Development of New Gas Cleaning System with Salt Solution Spray

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Abstract: For heavy oil fired boiler plants, the NH_3 injection Dry-ESP system has been applied to remove SO_3 since 1970's in Japan. This system has very high performance for SO_3 removal by the chemical reaction of NH_3 and SO_3. However, it generates a lot of by-product, ammonium sulfate and sulfite as solid industrial waste, which needs much cost for the system operation. Furthermore, ammonium sulfate and sulfite, due to very sticky dust, is apt to cause ash clogging in ESP hoppers and ash handling system. Now we have developed a new gas cleaning system for SO_3 removal by means of spraying SALT SOLUTION (ex. Na, Mg, K, Ca) to flue gas, which incorporates the new technology onto the conventional wet-FGD. This technology reusing the wet-FGD waste water has high performance of SO_3 removal, by that the sprayed SALT SOLUTION physically and chemically adsorbs SO_3 and the adsorbed solids are collected by the wet-FGD circulation water.

Keywords: SO_3 gas, Salt Solution, Spraying, Waste water, Adsorption, Retention time

1 INTRODUCTION

Recently in Japan, some boiler plants using residual oil (ex. PC, VR) are being planned and constructed, due to the world-wide oil price increase. This residual oil having very high sulfur content generates a huge amount of sulfuric acid (SO_3 gas) in the flue gas. MITSUBISHI has applied the NH_3 injection Dry-ESP system or wet-ESP system to remove SO_3.[1], [2]

Fig. 1 shows the NH_3 injection Dry-ESP system. In this system, NH_3 gas injected to the flue gas at the inlet of ESP is reacted with SO_3 gas by the chemical reaction and generates ammonium sulfate ($(NH_4)_2SO_4$) mainly. This by-product is collected by the ESP easily, so this system has very high performance for SO_3 removal. However, this by-product, due to very sticky dust, is adhered on the surface of ESP discharging electrode as well as collecting electrode and hoppers shown in Fig. 2. This adhesion causes frequently the operation problems of ESP and ash handling system.

Fig. 3 shows the wet-ESP system. In this system, the flue gas temperature is quenched to water-saturated conditions at the wet-FGD inlet and SO_3 gas condenses to form sulfuric acid mist (H_2SO_4), which is called SO_3 mist. Wet-ESP is installed downstream wet-FGD to remove fine particles, including SO_3 mist. In order to achieve high efficiency, however,

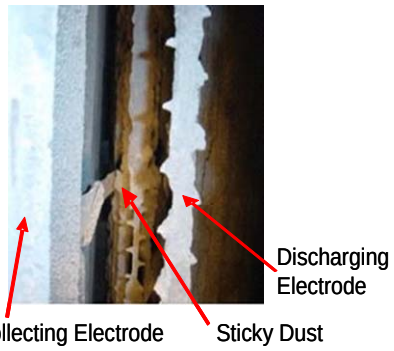

Fig. 2 Sticky dust in dry-ESP

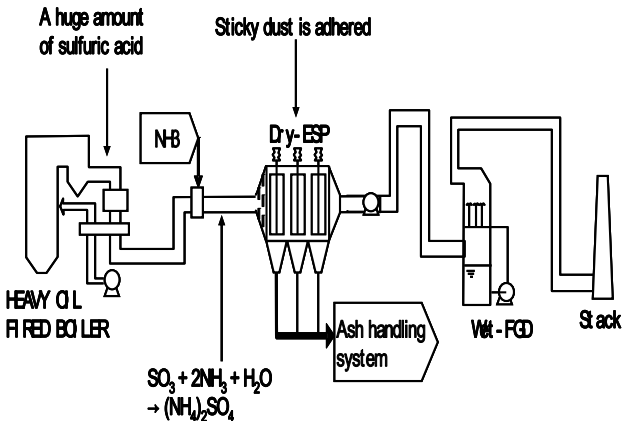

Fig. 1 The NH3 injection dry-ESP system

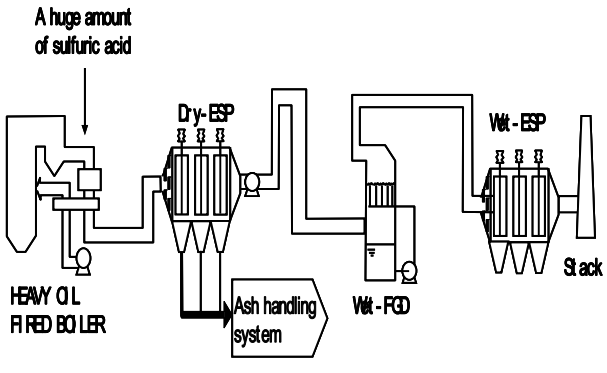

Fig. 3 The wet-ESP system

wet-ESP would be so a fairly large equipment due to very fine SO_3 mist that more compact equipment will be required.

