

# Study on Optimization Test Method of Ammonia Injection in SCR Denitrification Unit in Thermal Power Plant

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**Abstract.** The method and procedure of ammonia injection optimization test in SCR denitrification unit in thermal power plant are introduced. The SCR in a 220MW unit is investigated, through ammonia injection optimization test, the distribution uniformity of NO<sub>x</sub> at SCR outlet is improved, ammonia escape concentration is reduced, then the damage of ammonia escape to boiler tail equipment is reduced, the economic and reliability of unit is improved.

## 1. Introduction

With the increasingly stringent national environmental protection requirements and the implementation of ultra-low emission renovation in power plants, the emission of NO<sub>x</sub> is more restricted. Selective Catalytic Reduction (SCR) flue gas denitrification technology has become the main choice for coal-fired power plants to control the emission of NO<sub>x</sub> because of its high denitrification rate (up to 90%) and mature technology.

However, due to the lack of sufficient understanding of the SCR operation characteristics of the operators, blind ammonia injection leads to excessive ammonia injection and excessive ammonia escape. At the same time, after running for a long time, the uneven flow field of inlet flue gas and the decrease of activity of some catalysts will also lead to excessive ammonia injection and excessive ammonia escape. Ammonium bisulfate will be produced by the reaction of ammonia escaping with SO<sub>3</sub> in flue gas, which will cause corrosion of boiler tail equipment, especially aggravate ash blockage of air preheater [1-4], and seriously affect the safe and stable operation of the unit.

Therefore, in order to control ammonia escaping at a reasonable level, ammonia injection optimization test in SCR denitrification unit should be carried out regularly.

## 2. Method and procedure of ammonia injection optimization test

### 2.1. Method and procedure

Relevant scholars have realized a uniform distribution of NO<sub>x</sub> at the outlet of the denitration system and reduced the ammonia escape rate through a large number of on-site ammonia injection optimization tests [5-9]. However, there is no test standard for the ammonia spray optimization test at present. The following methods and procedures are used in this test, all tests are carried out under the normal operating conditions of SCR system.



**2.1.1. Cold test.** Before the ammonia injection optimization adjustment, the ammonia injection grille should be adjusted in cold condition to ensure that the ammonia injection branch pipe is unobstructed and the dilution air volume meets the requirements of ammonia injection.

**2.1.2. Soot blowing.** In order to exclude the affect to the denitrification reaction of ash deposit on the surface, thoroughly soot blowing of the SCR system should be carried out before the test.

**2.1.3. Preliminary test.** Preliminary test is carried out first, including the arrangement of measuring points, the calibration of CEMS and debugging of the test instrument.

**2.1.4. Basic test.** Basic test is carried out after the preliminary test, mainly testing the concentration distribution of NO<sub>x</sub>/O<sub>2</sub> at the inlet and outlet of SCR, the flue gas flow field at the inlet of SCR, and the concentration distribution of NH<sub>3</sub> at the outlet of SCR.

**2.1.5. Optimization test.** According to the results of basic test, the opening of each ammonia injection valve is adjusted to adjust the ammonia injection quantity of each ammonia injection grid and the concentration of NO<sub>x</sub>/O<sub>2</sub> at SCR outlet section and the distribution of NH<sub>3</sub> escape is measured. According to the test results, the manual valve opening of ammonia injection grille at the inlet of SCR was adjusted repeatedly to improve the uniformity of NO<sub>x</sub> distribution at the outlet of the system until the ammonia escape was controlled at a reasonable level.

## 2.2. Evaluation index

Guaranteeing the emission of NO<sub>x</sub> up to the standard, the ammonia escape concentration and the deviation coefficient of NO<sub>x</sub> concentration at outlet of SCR are two primary evaluation indexes of ammonia injection optimization test. Considering the policy of energy saving and emission reduction, the consumption of liquid ammonia still needs to be tested during the optimization of ammonia injection. Usually, after the optimization of ammonia injection, the amount of ammonia injection will be reduced. The evaluation indexes of ammonia injection optimization test are as follows:

(1) The average concentration of NO<sub>x</sub> at outlet of SCR, less than 100mg/Nm<sup>3</sup>;

(2) Ammonia escape, less than 3 ppm;

