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The Development & Application of Low Temperature Coal Saving Heat Recovery Electrostatic Precipitator

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Abstract: This article is mainly about the development background, principle and key points of Low Temperature Coal Saving heat recovery Electrostatic Precipitator (hereinafter referred to as ESP), focusing on its development & application on Yuejia Power 135MW circulating fluid bed coal-fired boiler and summarizing for further market expansion.

Keywords: ESP, coal-fired Boiler, heat recovery, energy saving, high efficiency

1 Development background

The traditional ESP technology has been widely applied on flue gas dust removal for coal-fired boilers, but high gas temperature and other factors bring higher dust resistivity placing bad effect on ESP dust collection efficiency.

During the Chinese 12th Five-Year Plan, China will intensify the implementation of energy-saving & emission reduction policy. Most the old coal-fired boilers will need a retrofit because of higher environment protection standards and lower emission requirements. But due to space and time period limit, the traditional ESP technology have it's limitation on both collecting efficiency and economical effects.

With the development of China's economy and the closure of small coal mines, the imbalance between coal supply and demand becomes even worse resulting in the intensified urgency for coal-fired power plants to improve management on means of energy-saving and technology innovation.

As a result, the research and development of Low Temperature Coal Saving ESP became more and more impendent. To meet the new requirement of national energy-saving policy, higher ESP adaptability on the operating condition by technological innovation became more necessary.

2 Hazard analysis of high emission temperature of coal-fired boiler

2.1 Every 10℃ raise of the gas emission temperature will cause 1.2%～2.4% increase of coal consumption.

The gas emission heat loss is the greatest among all boiler thermal losses, usually it will be around 5%～12%, which took up 60%～70% of the boiler heat losses .

The gas emission temperature is the principal factor of the heat losses, usually every 10℃ raise of the gas emission temperature will cause 0.6%～1.0% increase of gas emission heat losses and 1.2%～2.4% increase of coal consumption. In China, the actual emission temperature is generally higher than the designed value, especially for circulating fluid bed boiler, the emission temperature is higher than the designed value for 20~50℃, which causes huge heat losses.

For boiler system, the causes of high gas emission temperature are as below: large coal particles, lower coal volatile component, increased coal moisture, boiler slag-bonding, improper primary and secondary air distribution caused flame center shift up, ash slagging of convection heating surface, reduced heat exchangers. All of the factors above will cause high gas emission temperature of the boiler, among them, some issues can be solved to lower down the gas emission temperature, but it's hard to achieve the idle designed conditions due to actual restriction, the actual gas emission temperature is still on the high side.

2.2 The adverse effect to ESP of high flue gas temperature:

a) Higher gas emission temperature brings more gas volume and higher wind velocity in electric field, it will shorten the flue gas time period through the electric field and cause dust re-entrainment, and also the collecting efficiency will decrease by exponential relation. According to formula below, when v increase，η will decrease by exponential relation, Every 10℃ raised temperature will cause 3% increase of the flue gas volume.

Empirical formula:

$$\eta = 1 - e^{-\omega f} = 1 - e^{-\omega \frac{A}{Q}} = 1 - e^{-\omega \frac{2h\ln}{2hsnv}} = 1 - e^{-\omega \frac{l}{sv}}$$

In which:

η —Collecting efficiency（%），

ω —Effective migration velocity of dust particles （m/s），

f —Specific collection area（m^2/（m^3/s）），

A —Total effective collecting area（m^2），

Q —Flue gas volume（m^3/s），

h —Height of the collecting plate（m），

l —Length of the field（m），

n —Numbers of the passage，

s —Spacing（m），

v —Veloctiy（m/s）

b) Higher gas emission temperature will lower down the electric field breakdown voltage and collecting efficiency. Every 10℃ raised temperature will cause the field breakdown voltage drop by 3%。

Empirical formula:

$$U_{击} = \frac{U_0}{\left(\frac{T_t}{T_0}\right)^{\frac{2.1T_t - 386}{T_0}}}$$

Where:

$U_{击}$ —Actual breakdown voltage（V），

U_0—Breakdown voltage when temperature=T_0（V），
T_t =Raised temperature（℃）+273（K），
T_0 =273K.

