

Gaseous mercury removal in a hybrid particulate collector

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Abstract—Gaseous mercury removal from simulated flue gas by sorbent injection was estimated and the effect of an electric field applied to a particulate collector on mercury removal was analyzed. For this, a bench scale system which included a sorbent injection reactor and a hybrid particulate collector was made up. The hybrid particulate collector consisted of an electrostatic precipitator and a fabric filter. Activated carbon was injected into the reactor as a sorbent. According to the result of experiment using simulated gas prepared by injecting gaseous mercury into air, the mercury removal by activated carbon injection at 130 °C varied from around 3.9% at C/Hg ratio of 1,000 up to around 24.4% at C/Hg ratio of 50,000 including reaction in the hybrid particulate collector. When C/Hg ratio was fixed at 10,000 and temperature was changed from 50 °C to 150 °C, the mercury removal decreased from 43.2% to 1.9%. In addition, when high voltage was applied to the hybrid particulate collector, the mercury removal increased up to 63.1% at a C/Hg ratio of 5,000 and at a temperature of 130 °C. Considering baseline mercury removal efficiency of up to 50% in the utility boilers due to the acid gases containing in the flue gas, above results indicate that 90% or more of gaseous mercury could be removed.

Key words: Gaseous Mercury, Hybrid Particulate Collector, Adsorption, Sorbent Injection, Activated Carbon

INTRODUCTION

Recently, gaseous mercury, which is one of the representative HAPs (Hazardous Air Pollutants) among the air pollutants emitted as combustion flue gas, has prompted widespread concern in the USA and Europe. In order to control mercury emissions into the air, the concentration of mercury from all emission sources has been restricted to 50-130 $\mu\text{g}/\text{m}^3$ from the early 1990s in USA, Europe and Japan. Since the mercury concentration in flue gas of a power plant is low ($<10 \mu\text{g}/\text{m}^3$), but discharged volume is large, its total amount of mercury emission is very large. Thus, over 50% of air pollution control technologies in the developed countries are focused on the removal of gaseous mercury currently discharged from a power plant.

Mercury, a representative hazardous heavy metal, has an especially high vapor pressure, thereby providing high possibility of discharging as gas phase. Gaseous mercury is largely classified as elemental mercury (Hg^0) and oxidized mercury (Hg^{+2}). Conventional flue gas treatment facilities such as wet scrubbers can remove the oxidized mercury because of its high aqueous solubility but cannot remove the elemental mercury (approximately 50% of mercury which is contained in the flue gas) because of its aqueous insolubility. Therefore, in order to remove the elemental mercury, an oxidizer should be injected to convert it to oxidized mercury, or an injection/adsorption method using activated carbon or other proprietary sorbents, or a carbon filter made from a porous carbon material should be adapted.

The injection/adsorption method using sorbents like activated

carbon has been already applied to an incinerator in the developed countries in order to remove gaseous mercury. However, since the removal characteristics of the gaseous mercury within the flue gas by the sorbent injection/adsorption are largely affected by the flue gas composition and the operation conditions, it is difficult to accurately estimate and predict its removal efficiency.

In view of the system, the trend for flue gas control technology in developed countries is inclined to develop a hybrid technology combined with each pollutant removal technology. That is, each pollutant removal technology has excellent efficiency but requires too much cost because of the stricter regulations. This leads to a concentrated investment on the hybrid technologies and the hybrid methods according to the capacity and operation type of a boiler.

As such, in order to control multi-pollutants economically and effectively, it is required to integrate the highly selective technologies for each pollutant and to develop the operation technologies for demonstrating the performance of the integrated technologies.

This study investigated the effects of the flue gas composition and the operating condition on gaseous mercury removal in an integrated system for simultaneous PM/HAPs control. Further, the result of this study is for the purpose of being used as basic data for the accurate estimation of the removal efficiency of gaseous mercury within flue gas by sorbent injection/adsorption.

METHODS OF MERCURY REMOVAL

Mercury is a liquid at room temperature and can be easily converted to a gas at room temperature because of its higher vapor pressure than that of other heavy metals. Especially, whole mercury contained in coal or waste is exhausted in a gaseous state at higher than 1,000 °C which is a combustion temperature of coal or industrial waste. All of the gaseous mercury is highly probable to be exhausted as elemental mercury (Hg^0), which is not removed in a wet scrub-

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ber as a conventional combustion flue gas control facility. Because such elemental mercury, which is not removed in the scrubber, can be spread out through a stack, special care is required.