As a countermeasure which improves the operation problems of dry-ESP system or large equipment of wet-ESP system, we have developed a new gas cleaning system by means of spraying SALT SOLUTION to flue gas. This paper introduces the principle of the new technology, which deals with a SO_3 removing principle, together with the operational experience at our laboratory plant and the commercial plant.

2 FEATURES OF SALT SOLUTION SPRAY

(1) System Configuration

Fig. 4 shows a schematic image of the SALT SOLUTION SPRAY system, which is integrated with wet-FGD as shown in Fig. 3 at Part "A".

The SALT SOLUTION SPRAY system is a process for the selective removal of SO_3 from flue gas, and this technology involves the injection of wet-FGD waste water into flue gas.

SALT SOLUTION, which reuses wet-FGD waste water, contains a solution of sodium sulfate, magnesium sulfate, calcium sulfate, potassium sulfite, with low concentration. SALT SOLUTION is sprayed into the flue gas upstream wet-FGD, through the dual –fluid atomizing nozzles, and the spray droplets are dried up within several meters from the injection point and changed into the SALT SOLUTION dusts as shown in Fig. 4.

Then, most SO_3 are physically and chemically adsorbed on the surface of the SALT SOLUTION dust with a very high surface area, as a solid-phase reaction. Further, the SALT SOLUTION dusts, which are the dry reaction products, are easily resolved and are removed from the gas stream with the particles, normally into wet-FGD circulation water. So this system can reduce a lot of solid industrial waste and the cost of the system operation as compared with the NH_3 injection

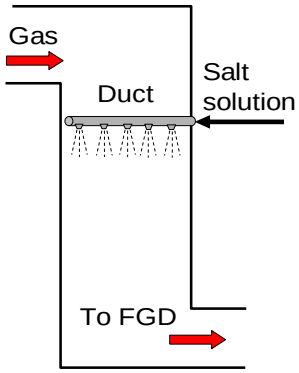

Fig. 4 A schematic image of the SALT SOLUTION SPRAY system

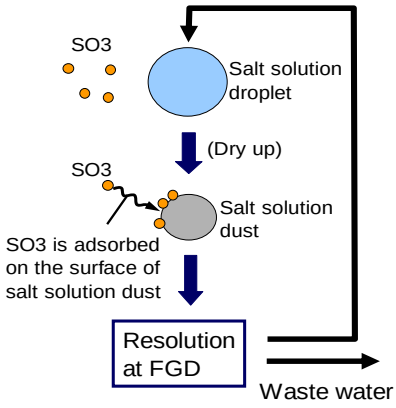

Fig. 5 Collection principle of the SALT SOLUTION SPRAY system

Dry-ESP system, and make dry-ESP more compact equipment because dry-ESP is collected only fly ash. Also this system can make wet-ESP more compact equipment as compared with the wet-ESP system.

