SF_6 EMISSION REDUCTION FROM GAS INSULATED ELECTRICAL EQUIPMENT IN JAPAN

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ABSTRACT

Joint study for technical standards for recycling and handling of SF_6 was conducted from 1996 to 1998 by the representatives of Academy, Utilities, Equipment Manufacturers and Gas Producers in Japan under the coordination of Electric Technology Research Association Japan (ETRA: Chair: Professor Takuma, Kyoto University), and the voluntary actions for SF_6 emission reduction from electrical equipment are being taken since 1998 in accordance with the criteria and agreement of the joint study. This paper describes the follow-up activities after the joint study and the voluntary action plans and presents the perspective of SF_6 emission for the future.

1. BACKGROUND OF SF_6 USAGE IN JAPAN

In recent years, since there has been a significant increase in electricity demand, substation equipment is required to be more reliable and compact, coping with higher voltage and larger capacity ratings. By application of sulfur hexafluoride (SF_6) to substation equipment like circuit breaker and switchgear, downsizing and less maintenance cost can be achieved to greater degrees than conventional air-insulated substation in virtue of its excellent performance of SF_6 . Therefore, Gas insulated equipment like gas circuit breaker (GCB), gas insulated switchgear (GIS) and gas insulated transformer (GIT) are being widely and commonly applied. Particularly in Japan where the land acquisition is extremely difficult, there is a large demand for gas insulated equipment as above.
On the other hand, since SF_6 was identified as a greenhouse gas in recent years, electric power companies and equipment manufacturers in Japan have been studying on countermeasures for limiting the release into atmosphere. Since the economical solution with alternative measure has not been found yet in spite of great efforts in the concerned fields, we have to continue to use the SF_6 with special attention. Therefore, consideration and practical actions should be taken to keep the SF_6 emission to a minimum so that we can make the best use of gas-insulated equipment.

2. SF_6 HOLDINGS AND EMISSIONS IN JAPAN (Obtained by Joint Study)

The world's production of SF_6 in 1995 was estimated approximately 8,500 tons. Of the total, some 30% were produced in Japan. SF_6 is mainly used for electric insulation. From the results of surveys in Japan on the amounts of SF_6 handled by gas producers and gas-insulated equipment manufacturers, conducted by the joint study, the amount of SF_6 and the quantity of emissions from 1990 to 1995 are estimated as shown in Fig. 2-1.

Generally, since SF_6 for electric insulation purposes is used in enclosed vessels, the amount of SF_6 holding increases in proportion to the amount of facilities. According to the survey, the amount of SF_6 possessed by the electric power companies had increased by 400 tons to 500 tons per year while the amount by the other industries had grown by 100 tons to 150 tons per annum.
Emissions from the gas producers are taking place from their production processes and in course of disposing of residual gas, which remained inside of returned SF_6 cylinders. Emissions at the equipment manufacturers occur in testing stage both during development and production in their factory as well as during the installation work at site. Emissions at the electric power companies correspond to the emission at maintenance stage and removal stage as well as natural leakage from equipment.

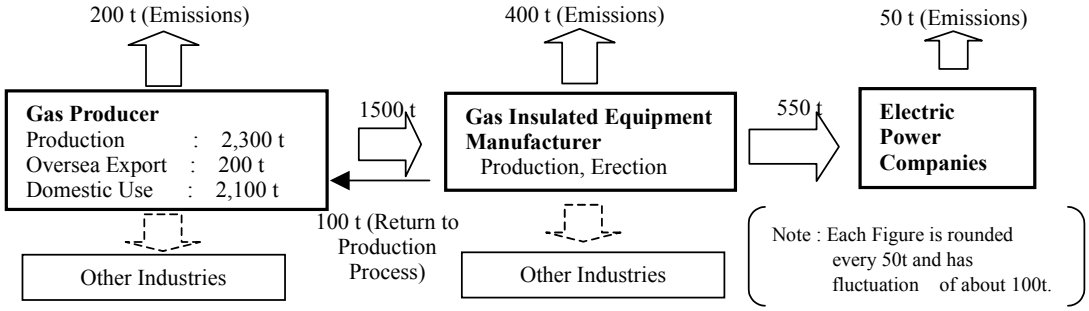

Fig. 2-1: *Outlook of Annual SF_6 Usage and Emission*

3. VOLUNTARY ACTION PLANS

In April 1998, Federation of Electric Power Companies (FEPC) and Japan Electric Manufacturers' Association (JEMA) announced the voluntary action plan for the reduction of SF_6 emission from electric equipment, respectively. Voluntary action plan was issued based on the results of joint study and the understanding that electric power companies and electric equipment manufacturers must make every effort to keep the SF_6 emission to minimum in order to make use of gas insulated equipment, since the economical alternative solution has not been found yet in spite of great efforts in the concerned field.

The actions to be addressed are as follows.:-

(1) Suppression of SF_6 emission from the development stage to the removal stage of gas insulated equipment
(2) Establishment and promotion of recycling system
(3) Brush up the current SF_6 Inventory system
(4) Development of new technology to minimize the use of SF_6 in equipment

4. SET-UP THE RECOVERY GUIDELINE

As a result of joint study, recovery target was set up as shown in table 4-1, which summarizes the current recovery rates and the target value in future. Points of guideline at respective stages are as follows.