It is known that mercury of 0.1-0.15 ppm is contained in coal on the average [1,2]. This is about 1/10th, compared with industrial waste which generally contains about 1.2-1.5 ppm [3]. Even though coal contains little mercury, its consumption is about one billion metric ton per year in the USA and approximately sixty million metric ton per year (coal-fired power plant and steel industry) in Korea. Thus, since the amount of mercury exhausted from the coal is more than that from industrial waste, this causes a problem.

It is reported that mercury of approximately 1,000 metric ton is generated worldwide from natural sources (rocks and ocean) and mercury of approximately 2,000-4,000 metric tons from coal-fired power plants or industrial waste incinerators [4]. In order to control gaseous mercury, Information Collection Request (ICR) was started from 1993 in the USA, and its regulation criteria and timing were established on the basis of human hazardousness in 1997. It was finally decided to install mercury emission control facilities on more than 70% of the power plants within USA until 2007 [5]. Since it was decided in Korea to regulate heavy metals including mercury from 2005, actual regulation is expected to be executed before long.

It is reported that mercury emission should be urgently regulated because 80% of the gaseous mercury is discharged into the air [2]. However, it is estimated that mercury of 80-150 $\mu\text{g}/\text{m}^3$ is generally generated from an incinerator and 10-50 $\mu\text{g}/\text{m}^3$ from a power plant.

As such, mercury concentration is high in the incinerator and low in the power plant. However, since the air flow rate of a power plant is much larger than that of an incinerator, the overall mercury exhausted from the power plant is considerably high. Accordingly, mercury removal in power plants as well as incinerators will receive great interest in the long term and it will be mandatory to install a mercury emission control facility on the power plant. Since mercury is contained in natural gas, oil, coal and so on, it is necessary

to remove it from fossil fuel-fired power plant systems. If regulations are enacted for installing mercury emission control facilities on power plants in the USA by 2007, it is highly probable that this will affect the regulations in Korea also. To prepare for that situation, it is necessary to establish measures for mercury removal technology. Because mercury tends not to diffuse far from its source but to accumulate nearby, its removal will be an urgent problem in areas where a power plant or incinerator is installed.

Mercury removal technology for a power plant is largely classified as two methods. One is to oxidize elemental mercury by a Wet Flue Gas Desulfurization (WFGD), and the other is to inject sorbents such as activated carbon. The removal of the oxidized mercury in the WFGD offers the advantage of no additional installation and operation expense. Thus, the WFGD is preferentially considered as the removal method of the oxidized mercury. However, if the mercury regulation is intensified, it is necessary to inject sorbents such as activated carbon because the WFGD cannot remove the elemental mercury.

As shown in Table 1, most of the sorbents that are currently developed for the removal of gaseous mercury are an activated carbon. Virgin activated carbon, iodine treated activated carbon, sulfur impregnated activated carbon, chlorine treated activated carbon, and nitric acid treated activated carbon with oxygen functional group and so on have been studied. Vanadium, molybdenum, manganese and so on have been studied as an inorganic matter and fly ash has also been studied.

REACTIONS OF MERCURY

Mercury within coal is mostly combined with pyrite (FeS_2) and cinnabar (HgS), which are inorganic, and further combined with coal marcceral, which is organic. Most mercury is decomposed and discharged to elemental mercury in the combustion process.

Many thermodynamic models of mercury generated from an incinerator, a power plant and a gasifier etc. have been developed al-

Table 1. Sorbents investigated for removal of mercury from power plant [4]

Sample	Composition	Description
I-AC	3.5% I	Iodine promoted activated carbon
S-AC	7.6% S	Sulfur promoted activated carbon
AC	0.4-0.9% S	Unpromoted carbon
Cl-AC	6% Cl	HCl treated activated carbon
HNO_3 -AC		Nitric acid treated activated carbon
V_2O_5 -Celkate	8-50% V_2O_5	Vanadium peroxide dispersed in celkate
Celkate	MgSiO_2	Synthetic magnesium silicate
Cl-Celkate	15% Cl	HCl treated celkate
K_2O - V_2O_5	3.4% K, 1.4% V	Potassium superoxide promoted vanadium pentoxide sorbent supported on celkate
MoO_3 /Celkate	46% MoO_3	Molybdenum oxide supported on MgSiO_2
Alumina	Al_2O_3	High surface area alumina
MnO_2 / Al_2O_3	7% MnO_2	Alumina supported MnO_2
CaCl_2 / Al_2O_3	10% CaCl_2	Supported halide salt
TS-7	3.5% S	Thio promoted aluminosilicate sorbent
MoS_2	87% MoS_2	Hydrodesulfurization catalyst
CFA	64% C	Unburned carbon separated from fly ash
CERF-FA	37% C	Fly ash

