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Summary of Cfb Boiler Cleaning Reform Technology

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Abstract: The project of converting two 310t/h CFB (circulating fluidized bed) boilers to natural gas in a certainining and chemical enterprise is introduced. The conversion content: According to the original design of CFB boiler, combined with the combustion characteristics of natural gas, the heating surface is recalculated and arranged, the heat exchange area and ratio are adjusted, the original cyclone separator is closed, and adding new SCR denitrification equipment and flue gas recirculation system. After actual verification, the main process parameters and performance of the boiler basically meet the requirements of the technical agreement. The results show that compared with the same in 2018, the fuel consumption in 2021 decreased by a total of 329,000 tons of coal and coke, natural gas increased by 170,000 tons, the comprehensive plant electricity consumption decreased by 0.6 million kW·h, which is equivalent to a total reduction of about 480,000 tons of carbon dioxide per year; the annual reduction of auxiliary materials was 127,000 tons, indirectly reducing dioxide by about 55,000 tons, and the total reduction was about 535,000 tons of carbon dioxide. The timely completion of the CFB boiler conversion project to natural gas has achieved the expected goal of reducing coal and carbon emissions and clean and green production in the enterprise. After the reconstruction, the boiler still has such as sudden increase in the amplitude of furnace vibration and high fluctuation of furnace negative pressure, which need to be further solved through technical research.

Keywords: CFB Boiler; Cleanse; Natural Gas; Reform; Energy Saving; Carbon Reduction

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1 Introduction

Under the "double carbon" goal, local governments have fully implemented the national green development strategy. The "14th Five-Year Energy Development Plan for Beijing proposes to vigorously promote "reducing coal, stabilizing gas, reducing oil, strengthening electricity, and increasing green", and the total dioxide emissions have reached a peak and then steadily declined. As a large refining and chemical enterprise located in the capital, a certain petrochemical company adheres to guidelines of "green development, innovation-led, transformation and upgrading, and building benchmarks", striving to build "four bases" and create "two leading enterprises" deeply promoting the action of green enterprises [1], actively optimizing the energy structure, and starting the implementation of CFB (circulating fluidized bed) boiler clean transformation in 2018. In 2020, the first domestic 310 t/h CFB boiler gas conversion project was completed, and the goal zero coal and coke was fully achieved, firmly establishing the state-owned enterprise image of "talking about politics, daring to take responsibility, being brave in innovation and making achievements", demonstrating the mission and responsibility of "big enterprises should make great contributions to the country", and contributing petrochemical strength to the construction of beautiful China [2].

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2 Scientific Proof

2.1 The Necessity of Transformation

First, the need for green development. Replace coke with natural gas to realize the clean of the boiler, basically eliminate SO_2, smoke dust pollution; adopt the latest low nitrogen combustion technology and High-efficiency SCR denitration technology to further reduce NO_X, and the emission control of various pollutants in the boiler flue gas reaches the world leading level, thoroughly eliminating the three wastes treatment problems of the original CF boiler [3].

Second, the need for safe production. The boiler unit of Yanshan Petrochemical has been in high load operation for a long time and once the CFB boiler is shut down, the steam system has almost no spare load, and once other gas-fired boilers fail, it will directly affect the operation of the company's refining and chemical production chain .

Third, the need to save energy and reduce carbon. Due to the reduction of ash and, the efficiency of heat transfer is improved, and the amount of air required for combustion is reduced [4]. After the implementation of natural gas transformation, various losses will be reduced, and the boiler design efficiency will be increased from 92% to more than 94%.

Fourth, the need to save resources. The CFB boiler was built and put into operation in December 2006 and March 2007 respectively, and it is a circulating fluidized bed of FW-310/9.81-M type manufactured by Foster Wheeler, with the main design parameters of the steam temperature of 540℃ and the steam pressure of 9.8 MPa. If it is forced to implement the policy of shutting down, it will result in hundreds of millions yuan of fixed assets loss.

Fifth, the need to reduce costs. Circulating fluidized bed boilers have the characteristics of wide fuel adaptability high flue-wind system resistance, and relatively serious heat surface wear [5]. Moreover, the system is complex, the process flow is long, and the-consumption is large, and the factory electricity rate and self-use steam rate are high. However, natural gas boilers have less auxiliary systems, no ash slag, dust removal and large power fans and other equipment, and the actual operation and maintenance costs are low.

2.2 Difficulties and Principles of Retrofitting

The main purpose of this retrofitting is to select appropriate retro technology, ensure the safe, stable and efficient operation of the boiler, make use of the existing facilities to reduce the investment of retrofitting, and effectively shorten the construction.