When the flue gas temperature drop down, it will increase the air density, decrease the intervals between gas molecules, the electrons impact kinetic energy and ionization effect, but it will higher the air breakdown voltage and ESP field operating voltage, which accordingly brings higher collecting efficiency.

c) The adverse effect of high flue gas temperature brings to ESP: Some 600MW Unit Boiler power plant in Guangdong Province, the flue gas temperature was up to 160℃ due to boiler coking during commissioning, it causes low collecting effect and smoked chimney. After water cooling wall retrofit, enlarging the heat exchange area, adding soot blower and some other fired-coal, the gas emission temperature was lowered down to around 130℃, the emission concentration was also brought down to around 30mg/m^3 due to higher collecting efficiency.

d) High flue gas temperature will increase dust resistivity and easily cause back corona and lower the ESP collecting efficiency. Usually the dust resistivity reaches its peak value when the gas emission temperature is around 150℃, and it will easily cause back corona with low voltage and high current, also lower down the collecting efficiency.

Conversely, low flue gas temperature will decrease the dust resistivity, and as it could be seen from Fig.1 The relation curve between gas temperature and dust specific resistance, when the flue gas temperature dropped from 150℃ to around 100℃, the correspond dust resistivity will fall for more than one order of magnitude.

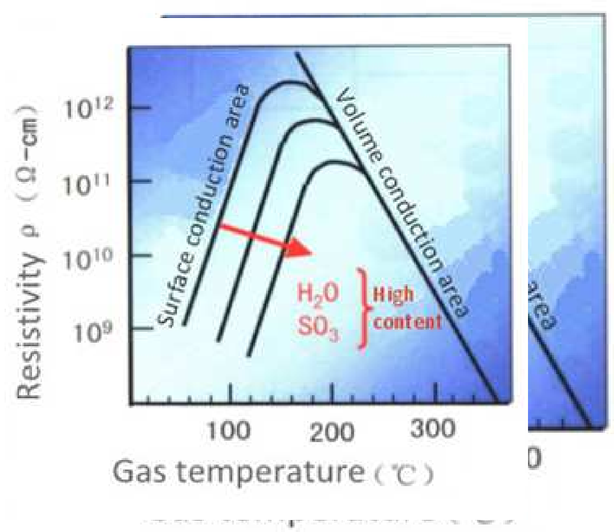

Fig.1 The relation curve between gas temperature and dust specific resistance

e) Higher gas temperature will increase gas viscosity and lower dust migration velocity in flue gas, which will lower the ESP collecting efficiency.

3 Low Temperature Coal Saving heat recovery ESP technology of Fujian Longking

As research and development high efficiency ESP with flue gas cooling down, dust collecting, high frequency power supply and energy-saving control technology, the Low Temperature Coal Saving ESP is typically used in coal-fired boiler flue gas dust collecting, but also applicable to some other kilns dust collecting.

The Low Temperature Coal Saving ESP mainly consists of inlet nozzle, gas distributer, flue gas heat exchange system, temperature controller, casing, collecting and discharge electrode, rapping system, hoppers, outlet nozzle, high voltage leading-in, and stairs & platforms.

With integrated application of flue gas cooling down, two stage and high frequency power supply technologies, the dust emission concentration will come down below 30mg/Nm3 except in some difficult cases such as Junggar high-alumina low sulfur bituminous coal-fired power plant.

3.1 Operating principle and process arrangement

The Low Temperature Coal Saving ESP's heat exchange was conducted between steam turbine condensate water and hot flue gas. It will decrease the steam extraction volume of the Low Pressure (LP) Heater in the condensate water system. The ESP operating temperature will be brought down from low state (120～170℃） to low low state (90~110℃), which can achieve both heat recovery and higher collecting efficiency.

3.2 Major Technical Specifications

a) Flue Gas Temperature Drop : ≥30℃

b) Collecting efficiency：Reaches the latest emission standards

c) Reduced Boiler Coal Consumption：1.0～3.0 g/kwh

d) Reduced ESP Power Consumption: ≥20%（ Energy saving Mode）

e) Flue Gas Pressure Loss: ≤500Pa （ESP + Heat exchanger）

3.3 Product Specifications:

a) The adaptive control system of Low Temperature Coal Saving: Import and analyze the data such as flue gas characteristic change, flue gas temperature change, filed operation parameters , volt-ampere characteristics curve, back corona index, opacity, flue gas acid dew point, etc. According to the result of automatic calculation by computer, the optimal parameters combination can be automatically found to keep ESP working at the best status.

b) Flexible arrangement with no limitation to the flied: The heat exchanger can be installed on the ESP inlet nozzle which also act as gas uniform distribution device; this can be used both for new and retrofit projects. Also the heat exchanger can be installed on ESP inlet nozzle independently, which can be used for some retrofit project with site area limitation.

c) Technology combination brings low emission: With integrated application of flue gas cooling down, two stages, high frequency power supply and energy-saving automatic control technologies, the dust emission concentration will drop down below 30mg/Nm3 except some difficult case such as Junggar high-alumina low sulfur and sodium bituminous coal-fired power plant.