Table 2. Reactions of mercury^a

Reaction no.	Reaction	Temp. (°C)
1	$\text{HgO(g)} \rightarrow \text{Hg}^{\text{e}}\text{(g)} + 2\text{O}_2\text{(g)}$	320 ^b , 680 ^c
2	$\text{HgCl}_2\text{(g)} + \text{H}_2\text{O(g)} \rightarrow \text{HgO(g)} + 2\text{HCl(g)}$	430 ^c
3	$\text{HgSO}_4\text{(s)} \rightarrow \text{HgO(g)} + \text{SO}_2\text{(g)} + 1/2\text{O}_2\text{(g)}$	320
4	$\text{HgO(s)} \rightarrow \text{HgO(g)}$	170 ^d
5	$\text{HgSO}_4\text{(s)} + \text{Cl}_2\text{(g)} \rightarrow \text{HgCl}_2\text{(g)} + \text{SO}_2\text{(g)} + \text{O}_2\text{(g)}$	110 ^c

^aReaction proceeds to the right at temperatures greater than, but to the left at temperatures less than, the stated temperature.

^bIn the absence of chlorine.

^cIn the presence of chlorine.

^dWhen $\text{HgSO}_4\text{(s)}$ is excluded from the model.

ready. Among these, the Frandsen model is said to be universal because it can explain the behavior of many elements [6]. The mercury reactions in a combustion process as Frandsen proposed are shown in the Table 2 [6].

$\text{HgSO}_4\text{(s)}$ is produced as the most stable chemical at a low temperature but becomes unstable by the presence of chlorine or at a temperature of 110 °C, which is a lower temperature. As shown in Table 2, most of the mercury is transformed into elemental mercury at a high temperature.

The most predominant factor in the gas-phase reaction of mercury is chlorine. As shown in an equilibrium reaction, the main product of the gas-phase reaction is HgCl_2 .

In reactions of mercury, another important thing is the reaction with fly ash. Mercury removal by fly ash in a power plant varies from 10% to 90%. Mercury removal performance of the fly ash depends on the unburned carbon content of it. And a temperature below 400 °C is preferable for effective mercury removal. It is also known that the finer the fly ash is, the more mercury adsorbed. Since the unburned carbon of the fly ash has no more active site than activated carbon or other sorbents of large specific surface area, the mercury adsorption of the fly ash is dominated by the surface chemistry of carbon.

It is known that mercury adsorption is dominated by the rank of coal. It is also known that bituminous coal captures HgCl_2 and sub-bituminous coal Hg^{e} . Additionally, the removal of HgCl_2 is irrelevant to the sulfur of a coal but Hg^{e} is largely related to the organic

sulfur contained in coal. In mercury removal over sulfur content, the mercury removal per unit sulfur content is not changed. In the case of sulfur impregnated activated carbon, the mercury removal is also not changed.

EXPERIMENTAL

Hybrid APCD (Air Pollution Control Device) for the simultaneous removal of PM/HAPs, which is developed in this study, is an equipment to control simultaneously PM like fine dust and HAPs like mercury through a single system. The equipment has a combination feature of a high efficiency filtering system and an adsorption system. The filtration system for PM removal adopts a hybrid particulate collector, in which an electrostatic precipitation part and a fabric filtration part are built up into a single system. In the filtration system, PM is electrostatically charged and initially collected to collecting plates and then the remaining PM, which is not collected on the collecting plates, is collected to a fabric filter. In this way, fine dust of $\text{PM}_{2.5}$ can be effectively collected.

Sorbent injection method was applied as an adsorption system for HAPs removal. In the adsorption system, sorbents are injected into the duct in front of the hybrid particulate collector to remove preferentially HAPs and then PM such as dust and sorbents are removed in the rear filtration system.

Fig. 1 shows an experimental process diagram of bench-scale Hybrid APCD for the simultaneous removal of PM/HAPs, which was used for this study.

The experimental apparatus is largely divided into a gas supply and control part, an adsorption reactor, a control part, and a measurement part. For convenience' sake, a simulated gas, which was made by mixing gaseous mercury or several gases to purified air, was used for the experiment. Gaseous mercury was supplied by mixing its vapor, which was evaporated by heating liquid mercury at a certain temperature, with the fixed flow rate of nitrogen.