(3) C<sub>v</sub>- deviation coefficient of concentration of NO<sub>x</sub> at outlet of SCR, C<sub>v</sub> is expressed as follows [10]

$$C_v = \frac{\sigma}{\bar{x}} \times 100\% \quad (1)$$

$$\sigma = \sqrt{\frac{1}{(n-1)} \sum_{i=1}^n (x_i - \bar{x})^2} \quad (2)$$

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad (3)$$

Where

$\sigma$  -standard deviation of mass concentration of NO<sub>x</sub>, mg/Nm<sup>3</sup>;

$\bar{x}$  -average value of mass concentration of NO<sub>x</sub>, mg/Nm<sup>3</sup>;

$x_i$  -mass concentration of NO<sub>x</sub> at a measuring point, mg/Nm<sup>3</sup>;

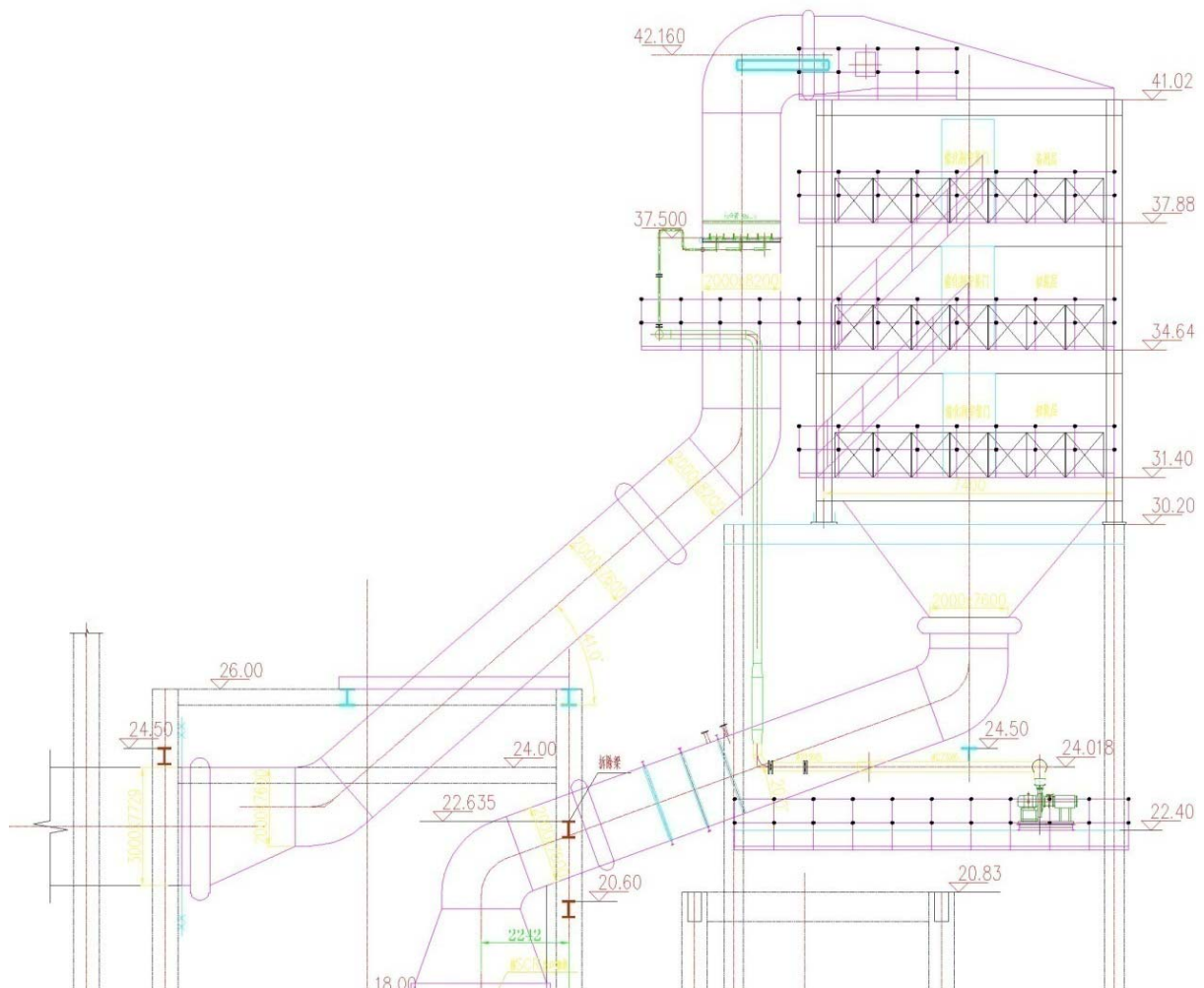
$n$  - number of measuring points.

