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Research on desulfurization wastewater evaporation: Present and future perspectives

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ABSTRACT

Nowadays wastewater zero emission in power plants has attracted great attention in the world. This paper describes the recent progress in the cooling of flue gas by the evaporation of desulfurization wastewater. The desulfurization wastewater slurry is mixed with pressurized compression air, and then sprayed into flue gas duct between the air pre-heater and electro-static precipitator or separated evaporation tower, to evaporate the wastewater instantaneously using the exhausted heat of flue gas. This process can reduce water consumption in flue gas desulfurization, cut down the traditional disposing expense consumed in desulfurization wastewater treatment, and reduce gypsum rain discharged from stack etc. This paper summarizes the negative impacts due to the omission of gas–gas heater (GGH) and the difficulties in desulfurization wastewater treatment in current power plants, and also points out that desulfurization wastewater evaporation technology is an important way to achieve zero emission of desulfurization wastewater or other high salt concentration wastewater and solve the problems related to omitting GGH. The instant regulation and control mechanism involved in desulfurization wastewater, migration and transformation rules of desulfurization wastewater and other key problems to be solved are also mentioned respectively. Hopefully, through multidisciplinary researches, evaporation treatment technology for desulfurization wastewater or other high salt concentration wastewater in coal-fired power plants will become mature and be applied widely in near future.

Contents

1. Introduction

Chinese energy structure dominated by coal will not be changed in short term. With the improvement of domestic economy, the electricity demand grows rapidly, thus leading to the increase in the coal construction of power plants, which increases the emissions of dust and SO_2. As one of main precursors of acid rain, excessive SO_2 has caused severe acid precipitating problem and smog in many areas of China. Therefore, Chinese government has made it particularly strict for flue gas treatment in coal-fired power plants in recent years. The power plants are facing more

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stringent environmental restrictions, especially after the implementation of new “air pollutant emission standards in coal-fired power plant” (GB13223-2011) in 2012 [1].

At present, in most coal-fired power plants in China, wet limestone–gypsum flue gas desulfurization (FGD) is most widely used. This is a mature technology with high desulfurization efficiency and availability [2], which is suitable to various kinds of coal and adaptable to boiler load changing [3]. Chnia has rich limestone resources and the desulfurization byproducts (gypsum) can be comprehensively utilized as additives in cement and other construction materials effectively. The temperature of flue gas entering desulfurization system through the electrostatic precipitator (ESP) is often very high (100–130 °C), causing the high evaporation water consumption in desulfurization tower, and affecting the life span of the absorber. Thus, flue gas reheating system was most widely employed in the early wet FGD systems, i.e., gas–gas heater (GGH), to reduce the inlet temperature of the flue gas entering into the scrubber and improve the discharging temperature of wet flue gas from stack, which is conducive to wet flue gas proliferation in atmosphere. But in actual operation in many power plants of China, lots of problems occurred due to the application of GGH, such as clogging and increasing pressure loss [4], which leads to the increases of investment and operation cost.

How to solve a series of problems caused by GGH? Based on years of researches on flue gas pollutants control and desulfurization wastewater treatment in thermal power plants, the authors put forward the idea that flue gas desulfurization wastewater is evaporated to reduce temperature of entering the absorber. This technology not only solves the problem of cooling the flue gas before entering desulfurization tower, but also provides a new way for desulfurization wastewater treatment. But the researches about desulfurization wastewater evaporation (DWE) have barely mentioned and the micro-mechanism about the technology also was not clear. There are still some questions about the technology applications in some aspects. Whether the evaporation was complete in flue duct? What influences aiming to electrostatic precipitator (ESP) and FGD system will be produced? Whether secondary pollutions will exist when desulfurization wastewater is injected into high temperature flue duct? Above questions should be answered before the wastewater evaporation technology in flue duct was used. So, this paper covers the negative impacts due to the application and omission of gas–gas heater (GGH) and the difficulties in desulfurization wastewater treatment in current power plants, and points out that desulfurization wastewater evaporation technology is an important way to achieve zero emission of power plants and solves the problems related to GGH.

