Application of the Lower Temperature Electrostatic Precipitator

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【Abstract】: On the prerequisite of energy-saving and heat recovery, lower temperature electrostatic precipitator technique can achieve a very high collecting efficiency. Compared with other dust removal technologies, the paper analyzes the principle, performance and energy-saving effect of the lower temperature electrostatic precipitator technology.

【Company】： Shanghai Metallurgical and Mining Machine Manufactory

【Key Words】： Electrostatic Precipitator, Collecting Efficiency, Low Temperature Heat Exchanger, ESP Technology, Gas Temperature, Dust Specific Resistance, Energy-Saving, Dust Emission.

According to GB13223-2011 *Thermal Plant Air Pollutant Emission Standard*，since 2012, the dust emission for newly-built power plants shall be less than 30mg/Nm^{3}and that for power plants in key areas shall be less than 20mg/Nm^3. The Twelfth Five-year-plan (2011-2015) says that GDP energy consumption should be reduced by 21% with the main pollutant overall emission significantly decreased. These above are put forwarded for more sever resource and environmental problem, which demonstrates the requirement of building a resource-saving and environmental-friendly society. As our government and the public attach more and more emphasis on energy-saving and emission-reduction, the dust-removal improvement shall not only meet the standard requirement but also lower the energy consumption and keep it be sustainable. Therefore, we have been cooperating with another company of our group on the development of the lower temperature electrostatic precipitator.

1. Dust Removal Solution

1.1 ESP Technology

Dust removal technology has been widely applied since 1990's. However, with the high-quality electrical coal mines become less, the quality of electrical coal increasingly fell. Since the close relation between dust collecting efficiency and dust specific resistance, the dust with its resistance less than 1×10^{4}Ω.cm, dust will be neutralized or even be positively charged, and then dust tends to enter the gas and lower the collecting efficiency. For dust with the resistance of 1×10^{4}Ω.cm ～ 1×10^{11}Ω.cm, when agglomerating, is properly neutralized. Then the flaky dust layer falls down when rapped, which can achieve a high dust collecting efficiency. However, for the dust with the resistance more than 10^{11}Ω.cm, it is really hard for them to be neutralized and dust layer becomes negative field. When the field strength increases, flashover phenomenon tends to occur in the little holes of covering layer with positive ions rejecting to the electrode. This is also called back corona phenomenon (refers to fig.1), which may lower the collecting efficiency. In order to meet the requirement of less than 30mg/Nm^3 and adapt ESP technology to a variety of coal, ESP should have the design of 5, 6 or 7 fields. So it is not a perfect choose, when it merely adopt the ESP technology.

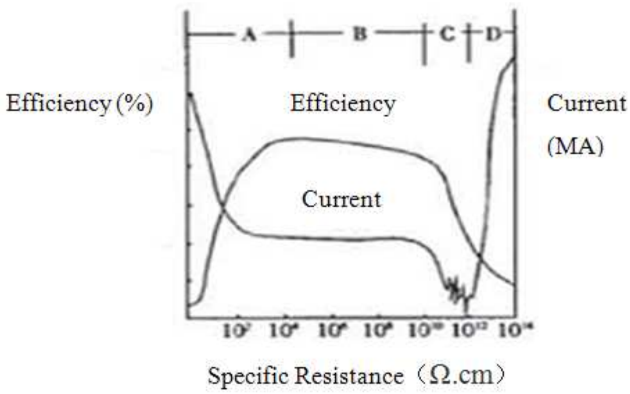

Fig.1 Relations between Dust Specific Resistance and Collecting Efficiency, C orona and Current

2 Fabric Filter Technologies

Fabric filter is a type of dust removal technology using a layer made of fabric material which is called "filter bag" to get dust precipitated. Fabric filter enjoys a high collecting efficiency, generally more than 99%. However, due to the poor adaption to different components and temperature of gas, erosion, moisture condensation and other phenomenon will be severely influenced the life-time of the fabric. Furthermore, since the huge loss in gas resistance, fan will have an increased resistance and electricity-consumption will increase. It is due to the high operation expense and maintenance cost that fabric filters has not been widely accepted and applied in China.

3 Lower Temperature ESP Technologies

Setting heat-recovering upstream of the ESP, the inlet gas temperature can be lowered, collecting efficiency improved, which is called lower temperature ESP technology. This system is consists of two main pieces of equipment, namely, lower temperature heat exchanger and lower temperature ESP. Lower temperature heat exchangers mainly functioned as heat-recovering and lowering gas temperature. The heat is used as the gas re-heater at the outlet of the desulfurization tower and increases the temperature above the acid-dew point, thus avoid corrosion of equipment downstream. Heat-exchanging is generally via water which flows through the fin tube inside the heat-exchanger. After flowing out of the exchange, the water will be 30℃ warmer.