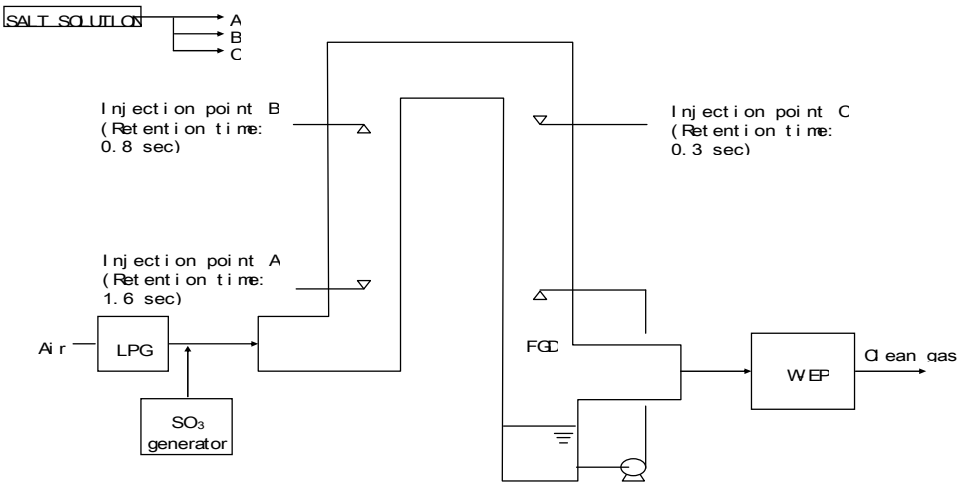

Fig. 6 A schematic diagram of laboratory plant

3 TEST RESULTS

(1) System used in the Laboratory Study

We have tested the SALT SOLUTION SPRAY system at our laboratory plant of which gas volume is 3,000 m^3 N[normal]/h. Fig. 6 shows a schematic diagram of the system, and Table 1 shows the specification of the system. Fig. 7 shows an overview of the plant.

Fig. 7 Overview of laboratory plant

Table 1 Specification of test facilities

		Laboratory model
Gas Volume	[m^3N/h]	2,500
Gas Temperature	[□]	185
SO_3 gas concentration	[ppm]	172

The flue gas is generated from liquid propane gas (LPG) burner. SO_3 gas produced by the SO_3 generator is injected into flue gas.

The concentration of injected SO_3 is 172 ppm. SALT SOLUTION is sprayed with a dual - fluid atomizing nozzle at the three injection points A, B and C of which the retention time to wet-FGD is varied 1.6 sec, 0.8 sec and 0.3 sec, respectively.

As SALT SOLUTION, four different solutions are tested, such as Na_2SO_4 and $MgSO_4$, $NaHSO_3$ etc. The SALT SOLUTION concentrations are varied from 3% to 17%, as well.

(2) Study results

Fig. 8 shows the results of the study for collecting SO_3 at the injection point A. As shown in the results, we have obtained the tendency that the SO_3 removal efficiency increases when the SALT SOLUTION (Na_2SO_4+$NaHSO_3$) concentration is varied from 5% to 17%. And we have almost the same performance of any sort of SALT SOLUTION at 5% concentration.

Fig. 9 shows the results of the study for the variations of the retention time and the SALT SOLUTION concentration. As shown in the results, we have the efficiency about 80% and over under the retention time over 1.0 sec when the SALT SOLUTION concentration is 15wt%. Even if the SALT SOLUTION concentration is 5wt%, we have the efficiency about 70 % under the retention time over 1.5 sec.

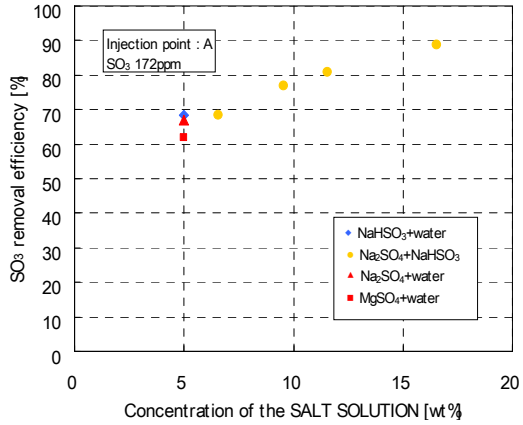

Fig. 8 SO_3 Removal vs. SALT SOLUTION concentration at the Injection Point A

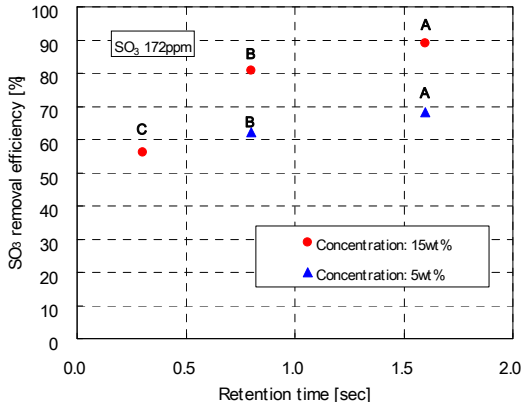

Fig. 9 SO_3 removal vs. retention time at three injection Points A, B, and C

It is confirmed that the new technology, SALT SOLUTION SPRAY system, is able to be applied the commercial plant under the retention time over 1.5 sec.