## 3. Ammonia injection optimization test

### 3.1. Object of study.

The object of this study is SCR denitrification equipment of 220 MW unit in a power plant. The boiler of this unit, which model is DG670/13.7-8A, is a  $\Pi$  type arrangement, ultra-high pressure, solid-state

slag removal and natural circulation furnace produced by Dongfang Boiler Work. The intermediate storage pulverizing system is adopted, and the tubular ball mill is equipped with hot air for powder feeding. The designed coal type is Jinzhong bituminous coal. SCR flue gas denitrification unit is arranged between economizer and air preheater, using liquid ammonia as denitrification reductant. The denitrification unit has two reactors, each with three layers of catalysts, and the catalyst is honeycomb type, as shown in Figure 1. The main design parameters of the reactor are shown in Table 1.



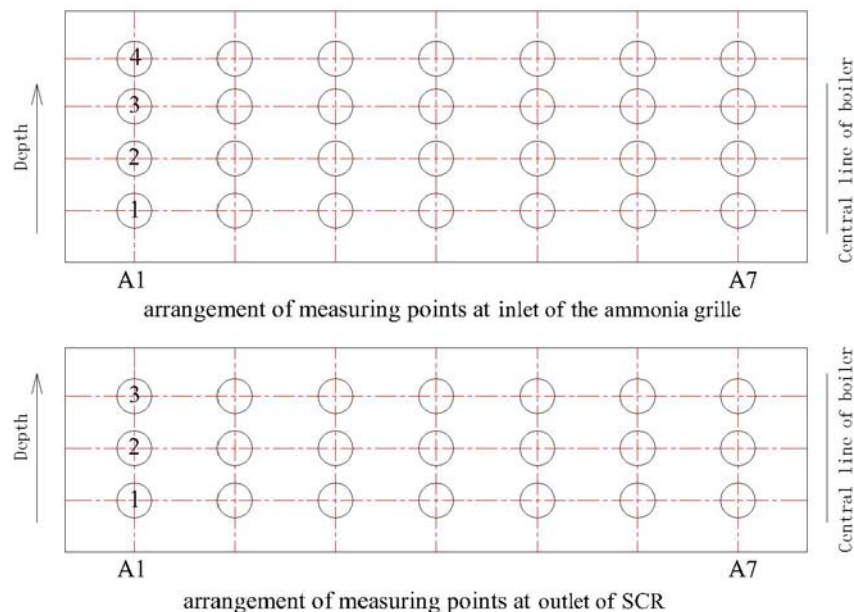
**Figure 1.** Facade layout of denitration reactor.

**Table 1.** The main design parameters of the reactor.

Item	Unit	Value
Design service temperature	°C	386
Maximum allowable service temperature	°C	420
Minimum allowable service temperature	°C	300
Ammonia escape	ppm	<3
Denitrification efficiency	%	>80
Transform rate of SO <sub>2</sub> /SO <sub>3</sub>	%	<1
Inlet NO <sub>x</sub> concentration(6%O <sub>2</sub> , dry)	mg/Nm <sup>3</sup>	450
Inlet SO <sub>2</sub> concentration(6%O <sub>2</sub> ,dry)	mg/Nm <sup>3</sup>	1744.1
Inlet SO <sub>3</sub> concentration(6%O <sub>2</sub> ,dry)	mg/Nm <sup>3</sup>	8.8
Fly ash concentration(6%O <sub>2</sub> , wet)	mg/Nm <sup>3</sup>	23.84
Distribution deviation of velocity of inlet flue gas	%	<15

### 3.2. Arrangement of measuring points and test method

**3.2.1. Arrangement of measuring points.** As shown in Figure 2, 7×4 measuring points and 7×3 measuring points are arranged separately according to the equal section grid method on the A and B sides of inlet of the ammonia grille and the outlet of SCR.