The lower temperature ESP technology is based on the prospect to overcome the re-entrainment phenomenon, which effectively prevents the back-corona from happening, showers the gas flow velocity due to cooler gas and let the gas stay longer in ESP. Therefore, better collecting effect and higher emission standard will be achieved. Japan IHI Company has experienced several application case of this technology, see table 1.

Below is the brief introduction of the function procedure of the Hitachi No.1 1000MW coal-fired power plant in Japan designed and manufactured by IHI Company. After flowing through the air pre-heater, high content dust and SO_2 gas will have its temperature decreased from 370° to 138℃. Then after passing the lower temperature exchanger, the gas will be 92℃, which starts

Power Plant	Fuel	Generation Volume (MW)	Time Put to Service	Low Temp. Exchanger		Dust Concentration Design Value (mg)		
				Inlet/ Outlet Temp.		Heat Recovery	Lower Temp. EP	Absorbing Tower
				(℃)	(℃)	Inlet	Outlet	Outlet
Linbei No.2	Coal	700	2003.6	130	> 80	9800	< 100	< 15
Changlunacer	Coal	1000	2003.12	138	> 80	15000	< 30	< 8
Zhujinlu Island	Coal	507	2007.1	130	> 80	14070	< 30	< 5
Zhugongxinjibing	Coal	150	2008.4	130	> 80	16100	< 30	< 5

Table 1 IHI Lower Temperature Heat Exchanger Application

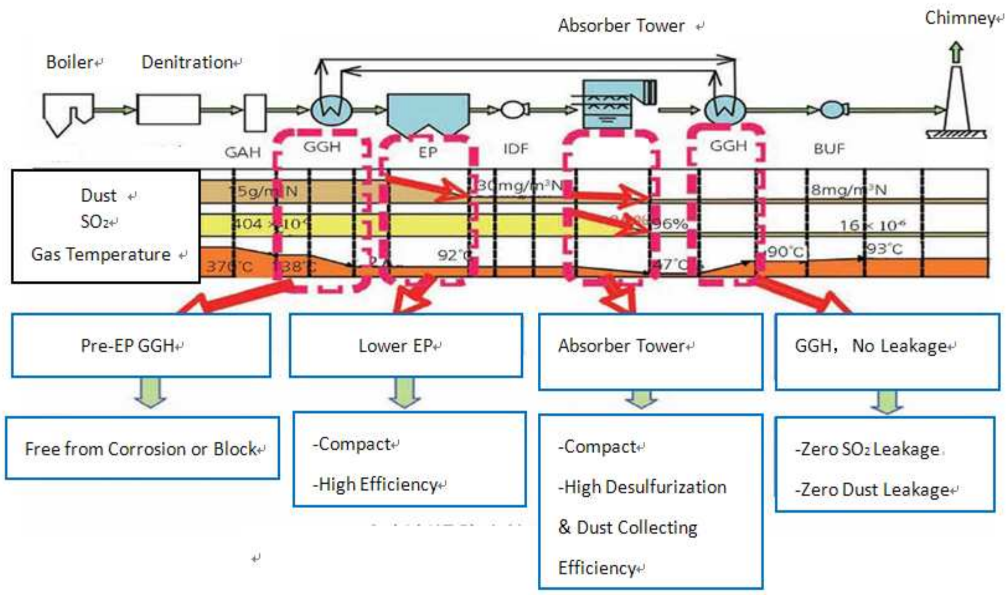

Fig.2 Lower ESP Application

entering the lower temperature ESP for dust precipitation.

After dust removal, the density of dust will be decreased to 30mg/Nm^3 with the collecting efficiency as high as 99.8%. Next, the gas gets the pressure upgraded by fans and has the SO_2 removed and gas temperature reduced to 47℃ by desulfurized tower. Such lower temperature gas has corrosive influence on equipment downstream, so reheating the gas by using the heat absorbed before by the lower temperature heat exchanger. Eventually, pure gas is emitted through a chimney. In fact, all the thermal power plants in Japan reheat the gas after desulfurization by the heat recovered by lower temperature heat exchangers. This is named

Taking a GGH to reduce the gas pollutant content after desulfurization and decrease the size of desulfurizers. Furthermore, a BUF can also be set before the chimney since the area is none-corrosive and none-abrasive with lower temperature, thus the abrasion to vane and corrosion to equipment can all be avoided with lower power consumption.

While in China, setting GGH is not compulsory to thermal power plant, which gives more possibilities to multiple-usage of the heat collected by lower temperature exchanger. For instance, heated water can be used as supply water for heating boilers, condensation water for stream turbine, which enhances the boiler working efficiency, saves the coal consumption. Even it can be sold as heating-supply source.

