

# Conceptual Design and Operation Results for SF<sub>6</sub> Decomposition and Pollution Control System

## SF<sub>6</sub> 분해 및 무해화 시스템의 개념 설계 및 운영 결과

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### Abstract

SF<sub>6</sub> is used as an insulating gas because of its excellent electrical insulation properties, non-toxicity, and non-inflammability. On the other hand, the global warming potential of SF<sub>6</sub> is 23,900 times higher than that of CO<sub>2</sub>. The Korea electric power cooperation (KEPCO) is responsible for 80% of the domestic SF<sub>6</sub> usage, and approximately 6,000 tons are currently charged in electrical and power facilities. KEPCO will gradually replace the insulating gas with SF<sub>6</sub>-free gas from 2023. SF<sub>6</sub> decomposition facilities are required because more than 60 tons of SF<sub>6</sub> will need to be disposed of annually from existing equipment. This study developed a novel decomposition and pollution control system that can process 60 tons of SF<sub>6</sub> per year. This facility can decompose more than 97.7% of SF<sub>6</sub>, with the emissions of hazardous and toxic materials below the legal limit.

*Keywords: SF<sub>6</sub>(Sulfur hexafluoride), Thermal decomposition, Decomposition rate, Global warming gas*

### I. Introduction

Reducing carbon dioxide emissions has attracted global interest to prevent global warming. In particular, the carbon emissions from meeting electricity and heat generation demand using mainly fossil fuel combustion account for more than 40% of total global emissions [1]. Therefore, several countries have implemented a range of policies to promote power generation using renewable sources [2] to reduce emissions.

Many gases, in addition to CO<sub>2</sub>, affect global warming. These gases are known as greenhouse gas(GHG). The global warming potential(GWP) provides a comparable CO<sub>2</sub> equivalent for measuring the climate effect of different GHGs. For example, the GWP is one for carbon dioxide, but 21, 310, 1300, and 23,900 for CH<sub>4</sub>, N<sub>2</sub>O, hydrofluorocarbons(HFCs), and SF<sub>6</sub>, respectively [3]. The Kyoto protocol and UNFCCC use the GWP to measure and reduce GHGs on a standard scale [4],[5].

SF<sub>6</sub> is an insulating gas in electric equipment, such as gas-insulated switchgear(GIS), gas-insulated transformers, and gas-insulated lines, because of its excellent insulating performance and thermochemical stability. In addition, the commercial market for SF<sub>6</sub> is expected to increase owing to the increasing electric demand[6].

The decomposition of SF<sub>6</sub> during the operating, maintenance, monitoring, and diagnosis of electric equipment has been investigated. Liu et al. [7] detected the by-products of SF<sub>6</sub>, which can be degraded easily by electrical discharges, such as electric arc, spark, or corona.

Yang et al. [8] examined the influence of trace H<sub>2</sub>O, O<sub>2</sub>, and PTFE vapor on the SF<sub>6</sub> by-products under arc discharge. Zeng et al. [9], [10], [11] analyzed the effects of local thermal faults and trace H<sub>2</sub>O and O<sub>2</sub> on SF<sub>6</sub> by-products.

The impact of SF<sub>6</sub> on global warming among the other GHGs is the largest because it has the highest GWP and is a very stable chemical with an atmospheric lifetime of 3,200 years[12]. Therefore, several institutes have been developing an eco-medium instead of SF<sub>6</sub> as the insulation gas for electric equipment. The Korea electric power cooperation(KEPCO), which consumes 80% of the domestic SF<sub>6</sub> usage, plans to provide SF<sub>6</sub>-free GIS, and will have surplus SF<sub>6</sub> in the future. In 2018, the contribution of domestic SF<sub>6</sub> emissions to global warming was only 1.2% [13]. On the other hand, as the replacement of SF<sub>6</sub> accelerates, approximately 6,000 tons of SF<sub>6</sub> possessed by KEPCO will need to be disposed of with pollution control[14].