2.2.1 Difficulties of Retrofitting

Different types of fuel. The original CFB boiler fuel is 100% solid fuel coal, petroleum coke, and the new fuel of the boiler after retrofitting is mainly natural gas, and it is used as waste gas resource recovery and utilization facilities which can consume the methane hydrogen and dry gas produced by the refining and chemical device.

Different types of furnaces. The typical characteristics of the circulating fluid bed boiler structure are that it has a circulating return system, including a cyclone separator, a J-valve, a return pipe, etc., and are a large number of suspended structures such as water-cooled screens and steam-cooled screens in the furnace [6]. And the natural gas boiler is generally a chamberfired furnace, which is a typicalЛ-shaped structure. No matter in the water-steam system or in the wind-smoke system, the difference is large.

Different combustion forms. Circulating fluidized bed boilers adopt fluidized bed combustion, and its main structure includes two parts: combustion chamberincluding dense phase zone and dilute phase zone) and circulating circuit (including cyclone separator and return system). The furnace bed temperature is usually a certain constant interval (generally 850~950℃), and the materials are recycled for 10~20 times, and repeatedly carry out and radiative heat exchange with the heating surface [7]. After retrofitting into a natural gas furnace, its combustion and thermal characteristics will change completely, and the combustion mode changes into combustion, natural gas is sprayed into the furnace through the burner, the ignition is rapid, the combustion time is short, the calorific value is higher, the air coefficient is smaller, the total amount of flue gas is less, and the center temperature of the furnace can generally reach 900-1100℃ or even higher [8, 9].

Different heat exchange ratios. Due to the low furnace temperature and other reasons, the proportion of radiation heat exchange in circulatingized bed boilers is low, and convective heat exchange is the main heat exchange, so more convective heating surfaces are arranged. While the furnace temperature of the natural gas is high, its radiation heat exchange ratio is large, and it can generally increase by about 1.2 to 2 times under the same conditions. Therefore, original heating surface of the circulating fluidized bed boiler needs to be redesigned and adjusted in this retrofitting.

2.2.2 Principles of Modification

Following the principles of safety, reliability, stability, economy, and high and speed, and based on the original CFB boiler design, combined with the combustion characteristics of natural gas, the heat transfer surfaces were re-calculated and arranged and the heat exchange area and ratio were adjusted; the boiler combustion system was redesigned and installed, the original combustion equipment and related flue and air ducts were, the original circulation loop was sealed, and new low-nitrogen combustion equipment for natural gas and ancillary pipelines, platforms, and accessories were installed on the water-cooled wall; an SCR denitration (selective catalytic reduction) device was set up in the air preheater area, and a low- economizer was installed; a flue gas recirculation system was added, and the modified boiler uses recirculated flue gas to participate in steam temperature regulation The following performance was ultimately achieved:

(1) Under the condition of rated feedwater temperature (150 ℃ ~155 ℃), the superheated steam temperature and pressure reached the rated value, and the rated continuous output of the boiler reached 310 t/h;

(2) At the rated condition the excess air coefficient remained at the design value, and the boiler ensured a thermal efficiency of 94% (based on the lower calorific value, including low-temperature economizer and air preheater);

(3) Under the rated condition, the emission concentration of NO_x at the boiler furnace outlet did not exceed 120 mg/m^3 (standard state, dry flue gas, oxygen content (volume ratio) 3%, calculated by NO); after the SCR denitration device, it met the standard of DB11/139-2015 "Emission Standard of Air Pollutants for Boilers" $NO_x \leq 30$ mg/m^3, $SO_2 \leq 10$ mg/m^3, particulate matter ≤ 5 mg/m^3.

(4) The boiler operates at 40%~100% of the rated pressure, and its temperature, pressure, flow, water level furnace negative pressure, oxygen content, wall temperature, and expansion all meet the design values, with no overheating phenomenon, and the amount of desuperheating water does exceed the design value. When the boiler is in the range of 75%~100% of the rated load, the superheated steam can maintain rated steam temperature: at 50% of the rated load, the main steam temperature of the boiler is not less than 530 ℃.

(5) The air distribution in the boiler furnace is uniform, the combustion is stable, and the fluctuation of the furnace pressure should be less than 50 Pa. The furnace burner should not vibrate or shake at any load, and the self-vibration of the burner should not exceed 6.3 mm/s [10] when operating at the maximum output thermal power.

(6) All valves, dampers, and actuators in the boiler's flue and air, steam water, fuel, and control systems are flexible in switch tests, and their openings, directions, and position indications are correct. The boiler's thermal automation and intering protection meet the safety operation requirements and operate correctly and reliably.