A hybrid particulate collector has a scheme, in which an electrostatic precipitation part is arranged between the fabric filtration parts. The collector has several characteristics, in which the collection efficiency of fine dust is enhanced and the amount of dust flowing into a fabric filter is decreased and the re-entrainment of the dust to the fabric filter is reduced in filter cleaning; the life of the fabric filter is prolonged by preventing damage by high voltage sparks. Fig. 2 shows the collection principle of the hybrid particulate collector.

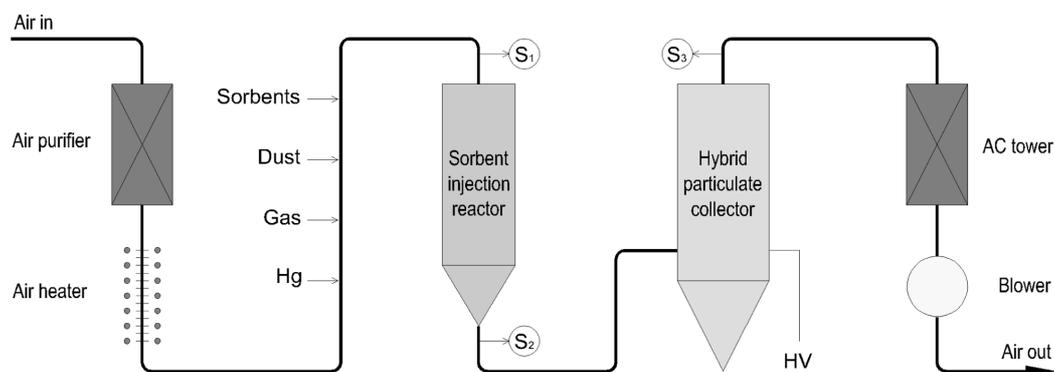


Fig. 1. Schematic diagram of bench-scale hybrid particulate collector for mercury removal.

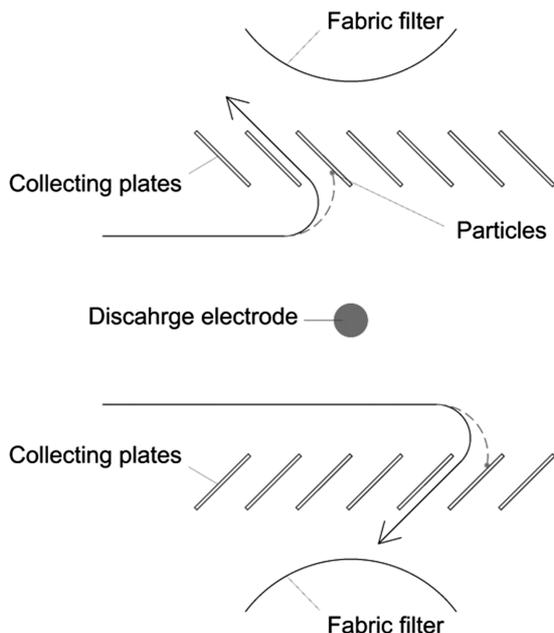


Fig. 2. Collection principle of hybrid particulate collector.

Gaseous mercury was analyzed by a mercury vapor monitor (Mercury Instruments, VM-3000). Sampling gas was passed through 10% (w/w) Na_2CO_3 aqueous solution and moisture remover before flowing into the mercury vapor monitor.

PM was measured by a particulate analyzer (TSI Inc., APS 3321). Ozone, which was generated by corona discharge, was measured by an ozone analyzer (Seres, OZ 2000G).

A sorbent injection experiment has been performed to analyze the mercury removal rate by measuring mercury concentration at the rear side of the hybrid particulate collector when changing the temperature of the simulated gas, the amount of the injecting sorbent, the type of acid gas, the charging condition of the collector and so on under circumstances at which the flow rate of the simulated gas and the supplies of mercury were kept constant at the inlet. Table 3 shows experimental conditions commonly applied to the sorbent injection experiment.

