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Economic Analysis of Low-pressure Economizer Retrofit on 670t/h Coal-fired Unit

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Abstract: After long operation, heat transfer characteristics and flue gas pressure drop of low-pressure economizer are deviated from design value seriously. Through low-pressure economizer retrofit on a 670t/h coal-fired unit , the flue gas pressure drop is decreased to 597.04pa,less than the guarantee value 750Pa, the water saving of desulfurization spraying is 25.92t/h, the reduction of coal consumption for power generation is 2.80g/kW·h. Its energy-saving effect is obvious and transformation expectation is achieved.

1. Introduction

The low-pressure economizer is one of the effective measures to save energy by utilizing the waste heat of boiler's flue gas exhaust[1]- [3]. The #4 boiler of a power plant is ultra high pressure,a middle reheat, single drum, natural circulation, solid slagging pulverized coal furnace, type WGZ - 670/140-2. The method of flue gas desulphurization is limestone – gypsum. In order to effectively reduce the exhaust gas temperature and make full use of the flue gas waste heat, the low-pressure economizer was installed in the flue outlet of the desulfurization booster fan In April 2009. In recent years, because of ash accumulation on the heating surface, heat transfer characteristics and flue gas pressure drop of low-pressure economizer are deviated from design value seriously. Therefore, the low-pressure economizer is reformed in the maintenance.

2. Transformation principle of low-pressure economizer

The installation position of low-pressure economizer and its connection mode in thermal system are not changed, brazing spiral fin tube is replaced by H-type fin tube, the length and height of the pipe group are not changed, the number of tube boxes is 12, some space is maintained between the front and rear tube boxes for maintenance, the dimension of assembled tube box is 5320mm×10600mm×5039mm. The material of high temperature tube is 20G, fin material is Q195.The low temperature tube is ND seamless steel tube, fin material is ND, and ND is not less than 30% total weight of heating surface. The main structure and design parameters of low- pressure economizer are shown in table 1.

Table 1. Structure and design parameters of low-pressure economizer

Project	Unit	Data
Diameter of light pipe	mm	38
Thickness of light pipe	mm	4
Pitch of fin	mm	18

Project		Unit	Data
Thickness of Fin		mm	2
BMCR condition	Temperature of flue gas in low-pressure economizer Inlet	°C	155
	Temperature of flue gas in low-pressure economizer outlet	°C	95
	Temperature of water in low-pressure economizer Inlet	°C	70
	Water inflow	t/h	320
	Flue gas flow	m3/h	846016
	Gas pressure drop	Pa	<750
	Water pressure drop	MPa	1.01

3. Low-pressure economizer system

3.1 Installation location

The low-pressure economizer is arranged in the flue between the desulfurization booster fan and desulfurization tower, as shown in figure 1. Through the dust collector, abrasion of tube will be reduced obviously. On the other hand, because the temperature of flue gas is decreased in desulfurization tower inlet, the operation cost of desulfurization system is reduced effectively for water saving of desulfurization spraying.

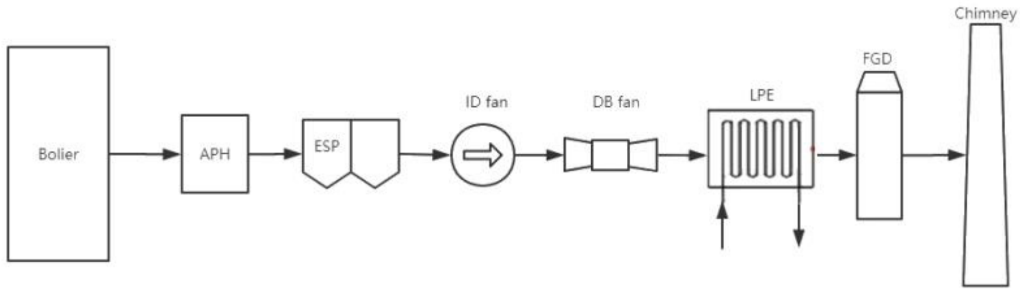

Figure 1. Schematic diagram of installation position of low-pressure economizer

3.2 Connection mode in thermal system

The low-pressure economizer is connected through parallel arrangement in thermal system, as shown in figure 2.Part of condensate water extracted from the No.1 shaft seal heater outlet and the No.2 shaft seal heater outlet is sent to the low-pressure economizer. It is sent to the No. 7 low-pressure heater outlet after heated by flue gas from desulfurization booster fan outlet. After mixed with condensate water in No. 7 low-pressure heater outlet, it enters into No. 6 low-pressure heater. The low-pressure economizer absorbs the exhaust waste heat of boiler, then the exhaust temperature is reduced. At the same time, the condensate water heated is returned to the low-pressure heating system to squeeze out the regenerative extraction steam of the turbine. If the turbine steam is not changed, the squeezing steam will be continued to expand and do work to improve the device economy.

