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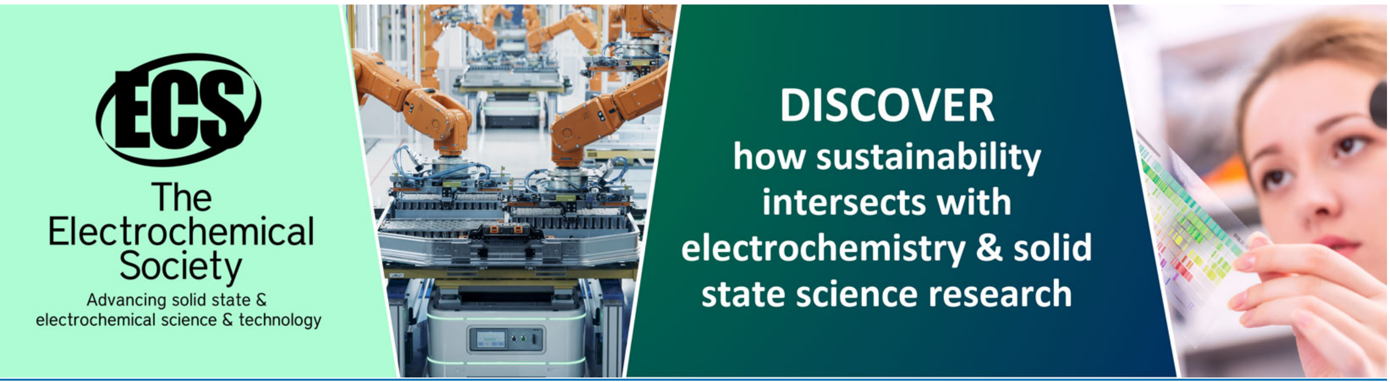

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Study on the influence of low nitrogen combustion on boiler operation

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Abstract. With the national emphasis on improving the quality of atmospheric environment and protecting the ecological environment, the standards for pollutant emission from power station boilers are becoming more and more strict. In response to national environmental requirements, low nitrogen combustion technology has been adopted in coal-fired power plants. However, the introduction of low nitrogen combustion technology has also brought a series of negative effects on boiler operation. It not only includes a dramatic rise in the high ash carbon content and heating water flow, slow load response rate and such influence on the unit economy, but also includes great reduction of reheat steam temperature under low load, rapid sharp rise of load steam temperature. The steam temperature decreases when load decreasing rate greatly reduces, the effects, such as big deviation between steam temperature and wall temperature, slagging furnace, high water wall, temperature corrosion and so on, have an impact on the stability of the security unit. This paper investigates 13 coal-fired power plants with capacity of 300 MW to 600 MW in Inner Mongolia autonomous region, to study the effects of low nitrogen combustion of boiler operation, pointing out the necessity of reasonable control of the export of nitrogen oxide content.

1. Introduction

Coal is the fossil energy which is used mostly, and promotes the development of the society at the same time, brings a series of environmental pollution problems including particularly acute consumption of coal resource of thermal power plant. With the national emphasis on improving the quality of atmospheric environment and protecting the ecological environment, the standards for pollutant emission from power station boilers are becoming more and stricter. On July 29, 2011, "standard of air pollutant emission in thermal power plant" (GB13223-2011), the new standard for existing and new thermal power project of pollutant emission carries out restrictive limitation[1]. In December 2015, the executive meeting of the state council decided to comprehensively implement ultra-low emissions and energy-saving transformation of coal-fired power plants by 2020. Ultra-low emissions, refers to that the power plant coal-fired boiler uses many kinds of pollutants efficiently coordinated removal technology integration system, making that atmospheric pollutants concentration conforms to the basic unit of gas emission limitation, namely the sulfur dioxide is not more than 35 mg/m^3, nitrogen oxides is not more than 50 mg/m^3, smoke is not more than 10 mg/m^3. In response to the national requirements, coal-fired power plants have been retrofitting boilers for environmental protection since 2011[2]. That the NOx emission control mainly has two channels: the first is to reduce NOx of newly generated in the combustion process, namely the low nitrogen combustion technology, mainly including low oxygen combustion, air classification and grade of fuel and so on[3,4]. The second is to remove the NOx which has been generated after combustion, mainly including Selective Non - Catalytic Reduction (SNCR) and Selective Catalytic Reduction (SCR). At the beginning of the NOx emission control reform, through environmental protection more than domestic companies and research institutes of economic analysis, with low nitrogen before furnace burner control of nitrogen oxide production, after the furnace adopts SCR removal nitrogen oxide emissions, the combination of these two approaches is most economic and effective, so most of China's coal-fired power plants are adopted as the low nitrogen burner and SCR mode[5]. At the beginning of the reforming, the catalyst that SCR used is expensive, to reduce the cost of renovation, the coal-fired power plants request that low after modification of low nitrogen burner, the SCR NOx concentration of the entry is as low as possible, which is even up to 100 mg/m^3 ~ 200 mg/m^3 in some power plants. However, with the completion of the modification of the low nitrogen burner, a series of negative effects have been brought to the operation of the boiler. In this paper, 13 thermal power plants with capacity of 300~600 MW in Inner Mongolia were investigated, and the influence of low nitrogen combustion on boiler operation was studied[6].