**Figure 2.** Arrangement of measuring points.

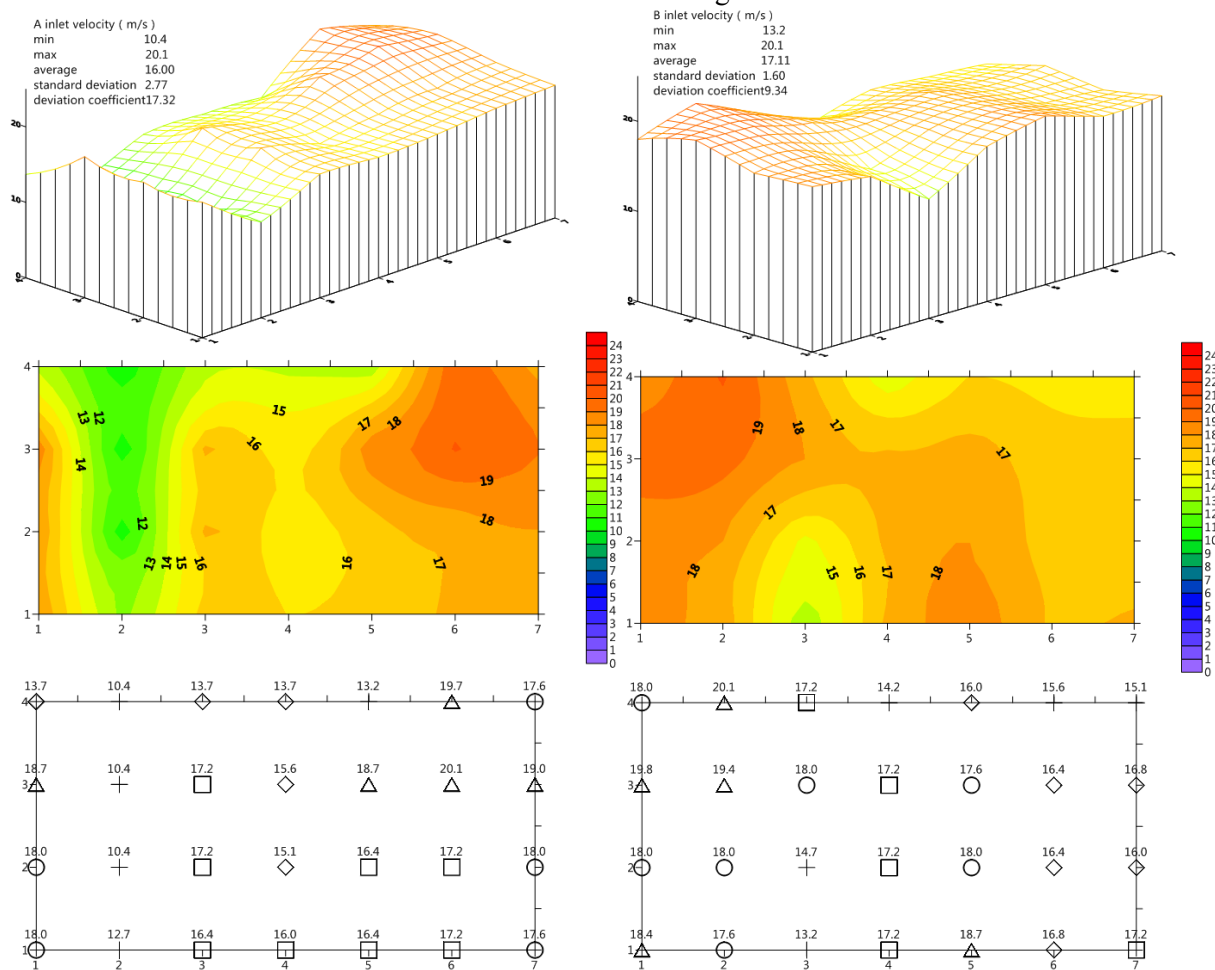
**3.2.2. Test method.** The flue gas velocity was measured by standard L-type Pitot tube and electronic microbarometer; the ammonia escape was measured by portable ammonia escape meter with laser method; the concentration of NO<sub>x</sub> in flue gas was measured by fast switching valve group and flue gas analyzer.

### 3.3. Basic test

The basic test was carried out under the condition of 200 MW electric load of the unit, and the flue gas flow field at the inlet, the NO<sub>x</sub> concentration field and ammonia escape concentration distribution at inlet and outlet of the two SCR reactors were tested.