d) Heat recovery with coal and power saving: The max temperature drop after heat exchange will be up to 30℃, reduce coal consumption for 1.0～3.0 g/kwh, reduce ESP power consumption under energy-saving mode for up to 20%.

e) Innovative design, high heat exchange efficiency: Heat exchange surface was designed as“membrane + H type fin Combination” assembled along the airflow direction, which will prevent gas turbulence, also it will brings less wearing and higher heat exchange efficiency.

f) Heat exchange with software support: Sufficiency heat exchange is the basic requirement of flue gas heat transfer. The calculation software is based on energy balance, equivalent enthalpy change and other calculations for heat exchange, the software will calculate the specific heat exchange area for every project by practical situation and related practical experience.

g) Online Monitoring and dynamic regulation: With temperature regulating valve on heat exchange main loop, the distributed control system will be set in every monitory site for online monitoring the flow, pressure and temperature of the heat exchange system, which will realize gas temperature dynamic regulation with good adaptability of load changes, coal saving and prevent low-temperature corrosion.

h) Heat exchange loop, orderly form but countercurrent arrangement: Heat exchange medium was arranged as orderly form but countercurrent with the flue gas, and maximize the temperature difference and the heat exchange duration for high efficiency exchanging.

i) Gas velocity control and minimized increase in flow resistance, without induced draft fan capacity increase: Due to flue gas resistance is directly proportional to the squared gas velocity, after heat exchanger installation, reduced gas velocity won’t cause significant dust resistivity increase. Meanwhile due to flue gas temperature lower down, the total flue gas volume through induced draft fan was correspondingly reduced for more than 5%. Hence the flue gas heat exchanger have no influence on boiler induced draft fan system capacity, and in actual fact, the induced draft fan will save more energy due to reduced volume flow.

4 The application of Low Temperature Coal Saving ESP on Guangdong Yuejia Power plant

4.1 Project Profile:

2*135MW Units of Guangdong Yuejia Power Plant were put into operation in 2005, with 440t/h ultrahigh pressure reheat circulating fluid bed Boiler designed and manufactured by Shanghai Boiler Works Ltd. Lime was added into the boiler for sulfur removal, and the mole ratio of designed coal Ca/S is 2.4. Each boiler matches with one 270/2-4 high voltage electrostatic precipitator. But the collecting efficiency is not stable due to coal variation. For higher and more stable collecting efficiency and satisfy the new national standard & local regulation of emission, our company undertook retrofit job for one of the boiler with heat recovery, coal-saving, high-efficient ESP.

4.2 Retrofit plan

a) Combined solution of heat recovery flue gas temperature adjustment and low low temperature ESP technology was adopted to improve flue gas condition, reduce dust resistivity, raise operation voltage and to achieve double effects of high collecting efficiency and saving energy. The detailed plan is as followed.

b) Installing heat recovery energy saving device at the inlet flue duct of the existing ESP.

c) Adopting high frequency power supply at the first several electric fields to effectively solve corona obstruction problem causing by big flue dust mass.

d) Upgraded the rapping system to top electromagnetic rapping system, of which the rapping strength and efficiency is program controlled and adjustable to satisfy delicate adjusting requirements under low low temperature conditions.

e) Adopting enhanced hopper wall thermal insulation and assistant heating constant temperature design to ensure smooth ash discharge.

4.3 The main technical parameters

No.	Item	Unit	Value	No.	Item	Unit	Value
1	Power generation	MW	135	**7**	Condensate water volume flow	m^3/h	100
2	Boiler capacity	t/h	440	**8**	Average gas velocity	m/s	10
3	Inlet flue gas volume	m^3/h	880,000	**9**	Average water velocity	m/s	1.4
4	Inlet gas temperature	℃	150	**10**	Flue gas pressure drop in Low Temperature Coal Saving section	Pa	250
5	Outlet gas temperature	℃	120(adjustable)	**11**	Water pressure drop in Low Temperature Coal Saving section	MPa	0.03
6	Inlet/Outlet water temperature	℃	45/75				

4.4 Performance Guarantee Test:

After retrofit, with the system's stable operation, the Low Temperature Coal Saving ESP control system monitoring screen and dust emission as shown in Fig.2, the PG test result is as below:

a) The outlet emission concentration dropped down from 100 mg/Nm^3 to 20~30mg/Nm^3 after retrofit.

b) The average opeating voltage in electric field has risen markedly, the average raised voltage is 8.8KV(16.2%), among them, the 4th electric field's average raised voltage reaches 12.5KV(26.6%).

c) With 70% designed condensated water volume, the flue gas temperature dropped from 138℃ to 108℃（decreased for 30℃）， and the condensated water temperature raised from 40℃ to 76℃(increased for 36℃), the heat exchange has a very good performance.

d) According to the power plant's operating data statistic for one month, it will save the coal consumption of 2.6g for every kilowatt hours, and power consumption of 25 kilowatt hours for induced draft fan per hour.