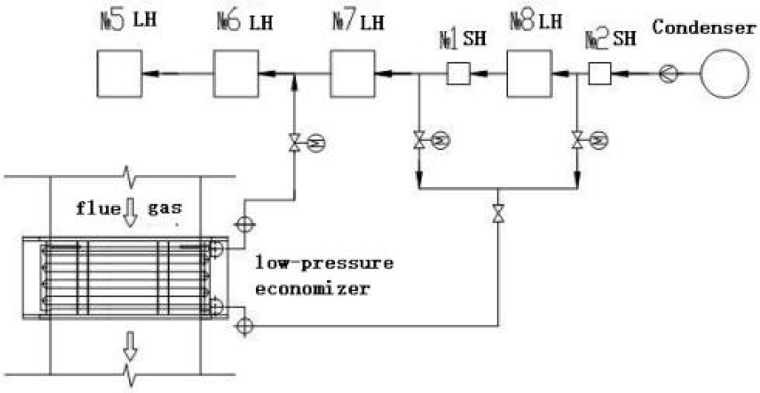

Figure 2. Schematic diagram of low-pressure economizer

4. Economic analysis of low-pressure economizer

The test and calculation are carried out according to the《Performance test code for utility boiler》(GB/T 10184-2015), and the equivalent enthalpy drop method is adopted to analyze the economy of thermal system.

4.1 Coal quality data for test

During the test, the common coal is burned, and the raw coal sample is taken at the entrance of coal feeder and tested in laboratory according to the standard, as shown in table 2.

Table 2. Coal quality data

Designatio	Car	Har	Sar	Oar	Nar	Aar	Mar	Qnet,ar
Unit	%	%	%	%	%	%	%	MJ/kg
Data	56.28	3.35	1.07	5.93	0.77	23.06	9.0	21.63

4.2 Flue gas pressure drop of low-pressure economizer

For the flue limitation, the static pressure measuring point at the entrance of the low-pressure economizer cannot be added. In test, the static pressure measuring points at desulfurization booster fan outlet and desulfurization tower inlet are adopted .Because the distance of the static pressure measuring point is above 60 meters, include expansion joint、circular square flue、diffusion pipe and other accessories, so it is necessary to subtract the resistance of all accessories[4]. At BMCR, the flue gas pressure drop of low-pressure economizer is 597.04Pa, less than the guarantee value 750Pa , as shown in table 3.

Table 3. Calculation results of flue gas pressure drop of low-pressure economizer

Project	Unit	Data
Flue gas pressure in desulfurization booster fan outlet	Pa	2826.43
Flue gas pressure in desulfurization tower inlet	Pa	2121.60
Flue gas pressure drop between desulfurization tower inlet and desulfurization booster fan outlet	Pa	704.83
Frictional resistance and local resistance between desulfurization tower inlet and desulfurization booster fan outlet	Pa	107.80
Flue gas pressure drop between inlet and outlet of low-pressure economizer	Pa	597.04

4.3 Water saving of desulfurization spraying

The flue gas temperature in desulfurization booster fan inlet and low-pressure economizer outlet is measured by k-type thermocouple through the grid method, then the flue gas temperature drop of low-pressure economizer is determined. When the flue gas temperature in desulfurization tower inlet is decreased, the spraying water in the wet desulfurization tower is decreased. The less heat released by flue gas in the desulfurizer tower is absorbed by the spraying water saved for raising the temperature from ambient temperature to saturated steam temperature under the flue gas pressure of the desulfurizer tower. At BMCR, water saving of desulfurization spraying is 25.92t/h, as shown in table 4.

Table 4. Calculation results of water saving in desulfurization tower

Project	Unit	Data
Temperature of flue gas in low-pressure economizer inlet	℃	157.82
Temperature of flue gas in low-pressure economizer outlet	℃	99.42
Flue gas temperature drop between inlet and outlet of low-pressure economizer	℃	58.40
Atmospheric temperature	℃	29.3
Atmospheric pressure	Pa	100450
Heat absorbed by low pressure economizer	kw	1.84×104
Water saving of desulphurization spraying	t/h	25.92