Non-degradable gases, such as SF<sub>6</sub>, can be disposed of in three ways: 1) thermal [15], 2) catalytic [16], and 3) plasma decomposition [17], [18], [19]. Thermal decomposition destroys stable molecules in a high-temperature furnace and can treat large quantities of gas. Han [20] examined the kinetic characteristics, such as reaction orders, rate-limiting steps, and activation energy, from SF<sub>6</sub> pyrolysis and evaluated the impurity-absorbing process for regenerating high purity SF<sub>6</sub>. The catalytic decomposition method can potentially dispose of the gas at relatively low temperatures but requires more studies for commercialization because of the degradation of the catalytic lifetime by poisoning[21],[22]. The thermal plasma decom-

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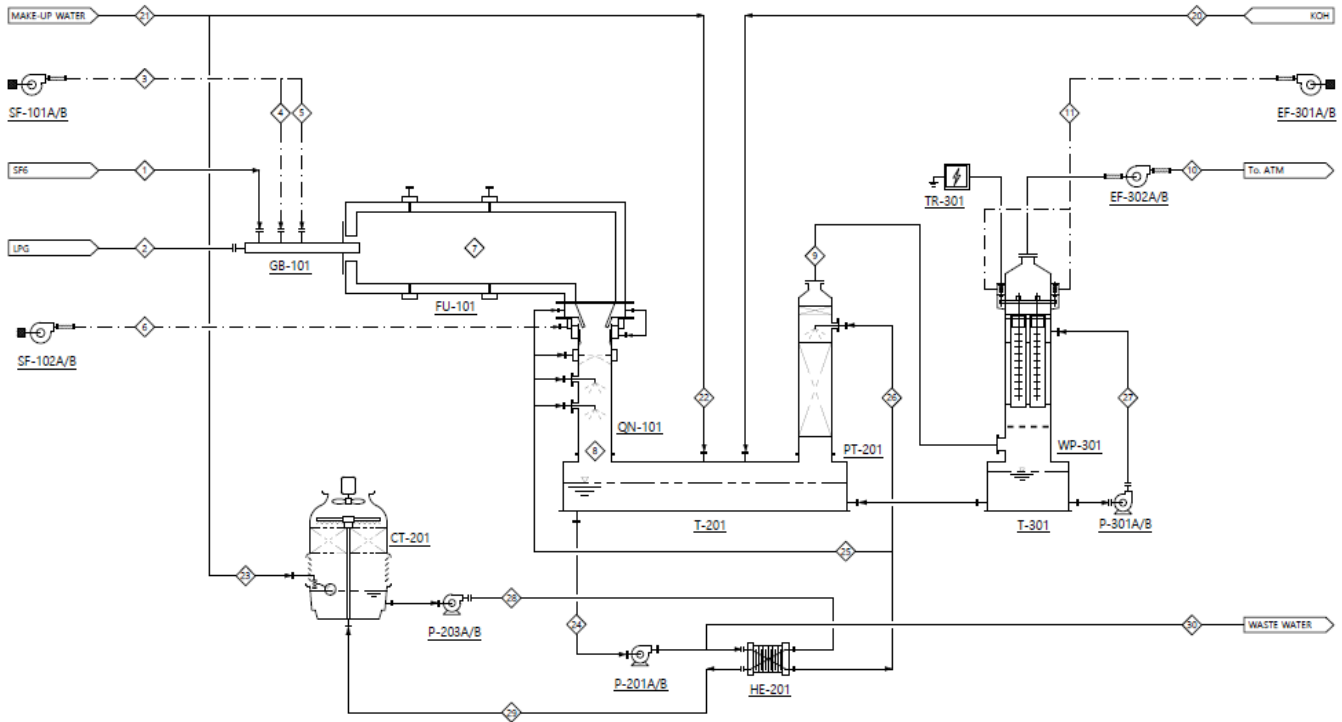


Fig. 1. Configuration of the SF<sub>6</sub> decomposition and pollution control system  
 (GB-101: Burner, FU-101: Incinerator, QN-101: Quencher, PT-201: Packed tower, T-301: EP, CT-201: Cooling tower, HE-201: Heat exchanger, T-201, T-301: Circulation tank)

position method, which generates a high reaction environment for the gas disposal, is suitable for small processes and emits few by-products. On the other hand, the method requires high economic feasibility by the low investment in equipment and energy efficiency enhancement[23]. Kim et al.[18] examined plasma decomposed particulate matter of low purity SF<sub>6</sub> used in semiconductor manufacturing. Zhang et al.[24] and Parthiban et al. [25] evaluated the possibility of non-thermal plasma(NTP), such as radio frequency plasma, microwave plasma, dielectric barrier discharge, and electron beam, being replaced with a conventional method due to low energy requirements and high chemical activities.