Pressure of the simulated gas was decreased as it passed through the experimental equipment. Mercury concentration measured by the mercury analyzer was in an actual condition, not in a standard condition. Thus, even though the amount of the supplied mercury was constant and there was no loss inside, the mercury concentration measured by the mercury analyzer was decreased across the equipment. That is, the absolute amount of the mercury was not changed, but, as its pressure was reduced, its volume was expanded, thereby decreasing the mass of mercury contained in the unit volume of the gas. Thus, mercury removal efficiency was acquired by comparing the mercury concentrations measured at the outlet of

Table 3. Experimental conditions of sorbent injection experiment

Gas flow	20 N/hr
Inlet mercury concentration	30 $\mu\text{g}/\text{m}^3$
Residence time	5 sec
Temperature	25-130 °C

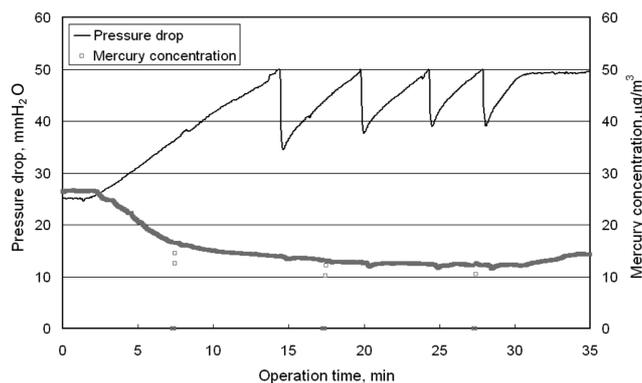


Fig. 3. Changes of outlet mercury concentration with filter cleaning.

the hybrid particulate collector when sorbents were injected or not injected.

RESULTS AND DISCUSSION

1. Effect of Filter Cleaning

Fig. 3 shows the mercury concentration at the outlet of the collector according to the filter cleaning in order to understand the relationship of sorbents collected on the filter surface with the mercury removal. HGR, which is a impregnated activated carbon (10 wt% sulfur) made by Calgon, USA, was applied as sorbent, and the C/Hg ratio was kept to be 20,000. Operation temperature was 130 °C.

From Fig. 3, as the activated carbon was continuously injected, the pressure drop in the fabric filter was linearly increased. However, the mercury concentration at the outlet was rapidly decreased at the initial time and then kept constant when activated carbon was injected with more than a certain amount. The rapid decrease of the mercury concentration at the initial stage of the experiment suggests that large amounts of mercury are adsorbed and removed in the sorbent injection reactor for a short time. If the activated carbon is continuously injected, the amount of the activated carbon remaining within the collector is increased. Thus, the collector itself other than the sorbent injection reactor plays a role as another reactor, thereby additionally decreasing the concentration of the incoming mercury. Then, when the amount of the mercury remaining within the collector is kept at equilibrium at a certain level, it is judged that the amount of the mercury exhausted through the outlet is kept constant.

When the pressure drop of the fabric filter was 50 mmH_2O , and the fabric filter was cleaned by a pulse air, activated carbon particulates collected on the surface of the fabric filter were detached to decrease rapidly the pressure drop of the fabric filter. However, the mercury concentration at the outlet of the collector was continuous before and after the filter cleaning, except the temporary change in the measured concentration value due to the inflow of the air for the filter cleaning. A possible reason is that the activated carbon collected at the surface of the fabric filter reacts very shortly with mercury and thus does not largely affect the mercury removal. Even though activated carbon particles are detached from the surface of the fabric filter by filter cleaning, the detached particles still remain in the collector and thus the amount of the activated carbon within

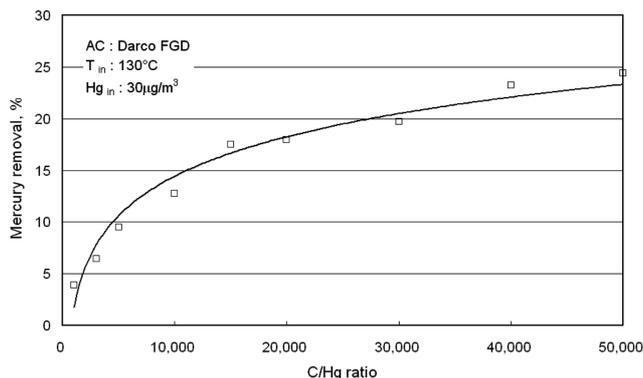


Fig. 4. Mercury removal efficiency with C/Hg ratio.

the collector is not changed largely.

2. Effect of C/Hg Ratio

Fig. 4 shows the change of mercury removal performance according to the supply rate of the activated carbon. NORIT Darco FGD was used as activated carbon. Mercury concentration at an inlet was kept to be $30 \mu\text{g}/\text{m}^3$ and SO_2 and NO gases were not injected. High voltage was not applied to the electrostatic precipitation part of the collector.