**3.3.1. Flue gas flow field at the inlet of SCR.** The flow velocity distribution of the flue gas was tested at the front of the AIG. The results are shown in Fig.3. The maximum flue gas flow rate at the inlet of the A reactor was 20.1 m/s, the minimum value was 10.4 m/s, and the deviation coefficient was 17.32%. The maximum flow rate of the inlet of the B reactor was 20.1 m/s, the minimum value was 13.2 m/s, and the deviation coefficient was 9.34%. The deviation coefficient of the flue gas flow rate at the inlet of the A-side ammonia grid is higher than the design requirement of 15%. This is mainly limited by the on-site installation conditions, the flue diversion before the AIG resulting in uneven distribution of air flow, resulting in greater velocity unevenness of the flue gas.

The flue gas flow rates at the inlets of A and B reactors were 137.76 kg/s and 146.76 kg/s, respectively. The results are shown in Table 2. The flow rate of flue gas on side A was 6.1% smaller than that on the B side, while the amount of ammonia sprayed on both sides was basically the same. The amount of ammonia sprayed on side A is obviously too large. Therefore, the ammonia injection control should consider the difference in the amount of flue gas on both sides of A and B.



**Figure 3.** Flue gas flow field at the inlet of SCR.

**Table 2.** Test results of the inlet flue gas flow.

Position	A	B
Inlet section size	8.2m*2m	
Average velocity (m/s)	16.00	17.11
Deviation coefficient (%)	17.32	9.34
Flue gas flow (kg/s)	137.76	146.76

**3.3.2.  $\text{NO}_x$  concentration field.** The distribution of  $\text{NO}_x$  concentration at the inlet of the two reactors was generally uniform, and the deviation coefficients were all below 10%. The test results are shown in Table 3.

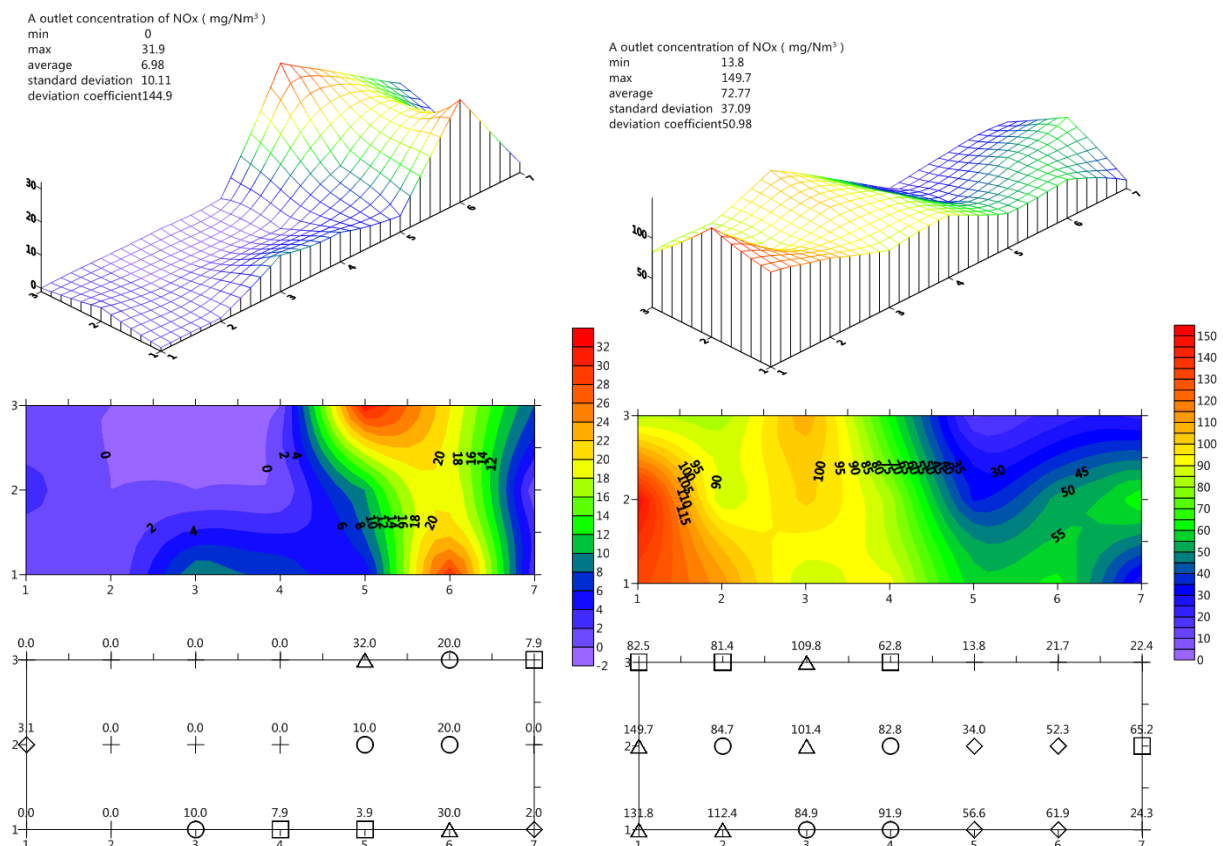
**Table 3.**  $\text{NO}_x$  concentration field at the inlet of SCR.