A commercial scale high-purity SF<sub>6</sub> decomposition and pollution control combined system has not been constructed despite the many studies of SF<sub>6</sub> decomposition and the necessity of pollution control for SF<sub>6</sub> disposal[26]. Thus, a previous study[27] examined the SF<sub>6</sub> reaction characteristics, including thermal decomposition, cooling, and neutralization, to derive design parameters for the commercial-level system. In this study, a novel decomposition and pollution control system operating each stage continuously was established to process 60 tons per year. More than 97.7% of SF<sub>6</sub> was neutralized and emitted at a steady state with no hazardous and toxic materials.

## II. Conceptual design of SF<sub>6</sub> decomposition and pollution control system

SF<sub>6</sub> decomposition and pollution control technology aims to emit a harmless gas into the air. A combustion reactor that can perform pyrolysis at up to 1000°C was selected to achieve a high decomposition rate by controlling the reaction mechanism. A quencher was required to prevent recombining products and generating by-products after decomposition. A post-treatment system was used for gas

neutralization and pollution control. The design factors and operating conditions of the customized package for a 60-ton per year were obtained from a performance evaluation of a pilot system[27].

### A. System configurations

Fig. 1 shows the configuration of the SF<sub>6</sub> decomposition and pollution system. The system consisted of a combustion reactor, quencher, circulation tank, packed tower, EP(Electrostatic Precipitator), and cooling tower. SF<sub>6</sub> gas was supplied to the combustion reactor with a temperature exceeding 1,000°C. The decomposed SF<sub>6</sub> gas cooled rapidly in the quencher to prevent thermal recombination and by-product formation. The decomposed gas passed through the circulation tank is primarily neutralized by the acid-base reaction in the wet scrubber. After pollution materials, such as fine dust, SO<sub>x</sub>, and NO<sub>x</sub>, were eliminated from the electrostatic precipitator, the flue gas was exhausted into the atmosphere with no harmful material. The circulation water, an alkaline aqueous solution, was used for quenching, scrubbing, and precipitating. Thus, the quencher and electrostatic precipitator also partially neutralize the decomposed gas. The used circulation water was cooled by heat exchange with fresh water from a cooling tower.

### B. SF<sub>6</sub> combustion reactor

The SF<sub>6</sub> combustion reactor has two parts: an incinerator and a quencher. An incinerator was selected because the thermal decomposition method can treat large quantities of gas.

#### 1) SF<sub>6</sub> incinerator

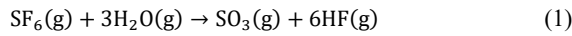
The incinerator applied to this system was designed to maintain a temperature higher than 1000 °C to encourage the decomposition

TABLE 1  
Design condition of the incinerator

Variables	Unit	Value	
SF <sub>6</sub> Inlet	Flow	kg/hr	25
	Temp.	°C	25
	Pressure	Bar	ATM
SF <sub>6</sub> Decomposition Rate	%	> 95	
Reaction temperature	K	1473	
Excess Air Ratio	-	1.3	
Cooling Air Ratio	-	0.49	

of SF<sub>6</sub>. Liquefied petroleum gas(LPG) was used as a fuel to provide the amount of heat required to increase the temperature. LPG is abundant and readily available.

The reaction mechanism of SF<sub>6</sub> decomposition in the incinerator is as follows.



The reaction order was assumed to be the first order according to a previous study[27]. The reaction rate according to the reaction order is as follows:

$$k = (\ln C_0 - \ln C)/t \quad (3)$$

$$t = v_0/V \quad (4)$$

where k is the reaction rate constant; C<sub>0</sub> is the initial SF<sub>6</sub> concentration(mol/liter); C is the residual SF<sub>6</sub> concentration after decomposition reaction(mol/liter); t is the residence time(second); V is the reaction volume(m<sup>3</sup>). The concentration term can be substituted as follows through the decomposition rate.

$$D. R(\text{Decomposition Rate}) = C/C_0 \quad (5)$$

The reaction rate can be expressed using the Arrhenius equation:

$$k = A \exp\left(-\frac{E_a}{RT}\right) \quad (6)$$

where A is the frequency factor; E<sub>a</sub> is the activation energy (kJ/mol); R is the universal gas constant(kJ/mol·K); T is the absolute temperature(K). The activation energy and frequency factor were 249.92 J/mol and  $8.5677 \times 10^7$ , respectively [27].

TABLE 1 lists the design condition. The SF<sub>6</sub> feed flow was 25kg/h, and the outlet flow of the incinerator was calculated from the stoichiometric ratio, excess air ratio, and cooling air ratio. The excess air ratio was applied for complete combustion, and the cooling air protected the facility and burner. Based on the above equations, the residence time of the incinerator was 1.4s, and the volume of the incinerator was 0.26m<sup>3</sup>.