4.4 Economic analysis of waste heat utilization in low-pressure economizer

Some exhaust waste heat absorbed by low-pressure economizer is used to heat the condensate water pumped from No. 2 shaft seal heater outlet and No. 1 shaft seal heater outlet. The heated backwater enters regenerative system from No.7 low-pressure heater outlet, which can reduce the regenerative steam extracted from No. 6, 7 and 8 low pressure heater. The equivalent enthalpy drop method is adopted to calculate the low-pressure economizer's economy at BMCR. The specific method as follows[5]: the exhaust waste heat recovered by low-pressure economizer is taken into the thermal system, the energy consumption for generating 1kg steam by the boiler remains unchanged. On the basis of this, the additional power generated by the reduction extraction will improve the turbine efficiency. For 1kg steam , its work done is called the equivalent enthalpy drop (H), and the work added by extraction steam reduced is called the equivalent enthalpy drop increment(ΔH), which are calculated by equations (1) and (2) respectively, and the coal reduction of unit power consumption is calculated by equations (3) and (4).

$$H = \frac{3600}{\eta_{jd} \times d} \quad \text{kJ/kg} \qquad (1)$$

$$\Delta H = \alpha_d \left[(h_d - h_{m-1}) \eta_m - \sum_{r=x}^{m-1} \tau_r - \eta_r \right] \quad \text{kJ/kg} \qquad (2)$$

Where: d is the steam consumption rate of the unit, kg/(kw.h); η_{jd} is the electromechanical efficiency of the turbine,%; α_d is the flow coefficient of low-pressure economizer; h_d is the water enthalpy in low-pressure economizer outlet, kJ/kg; h_{m-1} is the water enthalpy in $No._{(m-1)}$ low pressure heater outlet, kJ/kg; τ_r is the enthalpy rise of low pressure heater bypassed, kJ/kg; ; η_r is the extraction efficiency of low pressure heater bypassed,%.

Reduction of unit heat consumption rateΔq is ：

$$\Delta q = \frac{\Delta H . q}{H + \Delta H} \quad \text{kJ/（kw.h）} \qquad (3)$$

Where: q is the heat consumption rate of the unit, kJ/(kw.h).

Reduction of coal consumption for power generation △b is:

$$\Delta b = \frac{\Delta q}{\eta_p . \eta_b . 29300} - \Delta b_1 \quad \text{kg/（kw.h）} \qquad (4)$$

Where: η_b is the boiler efficiency,%; η_p is the pipeline efficiency,%; Δb_1 is the coal consumption for power generation for desulfurization booster fan power consumption, g/(kw.h).

Table 5. Economic analysis of waste heat utilization of low-pressure economizer

Project	Unit	Data
Water temperature in No. 1 shaft seal heater outlet	°C	82.02
Water temperature in No. 2 shaft seal heater outlet	°C	47.08
Water temperature in No. 7 low pressure heater outlet	°C	107.52
Water temperature in No. 8 low pressure heater outlet	°C	65.19
Water temperature in low pressure-economizer outlet	°C	109.10
Variation of equivalent enthalpy drop	kJ/kg	13.31
Equivalent enthalpy drop of the new steam	kJ/kg	1242
Relative variation of steam turbine efficiency	%	1.06
Reduction of coal consumption due to waste heat utilization of low pressure economizer	g/kw.h	3.23
Current of desulfurization booster fan	A	216.50
Flue gas pressure drop of low-pressure economizer	Pa	597.04
Power of desulfurization booster fan	kW	274.64
Relative change of desulfurization booster fan efficiency	%	0.131
Coal consumption for power generation for desulfurization booster fan power consumption	g/kw.h	0.43
Total reduction of coal consumption for power generation	g/kw.h	2.80

As shown in table 5, at BMCR, relative variation of steam turbine efficiency is 1.06%, the reduction of coal consumption due to waste heat utilization of low pressure economizer is 3.23g/kW.h, relative change of desulfurization booster fan efficiency is 0.131%, coal consumption for power generation for desulfurization booster fan power consumption is 0.43g/kW.h. In conclusion, total reduction of coal consumption for power generation is 2.80g/kW.h.

5. Conclusion

The heat exchange tube of low-pressure economizer in a 670t/h coal-fired boiler is replaced by H-type fin, the area and layout is recalculated . Through transforming, the flue gas pressure drop is decreased to 597.04pa,less than the guarantee value 750Pa,temperature of flue gas in low-pressure economizer inlet is decreased from 157.82°C to 99.42°C, water saving of desulfurization spraying is 25.92t/h, the reduction of coal consumption due to waste heat utilization of low pressure economizer is 3.23g/kW.h, coal consumption for power generation for desulfurization booster fan power consumption is 0.43g/kW.h, the total reduction of coal consumption for power generation is 2.80g/kW.h. The effect of energy-saving transformation has achieved the expectation.

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