

The SF₆ ReUse Program – A Case Study

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ABSTRACT

Solvay has launched its SF₆ ReUse Program in the USA, offering utility companies in particular the opportunity to dispose of their used SF₆ gas in a manner consistent with environmental awareness and protection. The program addresses the analysis, transport and reclaiming of used SF₆ gas to the point where it is ultimately fed back into the production stream. This paper illustrates the logistics of the SF₆ ReUse Program through a case study. An improperly labeled cylinder at a utility site containing what is suspected to be used SF₆ is handled by (1) taking samples for analysis to confirm that it is in fact used SF₆ and within Solvay's specification limits for ReUse, (2) transporting the cylinder in a secure manner to a location where it could be safely and properly trans-filled into dedicated used SF₆ cylinders and (3) transported to Germany where the used gas is fed back into the production stream thereby yielding virgin gas. The case study tracks the contents of the used gas from initial sampling through to introduction into the production stream. The paper also outlines the inventory management program utilized to ensure that every kilogram of used SF₆ is accounted for and tracked throughout the cycle of the ReUse Program.

INTRODUCTION

Despite its excellent properties as an insulating and arc-quenching medium in electrical circuit breakers and gas insulated substations, SF₆ has also been identified as a greenhouse gas, 22,500 times more effective at trapping infra-red radiation than an equivalent amount of CO₂. Recognizing their responsibility as a manufacturer of SF₆, Solvay Fluor und Derivate GmbH in Germany first introduced the ReUse program in Europe. In 95% of all cases, used SF₆ can be purified on site using gas purification carts. When the gas is deemed corrupt, the program offers utility companies the option of returning used SF₆ back to Solvay's production site where it is fed back into the virgin SF₆ production stream and therefore fulfills all the requirements of virgin gas. To date, more than 100 tons of used SF₆ gas from around Europe has been returned to Solvay Fluor for reclaiming. The details of the program are described elsewhere [1].

The SF₆ ReUse Program was first introduced in the United States in November 2000 at the EPA's first International Conference on SF₆ and the Environment [2]. At that time, Solvay Fluorides had made the commitment to offer the program in the United States, but there were still a number of logistical hurdles to overcome and some of these are described in the paper. The

SF₆ ReUse Program is now fully operational and is demonstrated through a case study of the first quantity of used SF₆ gas taken back for reclaiming from American Electric Power. This case study was made possible with the valuable assistance of AGA Gas, Inc.

USED SF₆ – A NEW PRODUCT

Because used SF₆ gas reclaimed from utility companies is ultimately fed back into Solvay Fluor's virgin SF₆ production stream, it must meet certain specifications:

H ₂ O content	max. 0.1 wt % (<1000 ppm)
Oil content	max. 0.1 wt % (<1000 ppm)
Thionyl Fluoride	max. 2.0 wt %
HF content	max. 3.0 wt %
CF ₄	max. 5.0 wt %
Air content	max. 30.0 vol %
Remainder	SF ₆
Non-radioactive	

From a hazards viewpoint, any gas reaching the upper limit of these specifications cannot be classified in the same manner as virgin SF₆ gas (Class 2.2, Liquefied Gas, Non-Flammable/Non-Poisonous). Therefore, a new Material Safety Data Sheet was generated with a new product name and the product classification was revised to reflect the compositional limits for the used SF₆ gas:

MSDS Product Name: USED SULFUR HEXAFLUORIDE
From Electrical Installations

Classification: Liquefied Gas, Toxic, Corrosive
N.O.S. (sulfur Hexafluoride, Hydrogen Fluoride)
Class: 2.3 + 8, UN3308, Hazard Zone D

The revised classification also meant that Used SF₆ gas could not be transported in virgin SF₆ gas cylinders. For the 115 lb (40 kg) cylinders, it was determined that DOT 3AA2265 type with a CGA 330 valve rated for HCl service was required. These cylinders are intended primarily for transporting used SF₆ domestically.

For overseas transport of larger quantities, Solvay Fluorides elected to go with 110A2000W ton cylinders with CGA 330 valves. However, this cylinder type was not DOT specified, but exemptions were granted for certain products. Solvay Fluorides was granted party status to the exemption allowing used sulfur hexafluoride to be transported in 110A2000W multi-unit tank cars [3]. In addition, under the International Maritime Dangerous Goods (IMDG) Code, the Competent Authority of the United States granted approval authorizing the transportation of used SF₆ in 110A2000W multi-unit tank cars by cargo vessel [4].

RECRUITMENT

Recruitment in Solvay Fluorides SF₆ ReUse Program posed a challenge. In order to offer the ReUse Program to a large base of potential partners, Solvay worked closely with AGA Gas, Inc., a member of the Linde Gas Group. As manufacturers and distributors of industrial, medical and specialty gases servicing a broad range of manufacturing sectors in North America including electrical utilities and OEM's, AGA Gas made it possible to reach and recruit partners in the SF₆ ReUse Program. For the current Case Study, AGA Gas also assisted in the logistics of sampling

and transportation of the first quantity of used SF₆ for reclaiming, as will be discussed in more detail below.

The first recruited partner, and the subject of this Case Study, was American Electric Power. AEP operates a large electricity generation, transmission, and distribution network with over 39,000 MW of generating capacity, 38,000 transmission miles and 186,000 distribution miles. It serves over three million customers in the United States. AEP's SF₆-containing equipment spans a broad range of specifications: its system has 1,270 SF₆ gas circuit breakers, ranging from 46 kV to 765 kV, and three gas insulated substations. In addition, AEP is a member of the EPA's SF₆ Emissions Reduction Partnership for Electric Power Systems.