Power Plant's Design Condition and Performance Data can be seen in Table 2.

Generator Power		1000MW
Heat Exchanger Inlet Gas Conditions	Treatment Amount	2868000 Nm³/h
	Temperature	138℃
	SO_2 Concentration	404*10⁶
	Dust Concentration	15g/Nm³
Lower EP Inlet Gas Conditions	Temperature	92℃
	SO_2 Concentration	404*10⁶
	Dust Concentration	30mg/ Nm³
Reheater Outlet Gas Conditions	Temperature	90℃
	SO_2 Concentration	16*10⁶ (Desulfurization Efficiency above 96℃)
	Dust Concentration	8.0mg/ Nm³

Table 2 Changlunacer Design Conditions and Operation Performance

3.1 High Dust-removal Efficiency

As per Fig.1, the reduced gas temperature can lower dust specific resistance to the highest collecting efficiency interval, i.e., $10^4 \sim 10^{11}$ (Ω.cm). For instance, dust resistance is decreased when the gas temperature reduced from 130℃ to 90℃. In our experience, dust with the lower alkali content, notably that with lower sulfur content, is more sensitive to temperature, resulting in resistance dramatically declining, in this case, from 10^{13} (Ω.cm) to 10^{11} (Ω.cm). Thus, the dust is just within the highest collecting efficiency interval. The resistance of alkali content dust itself, originally about 10^{11} (Ω.cm), will be reduced to 10^{10} (Ω.cm) after treated by heat exchanger.

	Project-1	Project-2	Project-3	Project-4
Casing &Hopper	S-TEN	SS400	SS400	SS400
Internal Pillar (Contact with Gas)	STK400	SS400	SS400	SS400
Strengthened Plate (Contact with Gas)	SS400	SS400	SS400	SS400
Discharge Electrode	SPCC	SUS316	Rolled Plate	High Tension Steel
Discharge Frame	SS400	SS400	SS400	SGP
Collecting Plate	SPCC	SS400	Rolled Plate	SPCC
Collecting Plate Frame	SS400	SS400	SS400	SGP

Table 3 Lower ESP Material

From Fig.1, within the high specific resistance internal, the lower resistance is, the higher collecting efficiency will be. To sum up, lower temperature electrostatic precipitation technology is effective in improving the collecting performance, while smaller scale of ESP, less fields and less power suppliers can be adopted, lower consumption can be achieved and less area can be covered.

3.2 Distinct Performance on Energy Saving

Take a 1000MW unit of ESP as example, heat with the amount of 1.64×10^{8}KJ/h can recovered by reducing the temperature by 30 ℃. The heated collected can be used to warmer the boiler supply water or gas engine condensation water, thus enhancing the boiler working efficiency. Since water evaporated when confronting hot gas takes up the main part of water consumption in the process of Wet-desulfurization, so if the gas temperature is 30℃ lower, 70t/h amount of water can be saved in this type of system.

Meanwhile, lower the temperature of gas, much less the actual gas amount, which will not only condensate the size of equipment downstream, but shrink the energy consumption for boiler induced draft fans and desulfurizing boost fans. While more resistance brought from a lower heat-exchanger can be added on a fan. As for a induced draft fan, in spite of the higher pressure, the gas flow amount to treat will be deflated, so power consumption is nearly the same. While for a pressure fan, power consumption will be less since the less gas flow amount.

2.3 To Avoid the Lower Temperature Corrosion

When a heat exchanger is set upstream of ESP, the dew SO_3 will be neutralized with alkali matter in dust. These dust will be finally removed by ESP, thus both exchanger and ESP can be made of carbon steel or similar material.

Since the coal source for all power plants in Japan is relatively reliable, the power plants generally keep the same type of coal to ensure the safety operation of ESP and Desulfurizer. Projects of IHI usually have the peak SO_2 inlet density of 982×10^{-6} and corresponding sulfur content of 1.17%. Since the SO_3 density and corresponding acid dew point both increase with the sulfur content of coal rising, thus corrosion is more likely to occur. It is only after carefully survey and calculation that can the lower temperature be used in the case of high sulfur content coal.