Item	A	B
Min (mg/Nm <sup>3</sup> )	430.9	475.4
Max (mg/Nm <sup>3</sup> )	585.4	540.1
Average (mg/Nm <sup>3</sup> )	522.87	513.7
Standard deviation (mg/Nm <sup>3</sup> )	51.20	20.50
Deviation coefficient (%)	9.79	3.99

There is a significant unevenness in the  $\text{NO}_x$  distribution at the outlets of the two reactors. The test results are shown in Figure 4.

**A reactor outlet:** The  $\text{NO}_x$  concentration is high near the center line of the boiler, the  $\text{NO}_x$  concentration in the outer wall area is low, and even a large number of zero values appear. The average  $\text{NO}_x$  concentration at the outlet section is 6.98mg/Nm<sup>3</sup>, the highest is 31.9 mg/Nm<sup>3</sup>, and the lowest is 0, the distribution deviation coefficient is 144.9%.

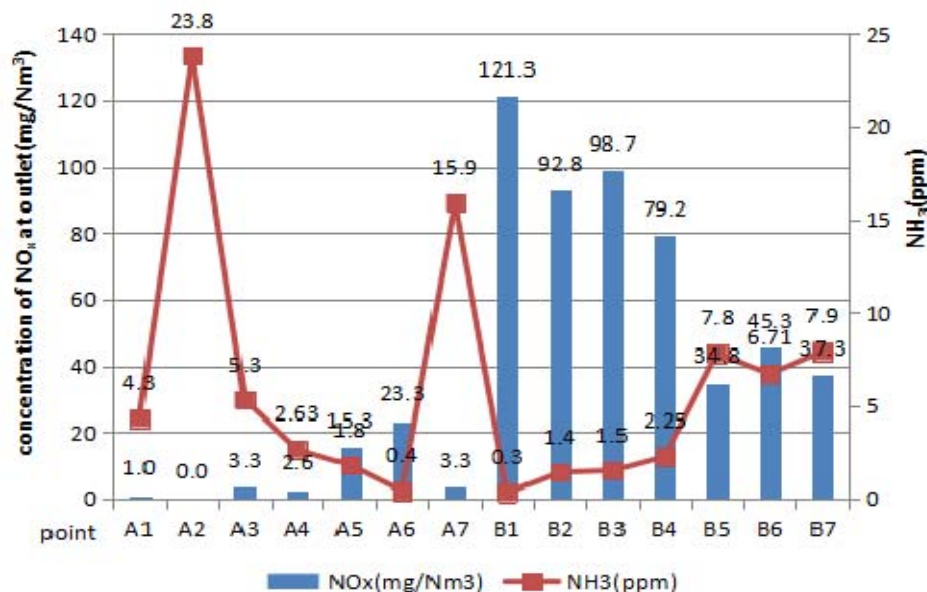
**B reactor outlet:** The  $\text{NO}_x$  concentration is high near the center line of the boiler, and the  $\text{NO}_x$  concentration is low in the outer wall region. The average  $\text{NO}_x$  concentration at the outlet section is 72.77 mg/Nm<sup>3</sup>, the highest is 149.7 mg/Nm<sup>3</sup>, and the lowest is 13.8 mg/Nm<sup>3</sup>. The distribution deviation coefficient is 50.98%.



