

# Study on Performance Optimization of SCR Denitrification of an Ultra-low Emission Coal-fired Power Unit

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**Abstract.** The distribution of NO<sub>x</sub> concentration, flue gas flow field and temperature at the inlet and NO<sub>x</sub> concentration at the outlet of SCR denitrification were measured in a 330MW ultra-low emission coal-fired power unit, and ammonia injection optimization was carried out to improve the performance of SCR denitrification. The test results show that the distribution of NO<sub>x</sub> concentration and flue gas temperature at the inlet of SCR reactor is relatively uniform, and the distribution of flue gas flow field at the inlet of SCR reactor is nonuniform. The distribution uniformity of NO<sub>x</sub> concentration at the outlet of SCR reactor is poor before optimization. The NO<sub>x</sub> concentration distribution at the outlet of SCR reactor is improved by ammonia injection adjustment, and the relative standard deviation of NO<sub>x</sub> concentration distribution at the outlet of SCR reactor A and B decrease from 48.7% and 33.8% to 12.1% and 14.7%, respectively.

## 1. Introduction

Coal-fired power plants are one of the main emission sources of nitrogen oxides (NO<sub>x</sub>) in China. In 2014, with much attention paid to pollutant emission from coal-fired power plants, Chinese government has put forward the ultra-low emission (ULE) for coal-fired power units. The emissions of dust, sulfur dioxide (SO<sub>2</sub>) and NO<sub>x</sub> are below 10 milligrams per cubic meter, 35 milligrams per cubic meter and 50 milligrams per cubic meter, respectively [1]-[4].

Low nitrogen combustion technology (LNB) and selective catalytic reduction (SCR) flue gas denitrification technology are commonly used in coal-fired units to control NO<sub>x</sub> emission. SCR technology uses ammonia as reducing agent, which can reach over 90% denitrification efficiency but also produce ammonia slip. The denitrification performance of SCR is not only related to catalyst activity, reaction temperature, molar ratio of ammonia to nitrogen oxide, but also related to the distribution of flue gas flow field and concentration field in the reactor [5]. With the retrofit of ultra-low emission SCR denitrification of coal-fired units, there exit nonuniform distribution of flue gas flow field and concentration field at the inlet of SCR reactor, which result in uneven distribution of NO<sub>x</sub> concentration at the outlet of SCR reactor, high concentration of ammonia slip, air preheater clogging, catalyst blocking and wear. It seriously affects the safety and economic operation of the unit [6]-[8]. Under the ultra-low emission standard, the distribution uniformity of concentration field in SCR reactor is more and more strict, which affects SCR denitrification performance. The optimization of the distribution of molar ratio of ammonia to nitrogen oxide in SCR reactor should be carried out.

This paper has measured the distribution of NO<sub>x</sub> concentration, flue gas flow field and temperature at the inlet of SCR reactor and the distribution of NO<sub>x</sub> concentration at the outlet of SCR reactor in a 330MW ultra-low emission coal-fired power unit. The ammonia injection optimization was carried out



to optimization of the distribution of molar ratio of ammonia to nitrogen oxide in SCR reactor so as to improve SCR denitrification performance.

## 2. Experiment

### 2.1. Unit overview

The field measurements were conducted in a 330MW coal-fired power unit. This unit adopts LNB and SCR technology to control NO<sub>x</sub> emission. The catalyst is arranged in three layers and the reducing agent is liquid ammonia. The liquid ammonia is first evaporated into gas ammonia, and then injected into flue gas before catalyst layers through the ammonia injection grid (AIG). NH<sub>3</sub> reacts with NO<sub>x</sub> through catalyst into N<sub>2</sub> and H<sub>2</sub>O. Each SCR reactor is equipped with eight groups of AIG, and each group of AIG is divided into two independent modules, which are arranged in different depth of flue gas duct respectively. A manual control valve is set on the pipe of each module to adjust ammonia flow so as to achieve uniform distribution of molar ratio of ammonia to nitrogen oxide on the whole flue gas duct section. NO<sub>x</sub> concentration at the inlet of SCR reactor is 450 mg/m<sup>3</sup>, NO<sub>x</sub> concentration at the outlet is less than 50 mg/m<sup>3</sup>, and therefore the denitrification efficiency is no less than 88.9% under the design condition.