The actual facility was designed to have a residence time of two seconds considering the margin based on the above calculation result. The ratio of the diameter and length of the reactor was calculated to be 0.5 m by applying the maximum value of five in the rule of thumb. Similarly, the actual facility is designed to have a diameter of 0.6 m and a length of 2.5 m, considering the margin. TABLE 2 lists the properties of the incinerator flue gas.

TABLE 2  
Properties of the incinerator flue gas

Composition	Vol %	wt. %
N <sub>2</sub>	67.53	65.44
O <sub>2</sub>	7.90	8.75
CO <sub>2</sub>	6.70	10.20
H <sub>2</sub> O	2.23	1.39
HF	13.40	9.27
SO <sub>3</sub>	2.23	4.95
Flow rate(kg/hr)	221.62	
Enthalpy(kcal/hr)	75,783	

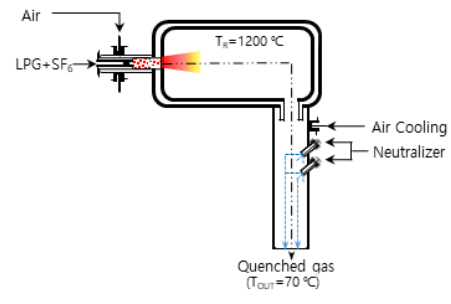


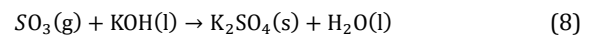
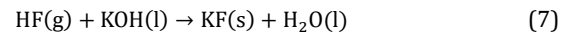
Fig. 2. Combustion reactor including the incinerator and quencher

## 2) Quencher

The purpose of the quencher is to prevent side reactions of decomposed materials through rapid cooling and enable the safe operation of subsequent facilities. Quenching is essential for preventing corrosion of the subsequent equipment because the decomposed materials are strongly acidic, such as HF and SO<sub>3</sub>, and are at high temperatures.

This equipment is designed to have a top-down gas flow, as shown in Fig. 2. In particular, Hastelloy-C, which is resistant to high temperatures and strong acids, was applied to the material of the part where the combustion furnace and the quencher are connected. In addition, to protect the equipment, the air was used to cool the connection part, and the temperature of the exhaust gas was cooled to less than 70 °C by direct contact with the decomposition gas through cooling water, i.e., the KOH solution for neutralization.

This system was designed using potassium hydroxide (KOH) for neutralization based on Equations (7) and (8).



The total neutralization heat value of 35,200 kcal/hr was obtained by applying the reaction values 118 kJ/mol and 153 kJ/mol of Equations (7) and (8).

In the process of cooling and neutralization, salts, such as KF and K<sub>2</sub>SO<sub>4</sub>, are generated, which have high solubility in water. The neutralizing liquid, in which the salts are dissolved, is circulated continuously in the circulation tank until a certain set value is reached at pH 11. This system predicted that circulation water, i.e., neutralization solution, would be saturated where the salt is dissolved. The control logic was configured to supply fresh water and

TABLE 3  
 Designed value for the quenched gas

Composition	Vol %	wt. %
N <sub>2</sub>	56.89	64.07
O <sub>2</sub>	6.77	8.30
CO <sub>2</sub>	5.57	9.39
H <sub>2</sub> O	30.77	21.24
Flow rate(kg/hr)	240.73	
Enthalpy(kcal/hr)	35,306	

a KOH solution if the electrical conductivity is higher than the calculated criterion.

The cooling tower and heat exchanger required for this cooling and neutralization process was designed as follows. The temperature of the quenched gas can be determined through an adiabatic saturation temperature(AST), and it can be calculated using the saturated vapor pressure and absolute humidity.

The saturated vapor pressure( $P_V$ ) is as follows, where TAS is the adiabatic saturation temperature:

$$\text{Log}P_V(\text{mmHG}) = 8.11 - \frac{1750}{T_{AS} + 235} \quad (9)$$

The absolute humidity ( $X_H$ ) is as follows:

$$X_H(\%) = \frac{MW_V}{MW_{air}} \times \frac{P_V}{(760 - P_V)} \quad (10)$$

where MW<sub>v</sub> is the molecular weight of the vapor, and MW<sub>air</sub> is the molecular weight of air.

