Research and Application of Low Nitrogen Burner for 600 MW Unit Boiler

Wuzhou Liang*
State Grid Shanxi Electric Power Research Institute of SEPC, Taiyuan, China
*Corresponding author e-mail: zhang_yi63@163.com

Abstract. High temperature corrosion on water wall is easily caused by burning high sulfur coal in low nitrogen burner of boilers in power station. Based on the combustion adjustment test of 600 MW unit boilers, this paper introduces the technical means of burner air distribution and coal mill operation optimization under low nitrogen combustion mode, realizes the optimal distribution of aerodynamic field in reductive and oxidative zones of boilers, and achieves the balanced control of boiler safety, environmental protection and energy saving when burning high sulfur coal. This technical means can provide reference for the operation of other similar boilers.

1. Introduction
The boiler model in a certain power station in Shanxi Province is B&WB-2090/25.4-M, with supercritical parameter variable pressure one-through boiler, single-reheat, balanced draft, bounding wall enclosure, dry-bottom, all-steel framework, opposed firing boiler, and full suspension structure boiler. The medium-speed mill coal pulverizing system and opposed firing are adopted in boiled, configured with dual channel swirl burner and NOx nozzle by B&W. The flue gas exhaust is set at the tail of boiler, using flue gas baffle to adjust the steam temperature of reheater.

The coal-fired sulphur content of this power station is 2.4%, belonging to high-sulphur coal. Based on the operation of similar low nitrogen burner in recent years, high temperature corrosion on water wall is easily caused. Thus, the combustion adjustment test of boiler mainly focuses on: controlling NOx emission, ensuring that there is no high temperature corrosion on water wall while controlling NOx emission [1], and guaranteeing the economic efficiency not lowered while controlling NOx emission.

2. The equal air distribution in same-layer burner
In terms of the opposed swirl combustion system, the large bellows are respectively mounted in the front and back walls, the secondary air enters the bellows from the air flues on both sides, and there is flow velocity at both ends of the bellows. The differential pressure between the bellows and the furnace is inevitably small at the middle and small at both ends, that is, the secondary air flow rate is high in intermediate combustion, and low in the burners at both ends [2]. Cold test shall be conducted on the secondary air flow rate inside and outside the nozzle of each burner, shown in Figure 1.

To realize the equal air distribution of burners in the same layer, the opening degree of secondary air baffle of six burners in the same layer shall be preset as 6%, 4%, 0%, 0%, 4% and 6%, respectively. Under same operating conditions, the secondary air flow rates inside and outside nozzles of the six
burners are tested to realize the equal air distribution for each burner, and the results are shown in Figure 2.

![Figure 1. The distribution of secondary air flow rate inside and outside six burners in the same layer](image1)

![Figure 2. The secondary air flow rate inside and outside six burners in the same layer after adjustment](image2)

3. The reasonable configuration of burner secondary air swirling blades
The burner of the project is divided into inner and outer air register, a small amount of inner secondary air ignites the coal powder, and a large amount of outer secondary air replenishes the air required for the subsequent burning of the burned coal powder. The inner and outer secondary winds rotate in the same direction. Changing the swirl angle can advance or delay the pulverized coal ignition point, further affecting the safe operation of the burner nozzle, the boiler combustion stability effect, the fly
ash carbon content and the NOx production amount. The adjustment range is 20 to 60 mm for the inner secondary swirling blade, and 40 to 80 mm for the outer secondary swirling blade.

According to the swirling blade test, when the opening degree of the secondary air swirling blade inside and outside the burner is 35 mm and 45 mm respectively, and the oxygen content of the furnace outlet is 3%, and the oxygen content near the water wall in the burner area is about 1.5%, there is no high temperature corrosion on the water wall.

Table 1 The opening degree of secondary air inside and outside the burner in each layer after test

| Burner | Swirling blade | Opening degree | #1 | #2 | #3 | #4 | #5 | #6 |
|--------|----------------|----------------|-----|-----|-----|-----|-----|-----|
| A      | inside mm      | 35             | 35  | 35  | 35  | 35  | 35  |
|        | outside mm     | 45             | 45  | 45  | 45  | 45  | 45  |
| B      | inside mm      | 35             | 35  | 35  | 35  | 35  | 35  |
|        | outside mm     | 45             | 45  | 45  | 45  | 45  | 45  |
| C      | inside mm      | 35             | 35  | 35  | 35  | 35  | 35  |
|        | outside mm     | 45             | 45  | 45  | 45  | 45  | 45  |
| D      | inside mm      | 35             | 35  | 35  | 35  | 35  | 35  |
|        | outside mm     | 45             | 45  | 45  | 45  | 45  | 45  |
| E      | inside mm      | 35             | 35  | 35  | 35  | 35  | 35  |
|        | outside mm     | 45             | 45  | 45  | 45  | 45  | 45  |
| F      | inside mm      | 35             | 35  | 35  | 35  | 35  | 35  |
|        | outside mm     | 45             | 45  | 45  | 45  | 45  | 45  |

4. The Effect of Burnout Air Volume on NOx Emissions and Boiler Efficiency

The low nitrogen burner performs deep air staged combustion, increases the high-burning air proportion, and correspondingly reduces the air distribution proportion in the main combustion zone, which can greatly reduce NOx emissions. The influence of the burnout air volume on NOx emissions and boiler efficiency is shown in Figure 3 and Figure 4.