### 2.2. Test method

According to DL/T 260-2012 (Performance checkup test code for flue gas denitration equipment of coal-fired power plants), NO<sub>x</sub> concentration, flue gas temperature and flue gas dynamic pressure at the inlet of SCR reactor and NO<sub>x</sub> concentration at the outlet were measured under 90% BMCR(boiler maximum continuous rating). The distribution of NO<sub>x</sub> concentration, flue gas flow field and temperature at the inlet of SCR reactor and the distribution of NO<sub>x</sub> concentration at the outlet were obtained. According to the distribution of inlet NO<sub>x</sub> concentration, inlet flue gas flow field and outlet NO<sub>x</sub> concentration, the manual control valve on the pipe of each module was adjusted to improve distribution uniformity of molar ratio of ammonia to nitrogen oxide before the first catalyst layer. The distribution uniformity of physical quantity such as NO<sub>x</sub> concentration and flue gas flow field is expressed by the relative standard deviation, which is defined by the following formula:

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

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

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

Where  $C_v$  is the relative standard deviation,  $\sigma$  is standard deviation and  $\bar{x}$  is the mean value.

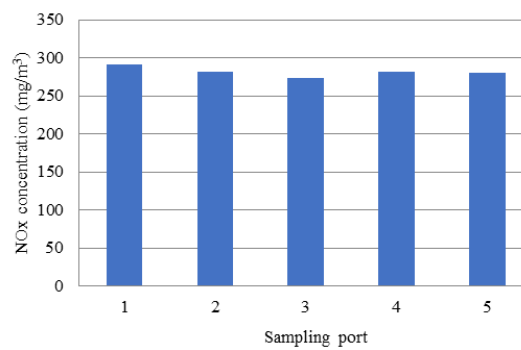
## 3. Results and discussion

### 3.1. The outlet NO<sub>x</sub> concentration distribution before optimization

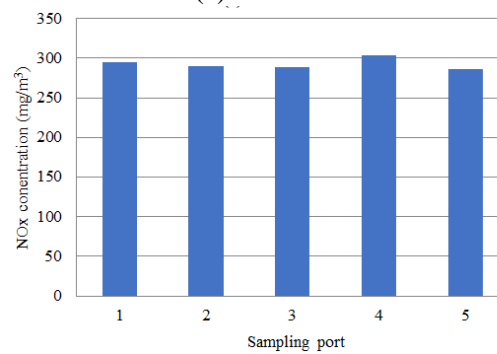
NO<sub>x</sub> concentration distribution at the inlet of SCR reactor before optimization is shown in figure 1. NO<sub>x</sub> concentration distribution at the inlet is uniform, and the relative standard deviation of inlet NO<sub>x</sub> concentration distribution of reactor A and B is 2.4% and 2.3%, respectively.

The distribution of flue gas dynamic pressure and temperature at the inlet of SCR reactor are shown in figure 2 and figure 3, respectively. The temperature distribution at the inlet is uniform, and the relative standard deviation of temperature distribution of reactor A and B is 0.5% and 0.3%, respectively. The distribution of flue gas flow field at the inlet of SCR reactor is nonuniform, and the relative standard

deviation of flue gas dynamic pressure square root distribution of reactor A and B is 21.9% and 21.3%, respectively.