The wet air enthalpy (H) is as follows:

$$H(\text{kcal/kg}) = C_{p_{DA}} \times T_{AS} + (597 + 0.45 \times T_{AS}) \times X_H \quad (11)$$

where  $C_{p_{DA}}$  is the heat capacity of dry air (kcal/kg °C).

Regarding the stable operation of the quencher, the conditions of quenched gas for maintaining the temperature below the design target of 70 °C were obtained, as listed in TABLE 3.

In the proposed system, the heat duty(Hc) for cooling could be calculated by considering the neutralization heat of the quenched gas:

$$H_c = m_i H_i + H_r - m_o H_o \quad (12)$$

where  $m_i$  is the inlet gas flow(kg/hr);  $m_o$  is outlet gas flow (kg/hr);  $H_i$  is the amount of heat per unit weight of the inlet gas (kcal/kg);  $H_o$  is the amount of heat per unit weight of the outlet gas;  $H_r$  is the heat of neutralization(kcal/hr). A cooling capacity of 20 RT (Refrigeration Ton) and a cooling flow rate of 15,229 kg/hr were designed based on a plate-shaped heat exchanger with a temperature difference of 5 °C between the inlet and outlet during the operation of the cooling tower. Considering the flow and temperature of the gas, considering both the decomposed and the quenched gas, the total flow rate of the neutralized solution(5 m<sup>3</sup>/hr), the diameter of the quenched air(0.4 m), and the length(0.9 m).

### C. Post-treatment System for Pollution Prevention

A post-treatment process is essential to meet the environmental regulations for the final emissions of flue gases(HF 2 ppm and SO<sub>x</sub> 30 ppm).

 TABLE 4  
 Designed conditions for the packed tower for neutralization

Items	Unit	Values
Packing	-	Tri-Pack 1inch
Liquid loading	gpm/ft <sup>2</sup>	50
Gas velocity ( $V_g$ )	m/s	0.29
Concentration		
HF	ppm	2
SO <sub>2</sub>	ppm	30

### 1) Packed tower for neutralization

In this facility, a packed tower was adopted. In the “packed tower,” an air pollution treatment system that resembles a wet scrubber system was used to remove particulates. This tower is the most common technology for removing gaseous (and aerosol) pollutants[28]. Some harmful gases are neutralized even in the quencher, but the main purpose of the quencher is to cool the decomposed gas. It is necessary to design a packed tower for the neutralization so the flue gas can legally be discharged throughout this system.

TABLE 4 lists the design conditions, which were set to have a removal rate of 99.5% or more of harmful substances.

The C-factor at the flooding point obtained by the performance curve of the supplier was 0.039 m/s, which is expressed using equation (13):

$$C_f = V_s \left[ \frac{\rho_v}{\rho_L - \rho_v} \right]^{0.5} \quad (13)$$

where  $V_s$  is super critical vapor velocity(m/s);  $\rho_L$  is the density of the liquid (kg/m<sup>3</sup>);  $\rho_v$  is the density of vapor (kg/m<sup>3</sup>). Based on that, the diameter of the packed tower was derived as 0.6 m.

Equations (14) and (15) were used to design the height(Z) of the packed tower based on TABLE 4.

$$Z = \frac{V}{S} \frac{1}{K_g a} \ln \left( \frac{C_i}{C_o} \right) \quad (14)$$

$$Z = H_{OG} \times N_{OG} \quad (15)$$

where  $V/S$  is a molar flux of gas;  $K_g a$  is the mass transfer coefficient;  $C_{i,o}$  is the concentration of gas at the inlet, outlet(ppm);  $H_{OG}$  is the HTU(Height of Transfer Unit) of the outlet gas(m);  $N_{OG}$  is NTU(Number of Transfers) of outlet gas(m).

The NTU values of HF and SO<sub>3</sub> were 11.5, and 6.6, respectively. HTU represents the separation effectiveness of the packed tower, which can be obtained from the performance curve supplied by the manufacturer. Based on the previous process, the height(Z) of the packed tower for the two substances, HF and SO<sub>3</sub>, was calculated, and the larger of the two was selected as the basic design value. The height of the packed tower was designed to be 1.6m considering the design margin.

### 3) Electrostatic precipitator

The most harmful substances become neutralized and harmless in the neutralizer. HF has a high solubility in water. Hence, HF is easy to process to a certain level, but it is difficult to operate stably below 2 ppm, as stipulated in the Air Quality Conservation Act.