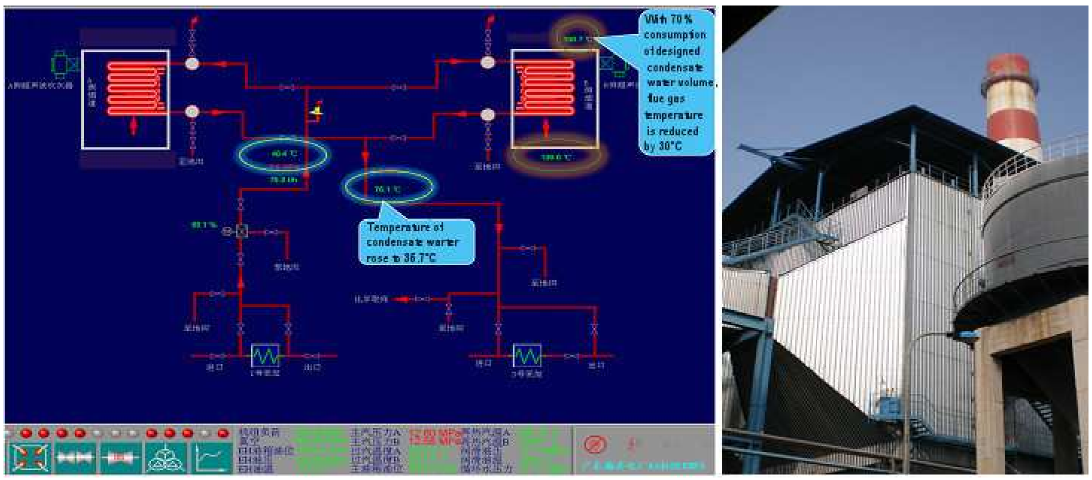

Fig.2 Monitoring screen of Low Temperature Coal Saving control system and its dust emission

4.5 Economic benefit analysis of Low Temperature Coal Saving heat recovery ESP

a) Coal saving: Every kilowatt hour will save the coal for 2g/KWh (annual average), we assume the boiler operates 5000h per year, the average price of coal is 900RMB/t, then the annually coal saving cost is:

$$(2/10^6)\times(1.35\times10^5)\times5000\times900/10000=1{,}215{,}000.00/\text{year}$$

b) ESP power consumption saving: Due to improved efficiency, if under energy-saving mode, about 20% of power consumption of the electric field operation can be saved. We assume the ESP normal operating power consumption is 250KW (price for every kilowatt hour is RMB 0.4), then the annually saved ESP power consumption cost is:

$$250\times20\%\times5000\times0.4/10000=100{,}000.00/\text{year}$$

c) induced draft fan power consumption saving: Due to flue gas temperature drop, the load of induced draft fan decline accordingly, even if there is additional resistance brought by the new heat exchanger, the power saving of induced draft fan will be 25 kilowatt hours per hour, and the annually saved induced draft fan power consumption cost is:

$$25\times5000\times0.4/10000=50{,}000.00/\text{year}$$

In conclusion, the retrofit will save the operating cost for 1,365,000.00 RMB every year which has its significant economic benefit. It's obvious that the Low Temperature Coal Saving heat recovery

ESP will have higher collecting efficiency and significant economic benefit, the saved cost is almost the same as the ESP normal operating cost (even more). So in actual fact the ESP comprehensive energy consumption for this project is Zero, which has remarkable economic and environmental benefits.

5 Conclusions:

The Low Temperature Coal Saving ESP for coal-fired power plant boiler can reduce the boiler power and coal consumption, and benefits on both environmental and economy, especially suitable for circulating fluid bed boiler’s high emission temperature. For coal-fired power plant with wet-flue gas desulfurization system, the Low Temperature Coal Saving ESP can reduce the water consumption, evaporation and moisture emission during Desulfurization. Hence the Low Temperature Coal Saving ESP has strong practicability with coal-saving, energy-saving, water-saving and reducing dust emission for energy conservation and high efficiency. It is a combination of flue gas temperature cooling and dust removal innovation which is fully compliance with the energy-saving and emission reduction policy in China with huge significant application value.

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