2. Effect of low nitrogen combustion on boiler operation

2.1. The carbon content of ash increases

Through tables 1 and 2 it can be seen that after modificating burner alteration ash carbon content increased than before, the worse the burnout characteristics of burning coal, a larger ash carbon content increases.

Table 1. carbon content of fly ash increased after the low nitrogen transformation of different coal species.

coal	V_{daf}	Carbon content of fly ash increases
High volatile bituminous coal	$V_{daf} \geq 30\%$	0.2～0.8
Medium volatile bituminous coal	$25\% \leq V_{daf} \leq 30\%$	0.5～1.2
Low volatile bituminous coal	$20\% \leq V_{daf} \leq 25\%$	0.5～1.7
Medium high volatile poor coal	$15\% \leq V_{daf} \leq 20\%$	0.8～2.1
Anthracite and low volatile lean coal	$7\% \leq V_{daf} \leq 15\%$	1.2～2.5

Table 2. The increase of carbon content in slag after the modification of different coal with low nitrogen.

coal	V_{daf}	The carbon content of slag increases
High volatile bituminous coal	$V_{daf} \geq 30\%$	0.5～1.3
Medium volatile bituminous coal	$25\% \leq V_{daf} \leq 30\%$	0.9～1.8
Low volatile bituminous coal	$20\% \leq V_{daf} \leq 25\%$	0.8～2.4
Medium high volatile poor coal	$15\% \leq V_{daf} \leq 20\%$	0.9～2.8
Anthracite and low volatile lean coal	$7\% \leq V_{daf} \leq 15\%$	1.2～3.3

After modifying Low nitrogen combustion chamber, the main combustion zone excess air coefficient reduced to 0.8 or so, the main combustion zone burning rate reduced, and the burning area is at close range from the bottom of the screen, when increase of burning area burnout rate is not enough to make up decrease of the rate of burning of the main area, the total rate of pulverized coal burning of burning furnace exit will reduce, resulting in fly ash carbon content increased.

After modifying Low nitrogen combustion chamber, a wind velocity and with powder basically remain unchanged, but the secondary air chamber of a stove or furnace bellows differential pressure decreases, and the secondary air volume is reduced, especially under the secondary air also USES reduce the size of the transformation, the secondary air volume decreases again, and further causing the secondary air powder ability weakened, once the wind pulverized coal ash hopper is easier to fall into the cold, causing slag carbon content increases.

2.2. Steam temperature anomaly

After the modification of low nitrogen burner, the abnormal steam temperature is shown in three cases:

- This situation is mainly in hedge swirl combustion mode of boiler and heat load of high volume on a tangential firing boiler. Analysis the reason for this is that a tangential firing boiler high volume heat load design (corresponding burning high volatile bituminous coal) and vortex hedge low nitrogen combustion boiler after modification, because in the main combustion zone excess air coefficient sharply reduce, burning rate is greatly reduced, the main combustion area after the pulverized coal combustion is serious, the flame center moves up too much, leading to higher furnace outlet temperature, furnace wall heat absorption decreases(vaporization decreases), heat absorption capacity of superheater and reheater increases, leading to that amount of water used to cool down increases dramatically(or a dramatic rise in the steam temperature). At the same time, after the low nitrogen of the swirl hedged combustion boiler, the slag will be intensified, the heat transfer ability of water cooling wall will be weakened, and the temperature of the furnace outlet will be increased, that further increases the temperature reduction water.
- The temperature of reheating steam under low load decreases greatly. This situation mainly occurs in the four-corner round of combustion boiler. The lower the volatility of coal burning, the greater the temperature of the low-load reheating steam decreasing. The lower the volume thermal load, the greater the reheat steam temperature under low load decreasing. For lean coal boiler using direct blowing pulverizing system, the reheat steam temperature under low load reduced to 20 ℃, for storage type hot air powder feeding system, if the transformation of low nitrogen burner adopts the partial three times the wind down, the reheat steam temperature under low load by up to 50 ℃. Analysis its reason is due to after modifying a tangential firing boiler of low nitrogen, if the gap between the transformed secondary air nozzle and the bellows is too large, the gap in the presence of large amounts of air exists leakage, the unstructured low load operation without corresponding secondary air of the burner while closed, but there is also air leakage, making when running in the low load operation of the burner the corresponding secondary air nozzle wind speed is low. When secondary wind speed is too low, the secondary air corresponding furnace inscribed circle diameter increases more, secondary air furnace flame is closer to water wall, making the amount of wall heat transfer increases, outlet smoke temperature of the chamber of a stove or furnace reduces, causing low load reheat steam temperature reduces.
- The steam temperature increases rapidly when the load is lifted, and decreases rapidly when the load is lowered. After the modification of the low-nitrogen burner, the steam temperature increases greatly in the process of lifting the load. Steam temperature sharply decreases when the load down is lower, biggest drop of steam temperature in 10 minutes can reach 40 ~ 50 ℃. For the heating surface and the rotor of the steam turbine, it is easy to generate alternating stress, which affects the service life of the unit. For boiler which its reheat steam temperature is under low load before modification is on the low side, steam temperature load reduction process in the original basis further reduce quickly, moisture content in the last stage blade rapidly increases, easy to cause that the last stage blade fractures, bringing bigger risk to unit safety. Analysis of the reason is that after modifying low nitrogen combustion chamber, because much lower excess air coefficient in main combustion zone decrease greatly(0.8 or so), the main combustion zone results in the situation that it seriously lacks of wind, and in the early period of the load process, oxygen gradually decreases, indicating that increasing rate of air flow is slower than increasing rate of the fuel quantity, although the air volume is increasing, but at the moment, excess air coefficient in the main combustion area is reducing, the main combustion zone lacks of wind more, combustion cannot develop, leading to the

burning rate of main combustion zone pulverized coal reduces, and because of increase of the combustible qualitative in burning area, burning is intensified, causing flame center moves up, furnace outlet temperature increases, causing a dramatic rise in the boiler steam temperature. Load down the process of oxygen increase gradually, the decrease of the air flow rate slower than the fuel quantity decrease rate, while air volume is reduced, but excess air coefficient in the main combustion zone increases, the main combustion zone burning rate increases, burning rate of the burning area burning reduces, flame center moves down, furnace outlet smoke temperature reduces, causing the boiler steam temperature greatly reduces.

2.3. The deviation of steam temperature and wall temperature is large

After the modification of the low-nitrogen burners of the four-angle circular combustion boiler, it is easy to produce large deviation of steam temperature and wall temperature in the separation screen and the rear screen. In severe cases, the reducing temperature water of superheater level-1 and level-2 increases greatly, resulting in the platen superheater steam temperature reduces, causing superheater outlet temperature decreases. If the first and second stage temperature reduction water quantity is not well controlled, the local pipe wall temperature of the plate type superheater exceeds the alarm value, and the long-term operation may cause the tube explosion of the plate over superheater. Analysis the reason for this is that clearance between the secondary air nozzle and bellows is too large and low load operation shutdown the corresponding secondary air door closed burner is lax, leading secondary wind speeds in the main burning zone decreases much, causing secondary air tangential diameter increases, making the main combustion zone swirl number increases, causing residual torsion of the upper chamber of a stove or furnace increases, led screen, high above, to increase steam temperature, wall temperature deviation increases, if low load operation in order to improve the reheat steam temperature to adopt the way that the set of burner operate, because the distance from the bottom of the screen to the upper burner reduce, this deviation will be further increased.

2.4. The load response rate is slow

After modifying boiler low nitrogen, the load response speed is reduced, often appears to keep pace with the scheduling requirements, performs that at the beginning of the load instructions change boiler capacity change is slow, but in late load rapid changes, overshoot in load, at the same time when varying load the steam temperature and steam pressure is not easy to control. Analysis the reason for this is that after modifying low nitrogen combustion chamber, the main combustion zone results in the serious lack of wind situation, and in load process, the oxygen content gradually decreases, air volume growth is slower than the amount of fuel, at this time ,in the main burn area excess air coefficient still reduce, the area of combustion lacks of wind more, burning develops slowly, causing increase of the steam content from water wall is little, the main steam pressure cannot rise up, causing loading speed decreases. In process of Load down oxygen capacity increases gradually, indicating the decreasing rate of the air capacity is slower than the decreasing rate of the amount of fuel, the main combustion zone excess air coefficient increases, the main combustion zone burning rate increases, the water wall evaporation decrease is limited, the main steam pressure cannot drop down, causing load reduction rate slows down.