Test conditions: unit load 600MW, ABCDEF coal mill in operation, six coal mills with equal output and 3.5% of furnace outlet oxygen content, the opening degree of burnout air door is 30%, 40%, 50%, 60%, 70%, respectively.

Based on the test results, it can be seen that with the increase of burnout air volume, the boiler efficiency decreases and NOx emission reduces. Combined with characteristics of burnout air door, the opening degree of burnout air door shall be appropriately 65%.

Figure 3 The trend of NOx emissions according to the variable opening degrees of burnout air door
The trend of boiler efficiency according to the variable opening degrees of burnout air door

5. The selection of reasonable furnace outlet oxygen
The basic mechanism of the low nitrogen burner is low oxygen combustion, reducing the excess air coefficient and oxygen concentration, so that the coal powder is burned under anoxic conditions; but the oxygen content is too low, and the high-sulfur coal is burned, the main combustion area of the boiler is in strong reduction, easily leading to high temperature corrosion on the water wall; low oxygen combustion will cause the carbon content of the fly ash to increase, resulting in the decreasing boiler efficiency. Therefore, via optimization test, to select an optimal operating oxygen level can achieve the best results in three aspects.

Test conditions: unit load 600 MW, ABCDEF coal mill in operation, six coal mills with equal output, the 60% of opening degree of burnout air door, and 380 t/h air volume, accounting for about 20% of total air volume.

The relation curve between boiler oxygen and efficiency
Figure 6 The relation curve between boiler oxygen and nitrogen oxide emission

The test results show that the boiler efficiency increases along with the increase of the furnace outlet oxygen output. When the oxygen amount reaches 3.5%, the boiler efficiency reaches the highest, and then the boiler efficiency decreases with the increase of the oxygen amount. NOx emission is in direct proportion to oxygen amount. When oxygen amount reaches 5%, the NOx emission is 470 mg/Nm3; when the furnace outlet oxygen is 2%, the oxygen near the water wall in the combustion area is less than 1%; when the furnace outlet oxygen is 3%, the oxygen amount in this area is about 1.5%. Therefore, at 600MW unit load, it is recommended to maintain the furnace oxygen amount between 3% and 3.5%.

6. The effect of coal mill combination on NOx emission and boiler efficiency
The combination of coal mills has a great impact on NOx emissions. The NOx emission of the next five operating coal mills is lower than that of the six coal mills. The main reason is that the flame center moves down, the NOx reduction zone lengthens, and NOx emission is significantly reduced. The test data is shown in Table 2. Test conditions: unit load 600 MW, 3.5% of furnace outlet oxygen content, and 60% opening degree of burnout air door.

Table 2 NOx emission and boiler efficiency in the combination of coal mills

| Operation of coal mills                              | NOx emission (mg/L) | Boiler efficiency (%) |
|-----------------------------------------------------|---------------------|-----------------------|
| Operating coal mills with equal output              | ABCDEF              | 465                   | 93.44                 |
|                                                     | ABDEF               | 352                   | 93.65                 |
| ABDE mills remain largest output, F mill for        | ABDEF               | 319                   | 93.92                 |
| complementary output                                |                      |                       |                       |

7. Conclusion
Firstly, after the preset opening degree of secondary air door, the static pressure difference along the width direction of the bellows is offset, so that the secondary air flow rates inside and outside the six burners in the same layer are basically the same.

Secondly, to select a reasonable furnace outlet oxygen, burnout air volume and a reasonable configuration of the secondary air swirling blade of the burner to form the “powder in air” in the combustion zone of the furnace. The area near the water wall is in an oxidizing atmosphere, avoiding high temperature flue gas flushing the water wall and preventing high temperature corrosion on the water wall. The middle part of the furnace is a reducing atmosphere, which reduces the amount of NOx produced.

Lastly, under the same load, reduce the number of coal mills in operation and increase the output of the lower coal mill can effectively reduce the NOx in the furnace.
Finally, through combustion optimization, the NOx emission is finally reduced to 319mg/Nm3, lower than the guaranteed value of 350 mg/Nm3. At the same time, the boiler efficiency reaches 93.92%, higher than the boiler efficiency guaranteed value of 93.43%.

References
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[2] Yang Zhen. Combustion Adjustment of a 600 MW Supercritical Once-through Boiler [J]. Journal of Power Engineering, 2007, 27 (4): 502-504.