2. The development and problems of GGH currently

Original desulfurization process used in Germany installed GGH at the entrance and exit of absorber, the gas–gas heat exchanger was designed for three intentions [5]:

(1) German environmental laws required that the discharge temperature of flue gas should not be lower than 72 °C in 1980s–1990s.
(2) Reduce the temperature of flue gas entering desulfurization absorber, in order to protect the corrosion protection layer, such as rubber interior liner in the absorber.
(3) Raise the temperature of flue gas at the outlet of the desulfurization tower above the acid dew point, to avoid acid mist carry-over in the flue gas, to protect the chimney.

Unlike Germany, U.S. environmental standards did not mention exhaust gas temperature at the outlet of chimney; thus GGH has no longer been set in the desulfurization systems generally since the 1980s. In Japan, due to the environmental standards, it demands that the temperature of flue gas at the outlet of chimney should not be lower than 75 °C, so almost all the flue gas desulfurization systems are built with GGH [6]. The initial desulfurization systems constructed in China were mostly installed with GGH, but there were also many problems in maintenance and operation, some listed as follows:

(1) GGH needs high investment. GGH equipment itself and the direct investment it relates to, including gas duct, civil structures and auxiliary systems, account for 20% of the investment in desulfurization system.
(2) The pressure drop of GGH is normal about 1000 Pa together with the pressure loss of gas duct, the total increase in pressure loss is about 1200 Pa. So the power of the induced draft fan must be augmented, thereby increasing operating costs.
(3) The leakage inside GGH will affect the efficiency of desulfurization system. Although the system can guarantee a low leakage rate below 1.0%, it is more difficult to achieve the high SO_2 removal efficiency facing stricter emission standards, especially the background of ultra-low emission implemented in China recently.
(4) Since the temperature of original flue gas drops under acid dew point in GGH, sulfuric acid is condensed at high temperature section of GGH. Sulfuric acid is very corrosive to the equipment and easy to adsorb fly ash. Fly ash and gypsum droplets carried over by cold flue gas result in serious scaling over the surface of GGH.
(5) The deposition will plug the gas pass way of exchanger elements, and gradually increase the GGH pressure drop, which may cause severe abnormality of induced draft fan.

A series of other factors, such as, the quality of coal, the efficiency of fly ash precipitator and online purging etc., may lead to the plugging of most GGH, and the increasing operation pressure loss of induced fan. Therefore, the energy consumption will increase and sometimes this even causes fan overloading so that the desulfurization system and the generating unit have to be shut down.

Recent years have seen a lot of controversy among scholars about the role of GGH in desulfurization system and the problems appeared in operation. A lot of power plants began to remove GGH in China, in order to save budget and simplify the system [7,8]. However, after getting rid of GGH, flue gas with high temperature goes through wet FGD system, resulting in the evaporation of a large amount of water from slurry, thus increasing water consumption by 50% compared to FGD system with GGH; the flue gas after desulfurization exists with high humidity, making the plume lifting height decrease, affecting the ground pollutants concentration with the diffusion of flue gas. Due to the low temperature of the flue gas after desulfurization, moisture in ambient air is close to saturation, thus it is easy to form “white smoke” or “gypsum rain” when the weather conditions are bad for diffusion and the serious corrosion to the chimney may also result from the condensation water in the chimney.

Aiming to the problems mentioned above, some plants began to reform GGH or adopt new ways for heat exchanging. For example, at the end of last century, Japan Mitsubishi Corporation (MHI) [9] developed a new process (called as FGD-MGGH) to solve corrosion problems of GGH, which was shown in Fig. 1. The cooling heat exchanger of MGGH was installed between the air pre-heater and the electro-static precipitator, while at the outlet of the absorber a conventional elevating temperature exchanger was installed. The cooling heat exchanger and elevating temperature exchanger were connected by a pipe filled with heat medium, so