A continuous water film type wet electrostatic precipitator is more efficient than the parallel connection of a normal wet scrubber. Hence, a water film type wet electrostatic precipitator was adopted in this study.

After the neutralizer, the quenched gas contained HF mist in the range of 0.1 to 1 micron. When a high voltage was applied between a discharge electrode (with a relatively small curvature) and a precipitator electrode (with large), a discharge started, then the electrons were supplied and absorbed by the air molecules to form ions. They are absorbed by the mist and become charged, so they can be collected by moving to the precipitator pole.

Fig. 3 presents a simple schematic diagram.

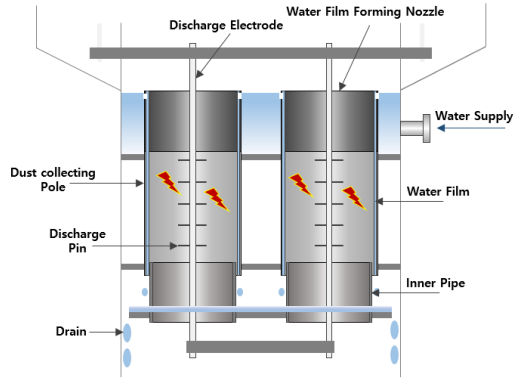


Fig. 3. Schematic diagram of an electrostatic precipitator



(a) Bird-eye view of SF<sub>6</sub> decomposition and control system (b) Incinerator for SF<sub>6</sub> decomposition

Fig. 4. SF<sub>6</sub> decomposition and pollution control system

### III. EXPERIMENTS PREPARATION

#### A. System Construction

Fig. 4 presents the SF<sub>6</sub> decomposition and pollution system. The system was designed to decompose 25 kg of SF<sub>6</sub> per hour. The facility area was approximately 210m<sup>2</sup>. TABLE 5 provides the detailed specifications of the equipment.

#### B. Quantitative measurement

The mass flow rate and composition of the exhaust gas were measured in real-time using a quadrupole mass spectrometer (QMS) with helium and Fourier transform infrared (FT-IR) spectroscopy [27]. The specifications of measuring instruments are summarized in TABLE 6.

The system performance is described as follows.

$$R_{\text{decomp}}(\%) = \left(1 - \frac{\dot{m}_{\text{inlet}}}{\dot{m}_{\text{outlet}}'}_{\text{SF}_6}\right) \times 100 \quad (15)$$

#### C. Start-up for steady state

Temperature adjustment is essential for the experimental result with high reliability. In addition, care should be taken when increasing the incinerator temperature to reach a steady state to avoid damage to the thermal insulation. The reaction temperature was adjusted by PID control at a fixed air-fuel ratio. The temperature was increased from room temperature to the target temperature (1000°C) at a rate of 75°C per hour. After reaching the target temperature, the fuel supply was adjusted to maintain the target temperature. Fig. 5 shows the variation in fuel flow and temperature with time using PID control. Close agreement was noted between the set point and process value, confirming the reliability of the incinerator used in this experiment.

The flue gas temperature was monitored to avoid by-products and thermal recombination of the decomposed SF<sub>6</sub> gas. The flue gas was cooled rapidly to less than 70°C in the quencher using circulation water. The high-temperature circulation was cooled using a plate heat

TABLE 5  
Specifications of equipment

Item	Type	Capacity	Size(mm)
LPG tank	Cylindrical	1000 kg	Φ1,300 × 1,454L × 2,142H
Burner	Vortex	100,000 kcal/h	-
Incinerator	Direct thermal oxidation	25 kg/h (SF <sub>6</sub> )	Φ600 × 2,500 L
Quencher	Water film, Spray	671 m <sup>3</sup> /h (1,300 liters)	Φ345 × 1,200H
Wet scrubber	Packed tower	211 m <sup>3</sup> /h (200 liters)	Φ 600 × 2,460H
Heat exchanger	Plate	3m <sup>2</sup> (heat transfer area)	
Cooling tower	Vertical, Cylindrical	Φ1,390 × 1,895L	0.4kW, 380V, 3Φ, 4P, 60Hz
Electrostatic precipitator	Water film, vertical	177 m <sup>3</sup> /h	640W × 640L × 2,600H
Cir. Tank 1	Rectangular	100 liters	2,430W × 1,000L × 785H
Cir. Tank 2	Rectangular	0.4 m <sup>3</sup>	640W × 950L × 985H
Water tank	Cylindrical	1.0 m <sup>3</sup> (200 liters)	Φ1,080 × 1,150H
Waste water tank	Rectangular	18 m <sup>3</sup>	5,200W × 2,200L × 1,600H
KOH tank	Cylindrical	8 m <sup>3</sup>	Φ2,100 × 2,400H
SUMP tank	Rectangular	0.14 m <sup>3</sup>	1,200W × 400L × 300H