**Figure 4.**  $\text{NO}_x$  concentration field at the outlet of SCR.



**3.3.3. Ammonia escape.** The test results of the ammonia escape at the outlet of the SCR are shown in Figure 5. It can be seen that the trend of the ammonia escape distribution is basically opposite to the trend of the  $\text{NO}_x$  concentration distribution. The average ammonia escape concentration at the outlets of A and B reactors are 7.73 ppm and 3.98 ppm respectively, both exceeding 3 ppm, and the peak values are 23.8 ppm and 7.9 ppm respectively. There is excess ammonia injection, so it is necessary to optimize and adjust the amount of ammonia sprayed.



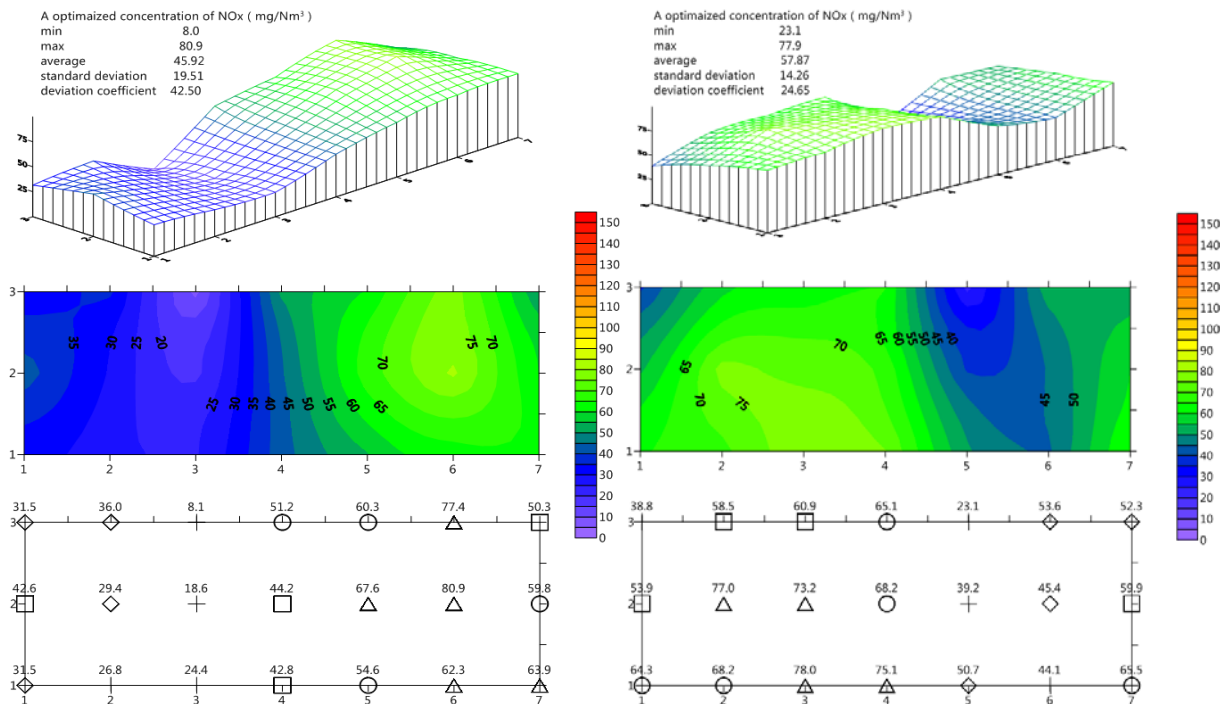
**Figure 5.** Ammonia escape.

The concentration of  $\text{NH}_3$  was measured at the center of each point, and the corresponding concentration of  $\text{NO}_x$  was taken as the average value of three values in the depth direction.