2.5. Slagging in the furnace

For the rotary flow hedged to combustion boiler, the slag formation in the furnace is easy to occur after the modification of the low nitrogen burner. Analysis the reason: cyclone hedge type burner with low nitrogen transformation, increasing the secondary air expansion cone Angle, making the expansion Angle of secondary air, increasing vortex intensity, the pulverized coal ignition advance a wind carried, and reflow is closer to the combustor wall, outside the burner outlet reflux flue gas temperature is higher, more and more high temperature flue gas with molten ash by reflux arrived at all round of the burner outlet wall, causing slagging around the burner. Due to secondary air expansion Angle increases, a tail wind pulverized coal air flow and secondary air mixture is abate, a tail wind is in serious situation which lacks of wind, under the effect of hedge, air in the center of the chamber of a stove or furnace move on both sides of the wall, and burn in the middle of the two sides wall, generating high temperature and high reducing atmosphere, causing coal blues melting point temperature decreases 150℃ above, making grey in middle of the side wall still maintain molten state when arrives, clung to the wall forming side wall slagging. Vortex hedge increases due to the secondary air combustion boiler expansion Angle, a tail wind pulverized coal and air flow and secondary air mixture is abate, a tail wind is in serious situation that lack of wind combustion, making the burn rate of the main regional coal burning furnace depth center is reduced, if wind penetration ability in SOFA center is insufficient, the pulverized coal burning rate arrived at the bottom of the screen is still low, rising temperature of the flue gas in the bottom of the screen, and higher than the ash melting temperature, melting ash condenses on the screen, forming slag on the screen.

When the low-nitrogen burners are transformed, if the primary and secondary air are cut in the same direction and the secondary air part adopts the CFS offset layout, the water cooling wall slag in the furnace will be easily formed after the transformation. Analysis the reason for this is that when tangential boiler low nitrogen is transformed, secondary style wind adopts CFS to decorate, if the offset Angle is too large, the furnace inscribed circle diameter is large, leading to that air pulverized coal flow paints the walls, causing the water slagging in the furnace.

2.6. Water wall high temperature corrosion

After the modification of the low-nitrogen burner, it is easy to produce high temperature sulfur corrosion in the middle part of the side wall when the coal with moderate sulfur content is used for the counter-combustion of swirl. For the four-angle round combustion mode, if the burner adopts the way of up and down thick and light, when burning high-sulfur coal, it is easy to have high-temperature sulfur corrosion on the fire side below the exhaust wind. Figure 1 shows the relation between H2S gas concentration and corrosion rate. Analysis the reason for this is that rotation flow impact hedge low oxygen combustion way side wall middle severe, at high temperature and strong reducing atmosphere environment, CO concentration is as high as 5000 ~ 10000 parts per million, owing to the high CO concentration, generated H2S gas concentration is also high (200 ~ 800 parts per million (PPM), with strong corrosion resistance, and high temperature corrosion is serious. When four tangential burner uses upper and lower shading, this side is in serious condition which lacks of wind, the concentrations of generated CO gas is high, when burning high sulfur coal, H2S gas concentration is high, if the diameter is larger, a wind pulverized coal in this side is close to the wall relatively, temperature is high, it is easy to occur high temperature sulfur corrosion easily in this side. Figure 2 shows the relation between H2S concentration and oxygen and CO concentration.

In SCR inlet, NO_x concentration control is lower, the higher level of the air classification is needed (the greater the burnout air volume),the main combustion zone excess air coefficient is lower, he burning rate of the burning area is lower, the corresponding fly ash carbon content is higher. The concentration of NO_x at the SCR inlet should be controlled according to the condition of the coal burned. The lower the volatile content of coal burning is, the higher the NO_x concentration control of SCR inlet is. If the concentration of NO_x at the entrance of SCR is not controlled according to the condition of coal species, the concentration of NO_x at the entrance of low-volatile coal species SCR is usually controlled too low, causing the carbon content of fly ash to increase significantly.