From Fig. 4, as the supply of the activated carbon was increased, the mercury within the simulated gas was adsorbed and removed, thereby decreasing the mercury concentration and increasing its removal efficiency. However, when the supply of the activated carbon exceeds the C/Hg ratio of 10,000, it is shown that the mercury removal efficiency tends to be a little increased.

It is judged to require the finding of the optimum point between the consumption of activated carbon for the removal of the gaseous mercury and its cost from the trend result. Further, it is expected that the optimum point can be varied by the application target and condition.

It is shown that mercury removal performance in the case of using real flue gas is greatly varied according to the type of the used fuel against the same injection of the activated carbon and additionally is larger than in the experimental result of this study [7]. Even though the composition and content of the real combustion flue gas are different according to the fuel type, the combustion flue gas contains some components such as HCl , SO_2 , NO_x , etc. and those components react interactively with the mercury or activated carbon to largely affect the removal of the gaseous mercury. However, this study shows that the influence of such components is excluded and only the reaction with the activated carbon and mercury is drawn.

Additionally, the particle size and size distribution of the supplied activated carbon as well as the C/Hg ratio as a standard of the supply of the activated carbon play an important factor. Generally, as the size of the activated carbon is decreased, the surface acting with the reaction is increased, thereby enhancing the removal efficiency of the mercury [8]. As the size of the activated carbon is made to be uniform, the removal efficiency of the mercury is shown to be high [9].

As a reference, the average particle size of Darco FGD applied for this experiment was $1.25 \mu\text{m}$, its MMD (Mass Median Diameter) was $4.57 \mu\text{m}$, and its geometrical standard deviation was 1.56.

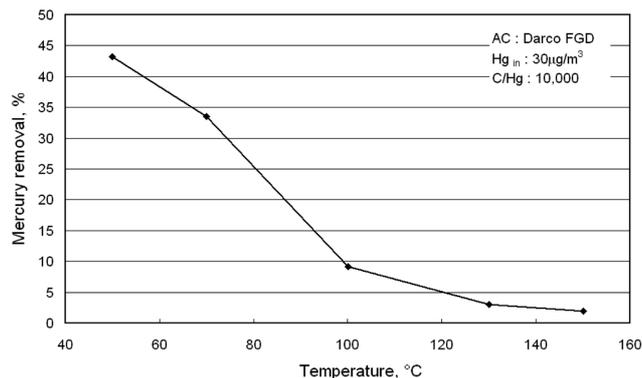


Fig. 5. Changes in mercury removal rate with temperature by the activated carbon injected.

3. Effect of Temperature

Fig. 5 shows the change of the mercury adsorption performance on activated carbon according to the temperature change. In this experiment, NORIT Darco FGD was also used as an activated carbon. At the inlet, mercury concentration was fixed to $30 \mu\text{g}/\text{m}^3$ and the C/Hg ratio to 10,000. SO_2 and NO gases were not injected to the simulated gas and high voltage was not applied to the electrostatic precipitation part.

It is shown from Fig. 5 that the mercury adsorption performance of the activated carbon is decreased as the temperature is increased. The result suggests that the mercury removal mechanism by the activated carbon is a physical adsorption and, as temperature is increased, the amount of the detached mercury is increased, thereby achieving equilibrium at a low adsorption condition.

That is, in order to increase the mercury adsorption efficiency by the activated carbon, the temperature of the equipment is reduced to below 100°C as low as possible. Accordingly, in order to set up the temperature condition suitable for the reaction, process design such as position control of the equipment and pipe design etc. should be performed.

4. Effect of Other Gases (SO_2/NO_x)

Fig. 6 and Fig. 7 show the change in mercury concentration at the outlet of the collector when SO_2 and NO are, respectively, injected to the inlet of the experimental equipment. Activated carbon was not supplied and high voltage was not applied to the electrostatic precipitation part. The supplies of SO_2 and NO were fixed to 1,000

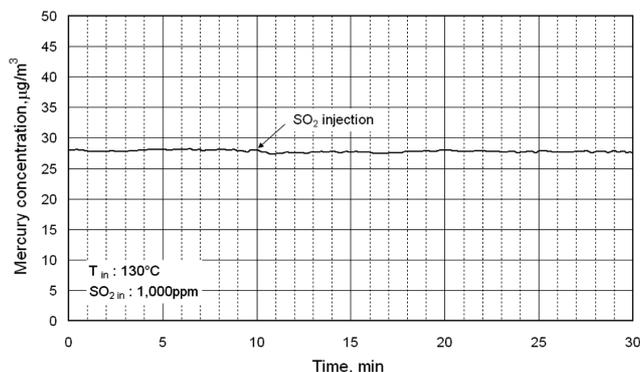


Fig. 6. Changes in mercury concentration with SO_2 injection.