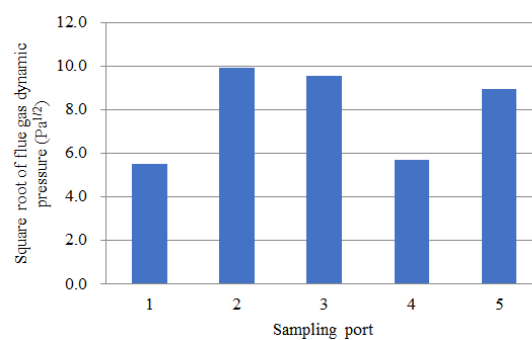


(a) Reactor A

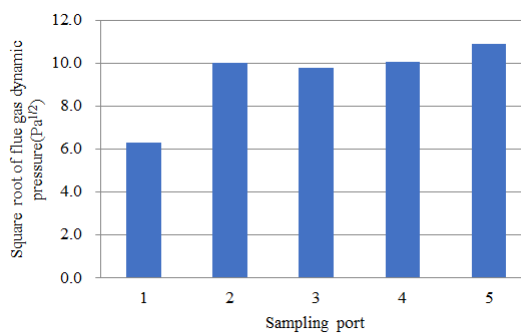


(b) Reactor B

**Figure 1.** NOx concentration distribution at the inlet.

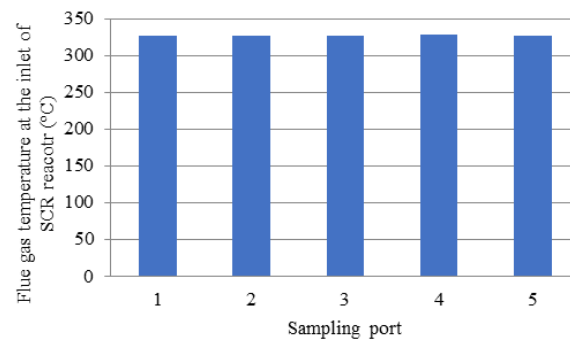


(a) Reactor A

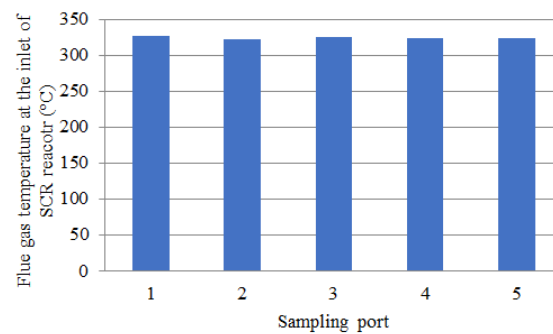


(b) Reactor B

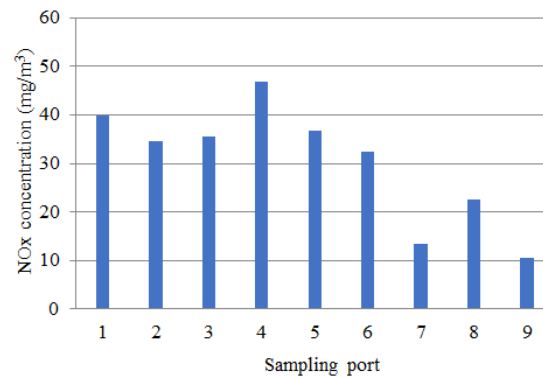
**Figure 2.** Square root of flue gas dynamic pressure distribution at the inlet.



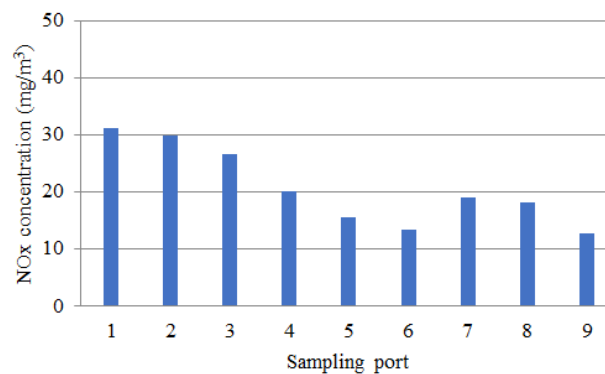
(a) Reactor A



(b) Reactor B

**Figure 3.** Flue gas temperature distribution at the inlet.

(a) Reactor A



(b) Reactor B

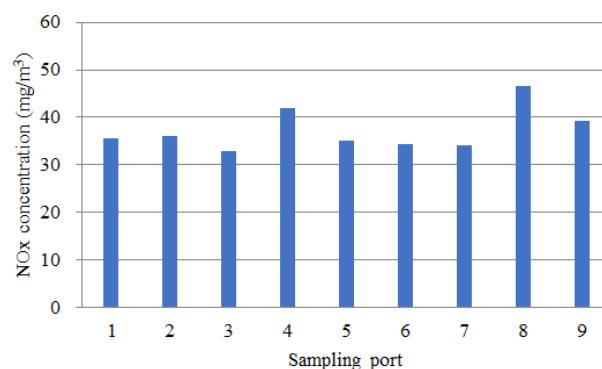
**Figure 4.** NOx concentration distribution at the outlet before optimization.