2 Case Introductions

Take a certain 1200MW unit as an example; it has a lower temperature dust removal system as below: a boiler is equipped with two lower temperature heat-exchangers. The heat-exchanger is vertically arranged with high temperature exchanger layer, middle temperature layer and low temperature layer which are made of a large amount of fin tubes. As heat exchanger media, streamer condensation water is flowing in the tube to achieve a high-efficient heat exchanging. A certain number of stream dust blowers are set on each heat-exchanger layer to avoid dust choking from happening. At the bottom of heat exchanger, hoppers are installed to collect the fallen dust. See Fig.3

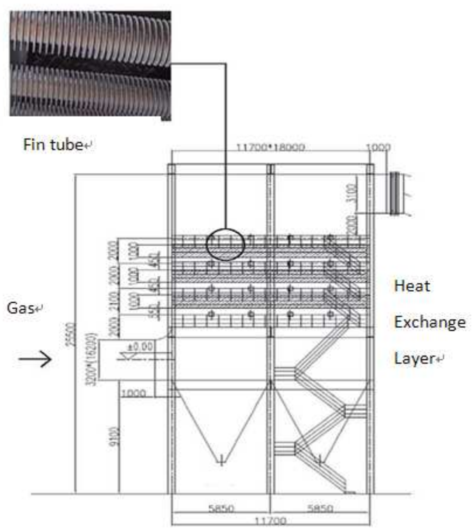

Fig.3 Heat Exchange Outline

A boiler is equipped with 2 lower temperature ESPs which have three chambers, five fields and fifteen power supply zones. Each ESP can treat 2752900 m^3/h of gas, which is one of the largest-size of ESP in China. The five-field solution is a result of considering dust characteristic, required efficiency and a certain margin. If a four-field solution is adopted, the collecting efficiency will be significantly decreased. In conclusion, the three-chamber-and-five-field is a reasonable solution. However, if adopting general type of ESP, six fields shall be taken to ensure that dust density at outlet should be less than 30 mg/Nm^3.

Besides saving much investment on equipment and cost in operation, lower temperature ESP can cover 20% less of area. Based on this project with ESP outlet requirement no more than 30 mg/Nm^3 and pre-heater gas amount requirement of 3798900 Nm^3/h, the design collecting efficiency is 99.88% (design coal), 99.93% (check coal) and 99.76% (guaranteed with one electrical supply area shut down). And the effective area of ESP is chosen 684m^2 according to the field gas velocity.

Considering lower temperature ESP re-entrainment problem is more instinct than general one, the gas velocity is set at 1.12m/s which is a little lower than that of general. So lower velocity brings less re-entrainment phenomenon and eases the influence on collecting efficiency. Collecting plate is made of SPCC（JJS）C type which is 15m high. While discharging electrode is mad of 316L stainless spiral wire and Q235 structure steel serrated wire, which can meet the various needs of power supply in different fields.

The Rapping for discharged electrodes and collecting plates are made by lateral turning hammer with the design of passage closing when rapping which prevents re-entrainment. And gas distribution equipment, a hopper are set at the inlet and outlet and a rapping plate is set inside the casing, which all makes sure the equilibrium distribution of gas and prevents the gas shortcut as well. The high pressure power supply takes a variety of method to adapt different coal, dust composition, thus keep the collecting efficiency while lower the energy consumption.

The lower temperature ESP casing bears higher negative pressure, so the strength and stiffness shall be high enough to meet the requirement of sealing and pressure loss. Hopper is heated by stream (including part of casing is heated), which ensures the fluidity of dust in the hopper and escapes the dust agglomeration and bridging. See Fig. 4.

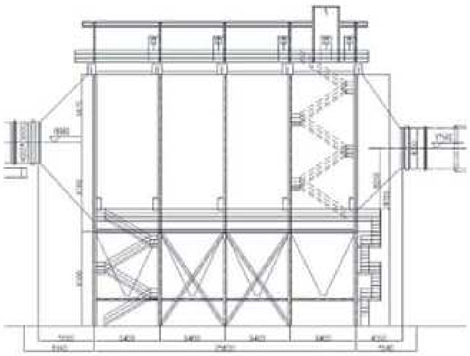

Fig.4 Lower ESP Outline

3 Conclusions

Lower temperature ESP features as high collecting efficiency, less area-covering, low power consumption, heat recovery, and decreased water use in desulfurization system, stable operation and little maintenance work. Internationally, lower temperature ESP is widely applied which makes it possible for it to get used in China.

This technology can meet the increasing stricter environmental-protection requirement and be against the backdrop of energy-saving and emission-reduction nowadays.

In China, the newly-built unit are generally large sized with the coal featuring medium or high heat value, medium dust composition, low sulfur content (lower than 1%), which offers a excellent environment for lower temperature ESP. In addition, for those large size units in operation, there is also the possibility of refitting the original system into the lower temperature ESP.

The original flue from air pre-heater outlet to dust precipitator can be a perfect place for adding low temperature heat-exchanger. The only work to do is design the size of the heat-exchanger according to this area. Not too much effort is needed for reconstruction, which can be accomplished during the overhaul period thermal power plants, if preparation is well-done ahead of time.