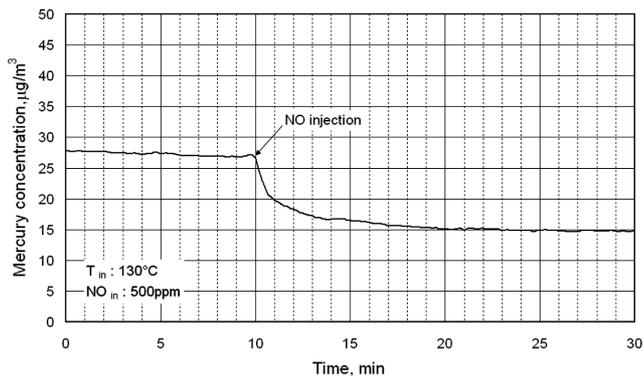


Fig. 7. Changes in mercury concentration with NO injection.

ppm and 500 ppm.

It is shown from Figs. 6 and 7 that mercury concentration is decreased even with no supply of the activated carbon when SO_2 and NO are, respectively, injected at an equilibrium condition. It is known that acid gases such as SO_2 and NO oxidize mercury directly or on the metallic surface like the internal surface of the equipment into the oxidized mercury, and thus a mercury analyzer to analyze only the elemental mercury cannot detect the oxidized mercury. The oxidized mercury is well soluble in water. If a wet type removal system to use such characteristics is installed, it can easily remove the oxidized mercury at the rear of the equipment.

When compared with SO_2 and NO injections, the mercury removal effect with SO_2 is small even in a large injection, but the mercury concentration of the outlet in NO injection is more largely decreased than in SO_2 injection. That is, it is known that NO has a larger effect on mercury removal. Even though most NO gases supplied for this experiment are exhausted as NO and some of them are oxidized into NO_2 , it is confirmed that such conversion ratio is very low in this experiment.

5. Effect of Electric Field Applied

A hybrid particulate collector for the removal of PM is equipment in which electrostatic precipitation and fabric filtration are combined. It applies high voltage to the electrostatic precipitation part at normal operation. When the high voltage is applied to the electrostatic precipitation part, free electrons are generated by corona discharge to charge particles. At this time, ozone is additionally generated by the decomposition and recombination of oxygen molecules in the air.

Ozone generation is increased over the application of voltage and the ozone concentration at the applied voltage of -25 kV is about 380 ppb.

Fig. 8 shows the mercury concentration of the outlet when high voltage is applied to the electrostatic precipitation part. Activated carbon was not supplied. It is shown in Fig. 8 that the outlet mercury concentration is lower by 7.6% at high voltage application point. The reason that the mercury concentration is reduced by the high voltage application is because ozone generated by corona discharge oxidizes elemental mercury directly or on the surface of activated carbon, thereby decreasing the mercury concentration. Another reason includes the possibility of direct oxidation of mercury by the corona discharge.

When mercury is oxidized by ozone, gaseous or particulate HgO

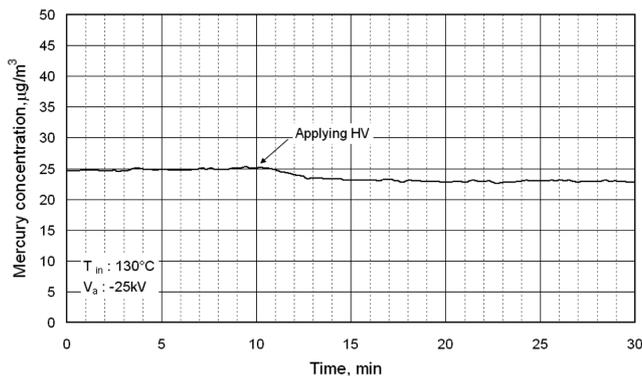
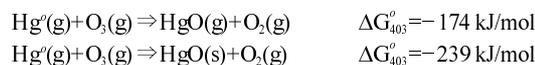


Fig. 8. Changed in the mercury concentration with high voltage application.

is formed as in the following reactions [10]. The values of free energy (ΔG°) at a temperature of 130°C (403 K) were calculated from a thermodynamic equation and Shomate equation [11].