TABLE 6  
Specifications of measuring instruments

Items	Specifications
QMS	Mass range: 1 – 200 amu Detection limit: 5 ppm Detector: Faraday cup, Secondary Electron Multiplier
FT-IR	Peltier cooled HgCdTe (MCT) detector Resolution: 4 cm <sup>-1</sup> Spectrum range: 900 ~ 4,200 cm <sup>-1</sup>

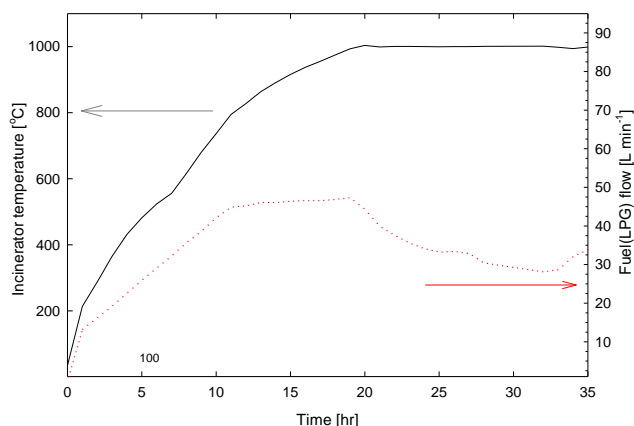


Fig. 5. Incinerator temperature(°C) and fuel flow with the time(hr) by the PID control

TABLE 7  
Operating values of each part

Part	Unit	Target Value	Operating Value
Surface temperature of Incinerator (Burner / Front / Middle / Back)	°C	Burner (> 100) Other part (> 50)	Burner (> 80) Other part (> 40)
Pressure of circulation tank	mmH <sub>2</sub> O	< -40	-30 ~ -20
Surface temperature of post-treatment equipment (Quencher, Packed tower, EP)	°C	< 40	< 25
Pressure of Circulation Pump	bar	3.5 ~ 4.5	4
EP purge fan	mbar	10 ~ 15	10 ~ 15
Quencher purge fan	mbar	10 ~ 15	10 ~ 15
Pressure of feeding system(LPG)	bar	0.6 ~ 0.9	0.7 ~ 0.8
Temperature of circulation tank (gas)	°C	< 70	< 40
Temperature of circulation tank (liquid)	°C	< 70	< 40

exchanger. The freshwater cooling medium was supplied from a cooling tower and returned to the heat exchanger. A two-stage cascade cooling system controlled the flue gas temperature to operate the decomposition system stably within the design conditions. TABLE 7 lists the operating values of each part at the steady state. There was a close agreement in which the operating value was within the design range, confirming the reliability of the quencher, circulation tank, and cooling tower for the experimental preparation.

TABLE 8  
Experimental results of SF<sub>6</sub> decomposition rate according to SF<sub>6</sub> feed rate (at 996.1 – 999.7 °C)

SF <sub>6</sub> Flow rate (L min <sup>-1</sup> )	Inlet flow rate		Cooling Air	
	LPG (L min <sup>-1</sup> )	Air (Nm <sup>3</sup> hr <sup>-1</sup> )	Quencher (Nm <sup>3</sup> hr <sup>-1</sup> )	EP (Nm <sup>3</sup> hr <sup>-1</sup> )
20	20.9	39.7	2.1	5.3
30	29.8	54.0	2.1	5.3
40	39.7	62.4	2.1	5.3
50	49.6	62.8	2.1	5.3
60	59.6	65.0	2.1	5.3

Incinerator Temp. (°C)	Conc. SF <sub>6</sub>		Decom. rate (%)
	Inlet (%)	Outlet (ppm)	
998.0	2.38	100	99.58
999.7	2.79	430	98.46
996.4	1.74	505	98.41
996.1	1.60	880	97.76
999.2	1.41	1050	97.72