NOx concentration distribution at the outlet of SCR reactor before optimization is shown in figure 4. NOx concentration distribution at the outlet is nonuniform, and the relative standard deviation of outlet NOx concentration distribution of reactor A and B is 48.7% and 33.8%, respectively. The result shows that the distribution of molar ratio of ammonia to nitrogen oxide before the first layer of catalyst is not uniform. The amount of ammonia injection is larger in some area, the corresponding NOx concentration at the outlet is lower, and the concentration of ammonia slip at the outlet is higher. The escaping ammonia reacts with sulfur trioxide to form ammonium bisulfate, which will result in corrosion and blockage of air preheater.

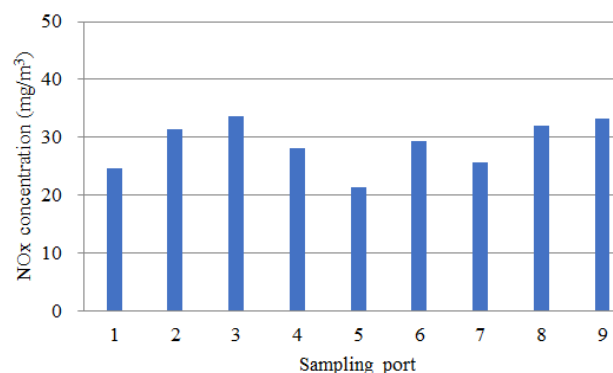
### 3.2. The outlet NOx concentration distribution after optimization

The flue gas flow pattern in SCR reactor is close to plug flow [5]. The modules of AIG are independent, and then NOx concentration at the outlet of reactor can approximately correspond to the opening size of the control valve of modules of AIG at the inlet of reactor. The opening of the manual control valve is larger in some area, the amount of ammonia injection is larger, and the corresponding NOx concentration at the outlet is lower. The opening of the manual control valve is smaller in other area, the amount of ammonia injection is lower, and the corresponding NOx concentration at the outlet is higher. Nonuniform distribution of molar ratio of ammonia to nitrogen oxide before the first catalyst layer affects denitrification performance. According to the distribution NOx concentration at the outlet of reactor, the manual control valve on the pipe of each module is adjusted to improve distribution uniformity of molar ratio of ammonia to nitrogen oxide before the first catalyst layer.

NOx concentration distribution at the outlet of SCR reactor after optimization is shown in figure 5. NOx concentration distribution at the outlet is improved, and the relative standard deviation of the outlet NOx concentration distribution of reactor A and B is 12.1% and 14.7%, respectively.



(a) Reactor A



(b) Reactor B

**Figure 5.** NOx concentration distribution at the outlet after optimization.

#### 4. Conclusion

The ammonia injection optimization was carried out to improve the performance of SCR denitrification in a 330MW ultra-low emission coal-fired power unit. The distribution of NO<sub>x</sub> concentration, flue gas flow field and temperature at the inlet and NO<sub>x</sub> concentration at the outlet of SCR reactor were measured. The distribution of NO<sub>x</sub> concentration and flue gas temperature at the inlet of SCR reactor is relatively uniform. The distribution of flue gas flow field at the inlet of SCR reactor is nonuniform, and the relative standard deviation of inlet flue gas dynamic pressure square root distribution of reactor A and B is 21.9% and 21.3%, respectively. NO<sub>x</sub> concentration distribution at the outlet of SCR reactor before optimization is nonuniform, and the relative standard deviation of NO<sub>x</sub> concentration distribution of reactor A and B is 48.7% and 33.8%, respectively. NO<sub>x</sub> concentration distribution at the outlet of SCR reactor is improved by ammonia injection optimization, and the relative standard deviation of NO<sub>x</sub> concentration distribution of reactor A and B is 12.1% and 14.7%, respectively.

#### 5. References

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#### 6. Acknowledgments

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