These two reactions are all spontaneous, since the values of free energy of the reactions are all negative at the tested temperature. Even though the free energy is a function of a temperature, the $\text{HgO}(\text{s})$ formation will occur preferentially at a temperature lower than 500°C . This is because the free energy of the $\text{HgO}(\text{s})$ formation is smaller than that of $\text{HgO}(\text{g})$ formation at below 500°C as shown in Fig. 9. The HgO decomposes into elemental mercury and oxygen at a temperature higher than 500°C [12,13].

The $\text{HgO}(\text{g})$ is easily removed by dissolving it into water and $\text{HgO}(\text{s})$ can be collected and removed by a filter like a fabric filter.

6. Overall Efficiency

Fig. 10 shows the change in the outlet mercury concentration according to various factors. It is shown from Fig. 10 that the mercury removal in case of the supply of activated carbon with NO is more than the sum of mercury removal efficiency in the case of the separate supply of activated carbon or NO. That is, it is known that the mercury removal efficiency is more than 60% even in a little supply of activated carbon. Since NO and NO_2 are very reactive,

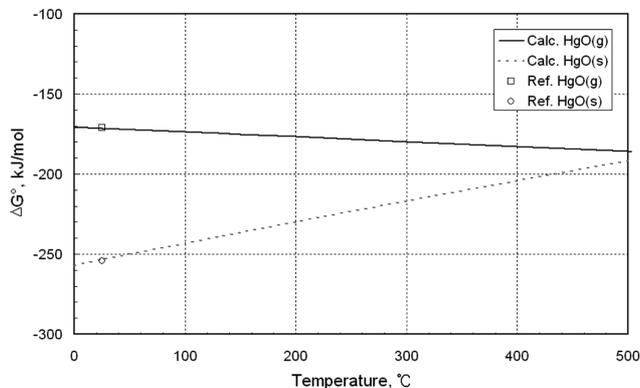


Fig. 9. Theoretical calculations of the free energy of HgO formation as a function of temperature (Reference values are from the report of B. Hall [10]).

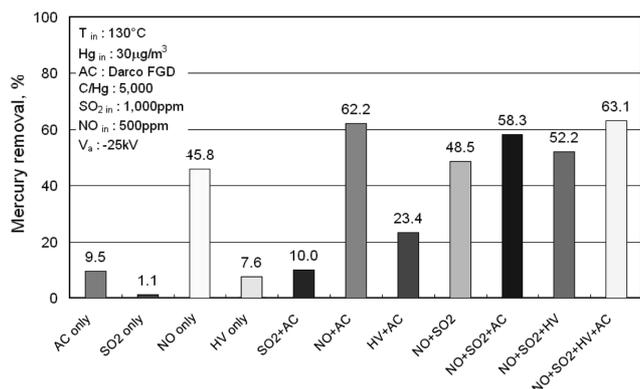


Fig. 10. Comparison of mercury removal efficiency with various operation conditions.

their effect of oxidizing the elemental mercury on the surface of materials such as carbon, metal, glass is known to be very high [14, 15].

In the case of the simultaneous injection of SO₂ and activated carbon, their effect is less than the sum of their individual effects. It is known that the activated carbon adsorbs SO₂ gas as well as mercury. That is, it is concluded that the concurrent supply of SO₂ and activated carbon will have a negative effect on the mercury removal.

The synergy effect of mercury removal is found to appear in the supply of activated carbon as well as the application of high voltage. It is assumed that the result is related to corona discharge and activation of the carbon surface by UV.

When high voltage is applied under a state of the simultaneous supply of the activated carbon with an acid gas, the mercury removal efficiency is raised up to 63.1%. Thus, it is known that the application of high voltage will be positive in the removal of gaseous mercury.

CONCLUSIONS

This study investigates the effect of the flue gas composition and the operation conditions on the removal performance of gaseous mercury in an integrated system for simultaneous PM/HAPs removal.

In mercury removal by activated carbon injection, it was found that the injection amount of activated carbon and gas temperature are very important factors. Furthermore, it was known that gas composition has a large effect on mercury removal. Mercury removal efficiency with activated carbon injection only was not large. However, in a flue gas containing acid gas like NO, the removal effi-

ciency increased to more than 60% even with little injection amount of the activated carbon because of the oxidation effect of the elemental mercury by NO.

When high voltage was applied to a hybrid particulate collector in order to increase the collection efficiency of PM, the elemental mercury was reduced due to the oxidation effect of mercury by ozone produced by corona. It was known that the mercury removal efficiency of activated carbon increased more than twice by the application of high voltage.

Thus, if these effects are properly combined, it is expected that high mercury removal efficiency of more than 90% can be acquired even with a small amount of activated carbon injected.

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