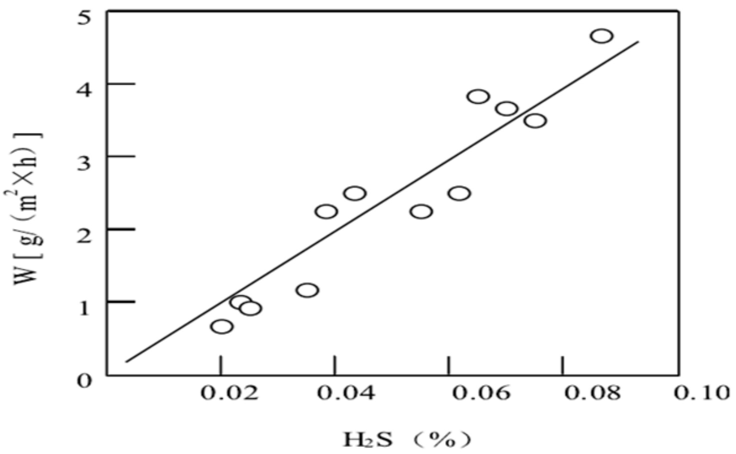

Figure 1. The relationship between H_2S gas concentration and corrosion rate.

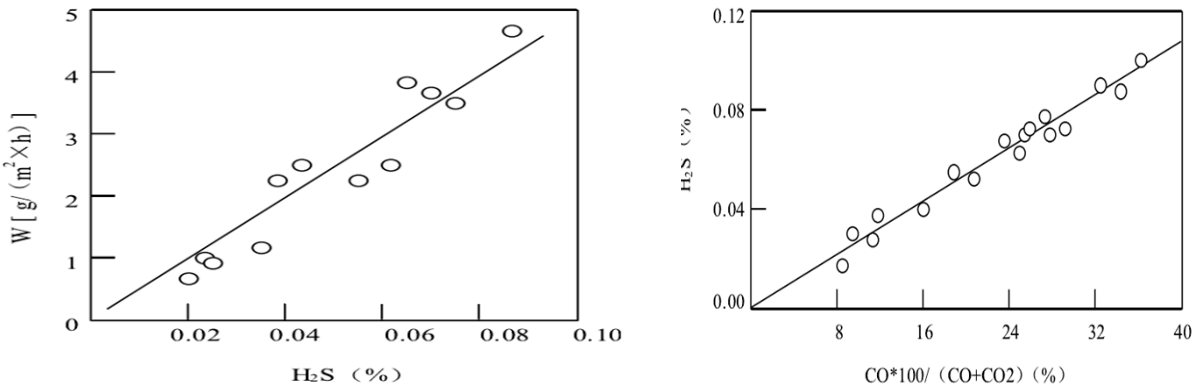

Figure 2. The relationship between H2S concentration and oxygen and CO concentration.

3. Conclusions

Despite the low nitrogen burner of boiler operation will have many adverse effects, and relying on low nitrogen combustion technology can not only control NOx to meet the requirements of environmental protection of the current, but cooperating after the flue gas denitration technology will make power plant NOx emissions have fallen to national standards, which has important significance to protect the environment. At the same time, we would like to down-to-earth, under low NOx combustion technology and the flue gas denitration technology combined with use cases, after the unit put into operation, dealing with the boiler flue gas denitration device to adjust the inlet flue gas concentration of NOx, and denitration equipment inlet concentration of NOx and NOx emission reduction of the total cost of the special test, finding out the best NOx density of the entrance, use this value and the minimum operating cost control principle to guide the boiler to operate, making the boiler NOx emissions is at the lowest total cost.

References

[1] Jiang X F 2015 Simulation and Analysis of the Low Nitrogen Coaxial Combustion System of a 1000 MW dual-tangentially-fired Boiler[J]. *Journal of Engineering for Thermal Energy & Power* **30** 58-65.

[2] Chen H, Huang QL, David B, *et al* 2013 Comparison and evaluation of low-nitrogen burner performance of 300MW power station boilers in China [J]. *East China Power* **41** 1116-9.

[3] Xing XD. Analysis on optimization operation of low-nitrogen combustion and denitration system of large capacity coal-fired boilers [J]. *Boiler Technology* **46** 60-4.

[4] LiuY, Sun H, Zhang GC 2016 Analysis of operating characteristics of low-nitrogen burner of

600MW unit boiler [J]. Guangxi Electric Power **39** 42-5.
[5] Yan XY 2015 Transformation and performance evaluation of low-nitrogen combustion technology for 300MW unit boiler [J]. *Metallurgical Power* **1** 37-9.
[6] Yu YL, Liu YJ, Gao ZP, *et al* 2013 Transformation and performance evaluation of low-nitrogen combustion technology for 600MW unit boiler [J]. *Inner Mongolia Electric Power Technology* **31** 11-5.