THE CASE STUDY

Background

A new circuit breaker was being installed at AEP's Amos, West Virginia station, when the unit failed as it was initially energized. Evidently, an arc occurred over the open contacts generating more than 44,000 amps of measured current. The maintenance engineers believe the arc was sustained for 20 minutes. The interrupter was also burnt and not reusable. The 120 psi rupture disk eventually burst and gas started to escape. Plastic sheeting was used to immediately cover and secure the rupture disk opening. The actual cause of the fault was never determined.

The SF₆ gas was evacuated from the circuit breaker directly into a gas purification cart. The breaker atmosphere was pulled down to 0 psig until a dust was noticed. The maintenance personnel anticipated that contamination with fluoride and/or sulfur decomposition by-products would be present. The SF₆ gas was circulated through the cart's purification unit numerous times and tested for SO₂ by the Dräger tube method. The SO₂ concentration could not be brought down to desired levels and the gas was deemed corrupt and could not be trans-filled back into the circuit breaker. Since there were no SF₆ cylinders on site, the maintenance personnel used the only compressed gas cylinders available which were empty nitrogen cylinders stored in inventory. The SF₆-filled nitrogen cylinders remained on site until AGA Gas was contacted for assistance. AGA Gas then acted as a liaison between Solvay Fluorides and AEP in the reclaiming of the used SF₆ gas.

Analysis

Reclaiming the first quantity of used SF₆ already posed a challenge because the gas was contained in a falsely labeled cylinder. Standard protocol dictates that a sample of the gas must be analyzed to ensure that it is within Solvay Fluor's specifications for reclaiming. This was especially important since the cylinder could not be safely transported until the contents were analyzed. A sampling kit containing lecture bottles and instructions were sent to an AGA Gas engineer.

In order to ensure that an adequate quantity of gas is available for analysis, Solvay Fluorides recommends to sample from the liquid phase. The SF₆-filled nitrogen cylinder was safely inverted to allow any liquid SF₆ to flow from the cylinder into the lecture bottle. This was a difficult operation since no other equipment was available to facilitate sampling. Furthermore, the scale used to determine how much sample was collected was only accurate to the pound. No difference was noted in the weight of the sample cylinder before and after. With no other options available, the AGA Gas and AEP engineers hoped that the differential pressure between the nitrogen cylinder and the lecture bottle was sufficient to obtain a reasonable quantity.

Under normal circumstances, the lecture bottles would be sent to the Solvay Fluorides laboratory in Catoosa OK for analysis. Another complication occurred when it was discovered that there was a glitch in the software of the Gas Chromatograph dedicated for analysis of used SF₆. The lecture bottles were thus sent to Solvay Fluor und Derivate GmbH in Germany to complete the analysis. It should be pointed out that due to the revised classification of used SF₆ gas (Class

2.3, toxic, corrosive) the lecture bottles could only be sent by cargo vessel. The results of the analysis are shown in the Table 1.

Table 1
Analysis of Used SF₆ Gas

Impurities		Concentration ppmw	Max. Concentration wt %
H ₂	Hydrogen	< 1	
Air	Oxygen and Nitrogen	233	30
CF ₄	Carbon tetrafluoride	1031	5.0
CO ₂	Carbon dioxide	152	
CHF ₃	Trifluoromethane	< 1	
SOF ₂	Thionyl fluoride	4881	2.0
SO ₂ F ₂	Sulfuryl fluoride	< 1	
NF ₃	Nitrogen trifluoride	< 1	
SO ₂	Sulfur dioxide	6545	

The analysis shows that the impurities are well within Solvay's allowable limits for reclaiming.

Transportation

Once the analysis confirms that the used SF₆ gas is suitable for reclaiming, the normal protocol would be to send the specially marked used SF₆ cylinders to the utility site for trans-filling. In most cases, the on-site gas cart would be used to facilitate trans-filling from the electrical enclosure (or other suitable container) directly into Solvay's SF₆ ReUse cylinders. Since the gas was contained in a compressed nitrogen cylinder, the parties involved determined that it should be sent to AGA Gas where the trans-filling would be conducted by trained personnel in a controlled environment with all appropriate safety measures in place.

The SF₆ ReUse cylinder was then sent back to Solvay Fluorides to log in weights and prepare the necessary paperwork for shipment overseas. At Solvay, the used SF₆ gas would normally be trans-filled from the 115 lb cylinder to the ton cylinder and once a sufficient quantity is collected, it would be shipped to Solvay Fluor in Germany for reclaiming. For the purposes of the Case Study, the 115 lb cylinder was shipped without trans-filling and without delay.

INVENTORY MANAGEMENT

The success of Solvay's ReUse program lies in large part to the control and tracking of every pound of used SF₆ gas it comes in contact with. To this end, a Microsoft Excel spreadsheet was developed to track every quantity of used SF₆ gas coming through its doors, and retains ownership until it is confirmed that the gas was introduced into the virgin SF₆ production stream in Germany and the empty cylinder is returned to its facilities in Oklahoma. A section of the spreadsheet is shown below:

area of the US and to meet the challenges of special gas handling scenarios such as in this Case Study.

The beneficial impact of the SF₆ ReUse program on global warming is evident: every pound of SF₆ taken back for reclaiming and therefore not released in the atmosphere is equivalent to an emissions savings of 22,500 pounds of CO₂ [5]. Another less evident, but equally beneficial impact to the environment as a result of the program is that the toxic decomposition products found in used SF₆ gas are also not released. Most importantly the SF₆ ReUse program has helped American Electric Power reach its goals of reducing SF₆ emissions.

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