3 Specific Transformation Situation

According to the theory of heat transfer, heat transfer has three forms: conduction, convection and radiation. Its calculation formula usually, conductive heat transfer: $Q=\lambda*A*(t_1-t_2)/\delta$, convective heat transfer: $Q=\alpha*A*(t_1-t_2)$, radiative heat transfer: $Q=\varepsilon* A*\{(T_1/100)^4-(T_2/100)^4\}$. Where Q is the heat flow, λ, α, ε are the corresponding heat transfer coefficients, A is the cross-sectional area, t_1, t_2 are the temperatures of the object, δ is the wall thickness, and T_1, T_2 are the absolute temperatures of the object. According the main forms of heat transfer, the heating surface of the boiler is generally divided into radiation heating surface and convection heating surface.

3.1 Reconstruction of the Steam System

3.1.1 Reconstruction of Radiation Heating Surfaces

Since furnace temperature of the natural gas boiler is relatively high, with the flame center temperature commonly above 1000 ℃, which is approximately 1.1 to1.5 times that of circulating fluidized bed boilers, it is necessary to appropriately reduce the original heating surfaces inside the boiler furnace.

Reconstruction of the cooling screen: The middle vertical section of the water cooling screen is cut off by about 16 meters, the bottom is moved up as a whole, and the connecting pipe, front wall seal, and drainage pipeline are renovated.

Reconstruction of the screen superheater: The middle vertical section of the screen superheater cut off by about 8 meters, the bottom is moved up as a whole, and the inlet connecting pipe, front wall seal, and drainage pipeline are renovated.

Construction of the water-cooled wall: The wear-resistant materials laid in the lower part of the furnace are removed, the wind hood on the air distribution board cut off, and the holes and wear-resistant materials are retained. The flue gas is then introduced into the furnace from here. The original holes of the wind water-cooled wall, side walls, and front and rear walls water-cooled walls are blocked (only manholes are retained for primary and secondary air, feeding, return material holes, etc.).

The water-cooled wall of the lower and middle side walls is made into a pipe screen according to the of the holes for the newly added burners; a peep hole is added in the middle of the water-cooled wall for observing the flame; and an flue gas temperature measuring device is added on the left and right sides of the furnace outlet.

3.1.2 Reconstruction of Convective Heating Surface

Since circulating fluidized bed boiler mainly relies on convective heat transfer, the original boiler a large number of convective heating surfaces arranged. However, after the reconstruction of the natural gas boiler, the furnace exit temperature is higher, but the corresponding flue volume is reduced. Therefore, taking into account the above factors, the original boiler's convective heat transfer surface was appropriately reduced.

Low temperature superheater reconstruction: The original boiler has three groups of tube screens for the low temperature superheater. The middle group of tubes was cut off, and the upper and lower tube groups connected through loose tubes.

Economizer reconstruction: The lower group of four circles of tubes was cut off from the economizer, and the import manifold was connected the economizer serpentine tube group through loose tubes.

Adding a low-temperature economizer: In order to reduce the flue gas temperature, a-temperature economizer was added after the denitrification exit flue, to heat the demineralized water. The low-temperature economizer is suspended a whole under the steel structure beam of the denitration device, and it is a spiral ribbed tube structure.

3.2 Reconstruction of Wind and Smoke System

Reconstruction of Cyclone Separator: The central cylinder of theone separator is retained, and the J valve and return line are removed. The return hole at the lower outlet of the cyclone separator is sealed with a plate, which is made of SA-240S30815 material.

Addition of a Smoke Recirculation System: This system setting up a recirculation fan, double-sealed damper, expansion joint, and recirculation flue, etc. By adjusting the distribution of smoke, the furnace temperature is adjusted, and the proportion of radiation heat absorption and convection heat absorption surface is regulated to participate in the regulation of the main steam temperature. Theirculation fan implements variable frequency speed regulation to achieve automatic regulation function.

Addition of SCR Denitration Device: The original tube-type air prehe is removed, and 2 layers of SCR denitration catalyst are added. The ammonia injection mixing system adopts the "vortex mixing device" patent technology and the denitration shell (flue), support, steel structure and platform are re-designed and installed at the same time.

Air Preheater construction: A group of horizontal tube-type air preheaters is added under the low-temperature economizer of the No. 1 furnace, with the air preater tube size of medium 40×1.5, arranged in a staggered manner, and the outside of the tube is sprayed with ceramics. The smoke gas goes outside the tube from top to bottom, the air goes inside the tube horizontally, the cold air enters in the middle, and the hot air goes out on sides.

Flue Reconstruction: The original lower group of tube-type air preheaters and ash hoppers are reconstructed, and the electric bag dust collector ash conveying system and other facilities are removed.

3.3 Reforming of Combustion Equipment

A natural gas burner is added on the right side wall of the furnace, and a combustion is set on both sides. The gas combustion system and gas and air pipelines are added. The burner is arranged with 2 low nitrogen burners per layer, 1 # furnace is divided into 4 layers with 8 pieces, and 2# furnace is divided into 3 layers with 6 pieces. Each burner is provided with independent air box, and a damper is set at the inlet of the air box, which is adjusted by an electric actuator, and the air volume of each can be controlled separately.