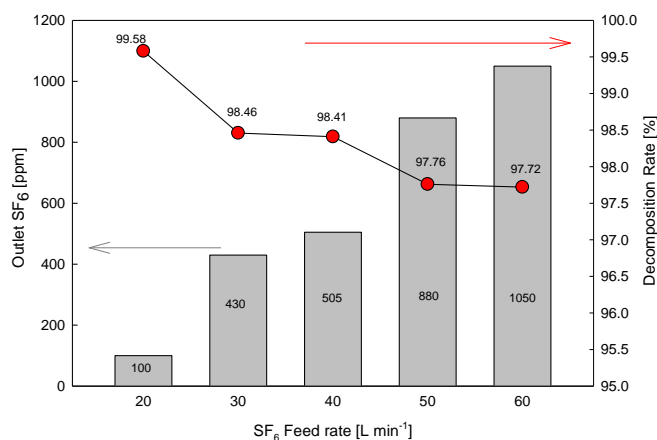


Fig. 6. Outlet SF<sub>6</sub> (ppm) and SF<sub>6</sub> decomposition rate according to SF<sub>6</sub> feed rate(L min<sup>-1</sup>)

#### IV. EXPERIMENTS RESULTS

The experiment was conducted to determine if the commercial scale decomposition system worked continuously. The evaluation was performed based on an analysis of the SF<sub>6</sub> decomposition rate and pollution discharged. In addition, the control logic was confirmed to continue to function normally.

##### A. SF<sub>6</sub> decomposition rate

To perform the decomposition efficiency assessment according to the SF<sub>6</sub> feed rate, SF<sub>6</sub> was supplied in the SF<sub>6</sub> flow range of 20 to 60 L min<sup>-1</sup> to confirm the decomposition rate assessment under the following conditions: 1,000 °C for the SF<sub>6</sub> supply, 20.9 - 59.6 L min<sup>-1</sup> for the fuel(LPG) supply, and 39.7-65.0 Nm<sup>3</sup> hr<sup>-1</sup> for air.

The currently established decomposition system could stably obtain the desired decomposition rate during operation under the conditions shown in TABLE 8 and Fig. 6.

TABLE 9  
Experimental results of pollutants according to  
SF<sub>6</sub> feed rate(at 996.1 – 999.7 °C)

SF <sub>6</sub> Flow rate (L min <sup>-1</sup> )	Inlet flow rate		Cooling Air	
	LPG (L min <sup>-1</sup> )	Air (Nm <sup>3</sup> hr <sup>-1</sup> )	Quencher (Nm <sup>3</sup> hr <sup>-1</sup> )	EP (Nm <sup>3</sup> hr <sup>-1</sup> )
20	20.9	39.7	2.1	5.3
30	29.8	54.0	2.1	5.3
40	39.7	62.4	2.1	5.3
50	49.6	62.8	2.1	5.3

Incinerator Temp. (°C)	Pollutants		
	HF (ppm)	SO <sub>x</sub> (ppm)	NO <sub>x</sub> (ppm)
998.0	0	0	9
999.7	0	0	9
996.4	0	0	10
996.1	0	0	13

## B. Pollution control

A pollution control system is required to treat acid gases, such as HF and SO<sub>x</sub>. A dilute KOH solution in the circulation tank was sprayed on the flue gas for neutralization. The use of a KOH solution depends on the pH and electrical conductivity. As the solution is used, the pH and electrical conductivity change. A part of the used solution flows to the wastewater storage tank based on an interlock system, and fresh 45 wt. % KOH solution and water are supplied from the KOH storage tank and water supply tank, respectively. TABLE 9 shows the amount of pollution discharged according to the SF<sub>6</sub> feed rate, which shows that pollutants, such as HF, SO<sub>x</sub>, and NO<sub>x</sub>, are controlled within the allowable range.

## V. CONCLUSION

A SF<sub>6</sub> decomposition and pollution control system was constructed and operated. The core technology of this study was designed to operate stably on a commercial scale of 60 tons per year. The reaction temperature was increased to 1000°C and maintained at that temperature. More than 97.72% of the SF<sub>6</sub> was decomposed and emitted with hazardous and toxic material below the legal limit at a steady state. The control logic was confirmed to function normally, including the interlock system. As a result of the experiment, it is expected that a commercial scale decomposition system of 60 tons per year can be operated stably in the future.

This study has established a novel SF<sub>6</sub> decomposition and pollution control system. A more comprehensive evaluation of the decomposition system will entail future research that applies sensitivity analysis, such as the adjustment of temperature and air-fuel ratio to supplement the present results, followed by a more compact size to reduce the cost of the established system.

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