6   | 7   | 7   |
| Adjusted opening | 7   | 8   | 8   | 5   | 4   | 5   | 5   | 5   | 4   |

Table 1. Summary table of manual valve opening degree of ammonia spray pipe
3.2.2. *NOX concentration test of the flue gas at the inlet of the denitrification device.* The width direction "A1" of the A side is the outermost side of the reactor. "A6" is the boiler center line side. The B side width direction "B6" is the outermost side of the reactor. “B1” is the boiler center line side. Depth 1 is a shallow depth position. Depth 2 is a position with a large depth.

![Fig.6 NOx concentration distribution at the inlet of the SCRA side](image)

**Fig.6 NOx concentration distribution at the inlet of the SCRA side**

The average NOx concentration at the A side inlet was 697 mg/m$^3$ (standard, dry basis, 6% O$_2$). The average NOx concentration at the B side inlet was 668 mg/m$^3$ (standard, dry basis, 6% O$_2$). The relative standard deviations of the NOx concentrations after the conversion of the denitration device A side inlet and the denitration device B side inlet were 1.7% and 3.0%, respectively. The concentration distribution is relatively uniform.

![Fig.7 NOx concentration distribution at the inlet of the SCRB side](image)

**Fig.7 NOx concentration distribution at the inlet of the SCRB side**

3.2.3. *NOx concentration field test of flue gas at denitrification unit outlet.* The width direction "A1" of the A side is the outermost side of the reactor. “A9” is the boiler center line side. The B side width direction "B9" is the outermost side of the reactor. “B1” is the boiler center line side. The depth 1 is a shallow depth position, and the depth 2 is a deep depth position.

The average NOx concentration at the A side outlet was 35 mg/m$^3$ (standard, dry basis, 6% O$_2$). The average NOx concentration at the B side outlet was 41 mg/m$^3$ (standard, dry basis, 6% O$_2$). The relative standard deviations of NOx concentrations after the conversion of the SCRA side outlet and the SCRB side outlet were 22.7% and 19.5%, respectively. Uniformity is significantly improved.
3.2.4. Ammonia escape test. The average NOx concentration at the A side inlet was 697 mg/m$^3$ (standard, dry basis, 6% O$_2$). The average NOx concentration at the outlet was 35 mg/m$^3$ (standard, dry basis, 6% O$_2$). The denitration efficiency was 94.91%. The average ammonia slip of the outlet was 1.47 mg/m$^3$ (standard, dry basis, 6% O$_2$). The average NOx concentration at the B side inlet was 668 mg/m$^3$ (standard, dry basis, 6% O$_2$). The average export NOx concentration was 41 mg/m$^3$ (standard, dry basis, 6% O$_2$). The denitration efficiency was 93.82%. The average ammonia slip of the outlet was 1.26 mg/m$^3$ (standard, dry basis, 6% O$_2$). The average ammonia slip at the outlet of a single furnace denitrification unit was 1.37 mg/m$^3$. The ammonia slip concentration distribution at the outlet of the denitrification device is shown in Fig.13.
3.2.5. Ammonia consumption test. In the time period that meets the test requirements and conditions, according to the NOx concentration, ammonia slip, dynamic pressure, static pressure and temperature measured in the test, the ammonia consumption of the A reactor is calculated to be 140kg/h, and the ammonia of the B reactor is calculated to be 125kg/h. The ammonia consumption of a single furnace is 265kg/h.

4. Conclusion
(1) Under the pre-condition, the non-uniformity coefficient of the concentration distribution of NOx (standard state, dry basis, 6% O$_2$) on the SCRA side was 92.8%, and the concentration distribution of NOx (standard state, dry basis, 6% O$_2$) on the SCRB side was distributed. The unevenness factor was 66.2%. Under the contrast conditions, the non-uniformity coefficient of the concentration distribution of NOx (standard state, dry basis, 6% O$_2$) on the SCRA side was 22.7%, and the concentration distribution of NOx (standard state, dry basis, 6% O$_2$) on the SCRB side was uneven. The coefficient was 19.5%. After optimization and adjustment, the uniformity of NOx concentration distribution at the SCR outlet was significantly improved.

(2) Under the pre-condition, the average ammonia slip of the SCRA side exit was 2.27mg/m$^3$ (standard, dry basis, 6%O$_2$), and the local ammonia slip peak was 3.90mg/m$^3$ (standard, dry basis, 6%O$_2$). The average ammonia slip of the SCRB side outlet was 2.31 mg/m$^3$ (standard state, dry basis, 6% O$_2$), and the local ammonia slip peak was 4.29 mg/m$^3$ (standard state, dry basis, 6% O$_2$). Under the comparative conditions, the average ammonia slip of the SCRA side outlet was 1.47mg/m$^3$ (standard, dry basis, 6%O$_2$), the local ammonia slip peak was 1.73mg/m$^3$ (standard, dry basis, 6%O$_2$); SCRB side exit The average ammonia slip was 1.26 mg/m$^3$ (standard, dry basis, 6% O$_2$), and the local ammonia slip peak was 1.29 mg/m$^3$ (standard, dry basis, 6% O$_2$). After optimization and adjustment, ammonia slip at the SCR outlet was significantly reduced.

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