The center wind and primary wind of the burner are adjusted by a manual regulating device, and the secondary and tertiary wind dampers the burner are adjusted by an electric actuator.

In order to further reduce NO_x emissions and enhance the mixed combustion in the furnace, one layer of combustion air one layer of wall air are arranged on the left and right side walls of the boiler respectively, and a total of 4 combustion air regulators and 4 wall air are arranged in the furnace.

3.4 Reconstruction of Boiler Control and Interlocking Protection System

In order to improve the level of automation, the DCS display is reconfigured based on the original DCS control system architecture, and new natural gas combustion system, field instruments, and new system valves are added to achieve and local joint control. This reconstruction has designed the automation adjustment of boiler automatic ignition, feedwater, desuperheating water, furnace combustion and negative pressure (forced draft induced draft, gas volume), and fixed water drainage automatic sewage discharge system [11], and has developed the function of one-key start and stop of-fired boiler automation (automatic purging, ignition start), to the maximum extent, reduce the workload of employees [12]. In terms of interlocking, it has designed the main steam pressure high, boiler water level, furnace pressure, burner flame total loss, induced draft fan total stop, induced draft fan total stop gas pressure low, main gas system quick break valve closing, manual MFT and other functions [13-16], to meet the basic requirements of safe operation.

3.5 Other Parts

The frame and platform ladders of the boiler are perfected, and the grid platform with good rigidity and-skid performance is set up at the positions where doors are required, measured, operated and maintained; the connection of the reformed boiler frame adopts full welding mode Holes are opened at the block position below the cyclone separator, and the cleaning wind is introduced to prevent the reignition of residual gas at the lower part the separator in the start-up stage.

4 Achievements and Shortcomings of the Transformation

The No. 2 and No. 1 furnaces were successively completed in December 2020 and December 2021, achieving the domestic first 310 t/h CFB boiler conversion to natural gas project, and reaching goals of reducing coal and carbon and clean green production.

4.1 Main Achievements

The effect of reducing coal and carbon is obvious. Compared with the same in 2018, the fuel consumption in 2021 decreased by 329,000 tons of coal and coke (84,000 tons of coal and 245,000 tons of petroleum coke), increased the combustion of natural gas by 70,000 tons, reduced the comprehensive power consumption of the plant by 0.6 million kW ħ, and increased the comprehensive heating ratio 81.7% to 93.6%, which is equivalent to a total reduction of about 480,000 tons of dioxide per year. The annual reduction of auxiliary materials such as limestone is 127,000 tons, indirectly reducing carbon dioxide by about 55,000 tons, and a total reduction of 530,000 tons of carbon dioxide.

Reduction of pollutant emissions. After the renovation, the boiler has excellent environmental protection indicators, reducing solid pollutants such as ash and gyps by nearly 170,000 tons compared to the same period; the emission of atmospheric pollutants exceeds the environmental protection ultra-clean emission standard, the measured NO_x emission before denitrification being less than 75 mg/m^3, and the NO_x emission after denitrification is stable less than 15 mg/m^3, which is far below the limit value requirement of 30 mg/m^3 for atmospheric pollutant emission of Beijing, and the reduction rate of NO_x emission is over 70%.

Full and effective re-utilization of enterprise resources. Through the investment in the natural gas conversion project, the value preservation and appreciation of fixed assets realized, and a loss of nearly 250 million yuan in asset impairment was avoided.

4.2 Shortcomings

After the renovation, the boiler has problems such as sudden increase in the amplitude of furnace vibration and high fluctuation of furnace negative pressure, which restrict the boiler's load-carrying capacity and have certain impact on the safe and economic operation of the boiler, and need to be further solved through technical research.

5 Conclusion

In summary, the application of reliable boiler design and low nitrogen combustion technology, denitrification technology to the 310 t/h CFB boiler for natural gas transformation, this technical scheme is in line with the national and Beijing's energy and environmental protection policies. In the of project implementation, it has effectively overcome the adverse factors such as the difficulty of transformation technology, the short construction period and the impact of the epidemic, and has solved problems of fire inspection signal fluctuation, low temperature economizer steam temperature deviation, and original petroleum coke slag shedding blockage and denitrification catalyst,., to achieve the completion and commissioning on schedule. After the actual operation test, it meets the actual production needs, and achieves the reduction of coal, petroleumke use and pollutant emissions from the source, with an average reduction of 46 t/h of coal and coke burning, which has played a strong and leading role in winning the capital's blue sky defense war and innovating green and low-carbon development.

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Biography

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