4 PERFORMANCE FOR COMMERCIAL PLANT

(1) System used in the commercial plant

This system is applied and tested for a commercial plant of heavy oil fired boiler. This is installed at the inlet of wet-FGD and used the waste water of the wet-FGD. Fig. 10 shows a briefly illustrate the system used in the study and Table 2 shows the specification of the system.

(2) Performance for the Commercial Plant

As shown in Table 3, 82% of SO_3 removal efficiency was obtained by the SALT SOLUTION SPRAY system in the commercial plant. Furthermore, the system can achieve more than 95% efficiency of SO_3 removal including wet-ESP, which proves to be an advanced and economical system for SO3 removal. The system applied to this commercial plant has been successfully operating since October in 2006.

And the by-products, SALT SOLUTION dusts and SO_3, were resolved and did not remain inside the wet-FGD at the annual maintenance.

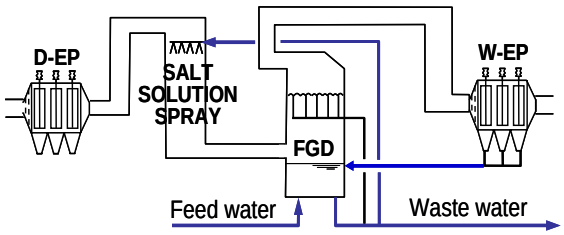

Fig. 10 SALT SOLUTION SPRAY system at commercial plant

Table 2 Specification of Commercial Facilities

		Commercial plant
Gas Volume	[m^3N/h]	288,000
Gas Temperature	[℃]	185
SO_3 gas concentration	[ppm]	172
Retention time	[sec]	1.5
Sort of SALT SOLUTION	-	Na_2SO_4
SALT SOLUTION concentration	[wt%]	5-6

It is confirmed that the new technology, SALT SOLUTION SPRAY system, is able to be applied the commercial plant with the conventional dry-ESP and wet-ESP installed downstream of wet-FGD.

Table 3: Performance Test Result of SALT SOLUTION SPRAY System at Commercial Plant

Table 3 Performance test result of SALT SOLUTION SPRAY system at commercial plant

		Commercial plant
Gas Volume	[m^3N/h]	316,000
Gas Temperature	[℃]	187
SO_2 (FGD inlet)	[ppm]	2904
SO_2 (FGD outlet)	[ppm]	17.9
Efficiency of SO_2(FGD)	[%]	99.4
SO_3 (SSS*1 inlet)	[ppm]	65~130
SO_3 (SSS*1 outlet)	[ppm]	11.6*2
SO_3 (W-ESP outlet)	[ppm]	0.9~3.0
Efficiency of SO_3(SSS*1)	[%]	82.2*2
Efficiency of SO_3*3	[%]	> 95.4
Dust*4 (SSS*1 inlet)	[mg/m^3N]	48
Dust*4(SSS*1 outlet)	[mg/m^3N]	-
Dust*3 (W-ESP outlet)	[mg/m^3N]	1.0
Efficiency of Dust*5	[%]	97.9

*1: SALT SOLUTION SPRAY
*2: when 65 ppm at SSS inlet
*3: SALT SOLUTION SPRAY + W-ESP
*4: Dry base @ actual O_2
*5: W-ESP

5 SUMMARY

A new technology, the SALT SOLUTION SPRAY system has been developed and has demonstrated using our laboratory plant and the commercial plant. It is confirmed that the SALT SOLUTION SPRAY system can achieve more than 80% of SO_3 removal efficiency, keeping an adequate retention time, which is not affected by the sort of SALT SOLUTION.

Also the by-products, SALT SOLUTION dusts and SO_3, are easily resolved into the wet-FGD circulation water, so that this system can reduce a lot of solid industrial waste and the cost for the system operation, as compared with the NH3 injection dry-ESP system.

A new gas cleaning system of SO_3 removal, combined with dry-ESP, wet-FGD and/or wet-ESP instead of the NH_3 injection dry-ESP system, proves to be applicable for heavy oil fired boiler plants.

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