### 3.4. Result of optimization test

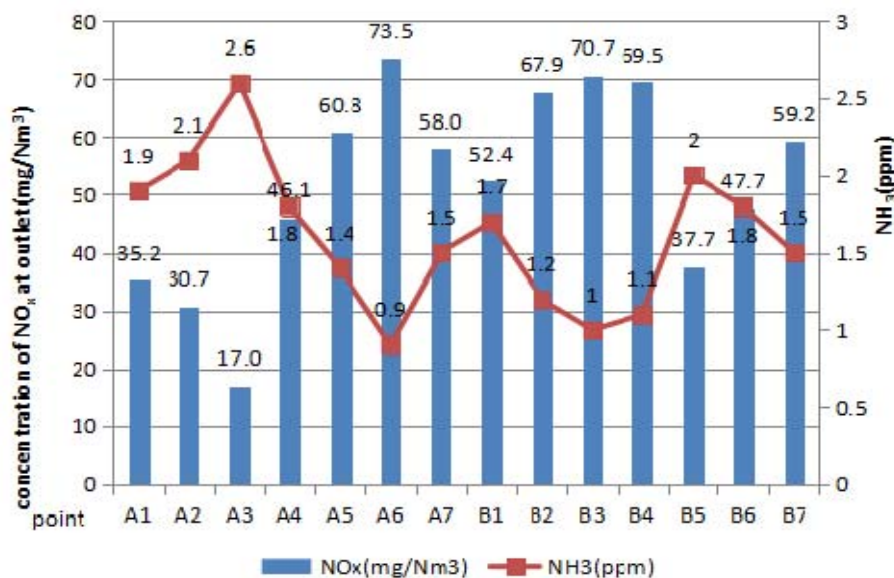
The ammonia injection optimization adjustment test was carried out under the 200MW electric load condition of the unit. According to the distribution of the  $\text{NO}_x$  concentration at the outlet section of the measured reactor, the manual adjustment of the butterfly valve opening of each branch of the AIG was adjusted several times until the uniformity of  $\text{NO}_x$  concentration distribution at the outlet reached the ideal condition and the ammonia escape reached the standard (<3ppm, both average and peak value).

**3.4.1.  $\text{NO}_x$  concentration at the outlet of SCR.** The distribution of  $\text{NO}_x$  concentration at the outlet of SCR after optimization is shown in Fig. 6. The average value of  $\text{NO}_x$  concentration at the outlet of a reactor is 45.92 mg/Nm<sup>3</sup>, the highest value is 80.9 mg/Nm<sup>3</sup>, the lowest value is 8 mg/Nm<sup>3</sup>, and the deviation coefficient is 42.5%. The average concentration of  $\text{NO}_x$  at the outlet of B reactor was 57.87 mg/Nm<sup>3</sup>, the highest value was 77.9 mg/Nm<sup>3</sup>, the lowest value was 23.1 mg/Nm<sup>3</sup>, and the deviation coefficient was 24.65%. After optimization, the uniformity of the distribution of  $\text{NO}_x$  concentration at the outlet of SCR has been significantly improved.



**Figure 6.** NO<sub>x</sub> concentration at the outlet of SCR after optimization.

**3.4.2. Ammonia escape.** The results of ammonia escape test after optimization and adjustment are shown in Figure 7. The average values of ammonia escape concentration at the outlets of A and B reactors were 1.74 ppm and 1.47 ppm, and the peak values were 2.6 ppm and 2.0 ppm respectively, which were less than 3 ppm. The ammonia escape concentration reached the standard.



**Figure 7.** Ammonia escape after optimization.

**3.4.3. The consumption of liquid ammonia.** The amount of ammonia sprayed on both sides of A and B decreased from 53kg/h and 54kg/h to 47kg/h and 50kg/h.



#### 4. Conclusion

Through ammonia injection optimization, the uniformity of NO<sub>x</sub> concentration field at outlet of SCR was improved, and the concentration of ammonia escape was also decreased. The uniformity of NO<sub>x</sub> concentration field at the outlet of A-side reactor was increased by 70%. The uniformity of NO<sub>x</sub> concentration field at the outlet of side B was increased by 51.6%, and the ammonia escape concentration at the outlet of SCR was controlled within 3 ppm.

NO<sub>x</sub> uniformity at SCR outlet should not be excessively pursued. Especially for the SCR denitration device that has been put into operation for 1-2 years, when the ammonia injection optimization test is carried out, it should be appropriately adjusted according to the distribution of the escape ammonia concentration. The uniformity adjustment is more suitable for the SCR denitration unit of the new commissioning unit.

Under the condition of meeting the environmental protection index, the ammonia injection quantity and the denitrification efficiency can be reduced appropriately to improve the operation economy of the denitrification system.

As the running time increases, the activity of the catalyst will continuously decrease, and the unevenness of the flue gas flow field will also change. The ammonia injection optimization test should be carried out regularly.

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