(1) During Development Stage of Equipment

In the past, SF_6 had not been fully recovered at interrupting test or switching test during development stage because such tests generate dissolved gases. However, we set up the target and decided to promote the recovery by applying filters and the like so as to remove dissolved gases to a sufficient degree.

(2) During Equipment Manufacturing

Product testing during manufacturing is only the work related to SF_6 handling. Though recovery had been performed during manufacturing, further efforts shall be required.

(3) During Equipment Installation

Since the duration of SF_6 recovery during installation becomes longer to satisfy the target, further improvement for work process shall be strongly required.

(4) During Maintenance work

When internal inspection, recovery of SF_6 before opening the gas compartment, and vacuum up procedure and SF_6 filling process after internal inspection are required. When SF_6 is recovered to the higher degree, out-of-service time is expected to be longer than before. Since it is very difficult to secure the required out-of-service time especially in urban area, reclaimer with higher efficiency or maintenance strategy to extend maintenance interval are required.

(5) During Equipment Removal

When remove SF_6 gas-insulated equipment, SF_6 should be reclaimed to the target degree, which is similar to the case of the maintenance in principle.

Table 4-1: *Current recovery rates and future gas recovery guidelines (The indicated recovery rates apply to cases where recovery is performed on equipment/facilities with a rated gas pressure of 0.4 MPa·Gage.)*

		Recovery terminal pressure		Recovery rate	
		Lower than 110 kV	110 kV or higher	Lower than 110 kV	110kV or higher
Before 1995	During testing	No Recovery		No Recovery	
	During manufacture	0 - 0.05 MPa-gage		Approx. 70%	
	During installation/ Maintenance	No Recovery	0 - 0.05 MPa-gage	No Recovery	Approx. 70%
	During removal	No Recovery		No Recovery	
Future (Not later than 2005	During Testing/ Manufacture/ Installation/ Maintenance	0.015 MPa-abs (114 Torr) or lower		97% or higher	
	During removal	0.005 MPa-abs (38 Torr) or lower		99% or higher	

5. SF_6 GAS QUALITY CRITERIA

For decreasing the emission of the SF_6 , it is essential to minimize the SF_6 emission and recover it for recycling. For such recycling, a new SF_6 quality control standard should be indispensable. The representatives of Academy, Utilities, Equipment Manufactures and gas producers jointly set up the criteria as shown in table 5-1 as the achievement of the Joint study.

Table 5-1: *Quality control criteria for SF_6 gas*

		Permissible limits	Criteria
SF_6 gas purity		95 vol. %	97 vol. %
Air		(5 vol. %)	(3 vol. %) including CF_4
Moisture content	Equipment without current interruption	1000 ppm (vol.)	500 ppm (vol.)
	Equipment with current interruption	300 ppm (vol.)	150 ppm (vol.)
Dissolved gases/decomposition products		–	No color reaction in detecting tube

6. SF_6 RECYCLING FLOW

A RECYCLING FLOW for SF_6, which is shown in Fig. 6-1, has been established based on the above SF_6 handling criteria as the achievement of the Joint study. In each phase of the flow, recycling should be promoted when handling SF_6 . Provision shall be made to enable the use of not only new SF_6 but also recycled one at every step of the flow.

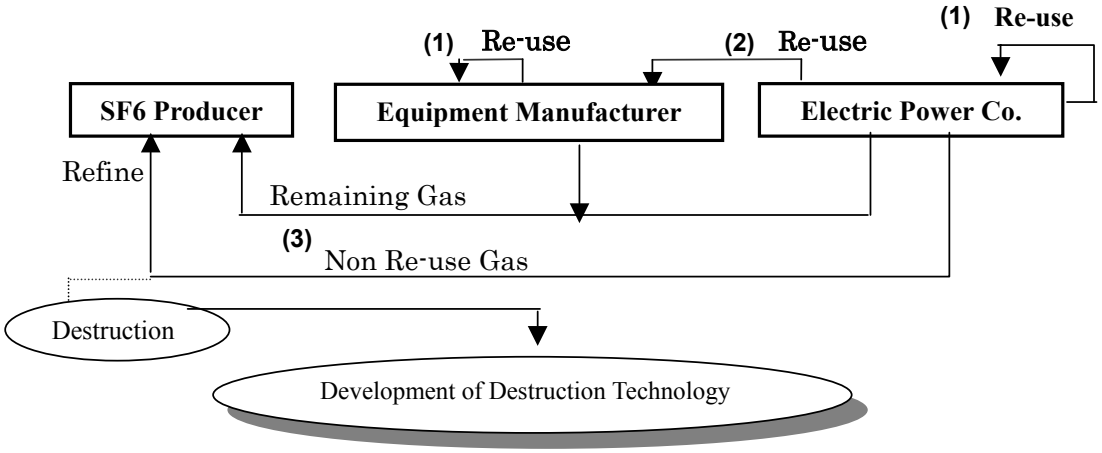

Fig.6-1: *SF_6 recycling flow*

To make efficient gas-recovery operations possible, the following principles should be observed:

1. Recovered SF_6 that meet the required quality control level should be reused by electric power companies and gas-insulated equipment manufacturers.
2. Even when SF_6 recovered from removed equipment satisfies the required quality control level, its reuse in electric power companies is not efficient if the SF_6 is available in large quantities. If this is the case, recovered SF_6 should be brought in to gas insulated equipment manufacturers.
3. If recovered SF_6 fails to reach the required quality control level, the SF_6 should be returned to its producers for refining or destruction.

7. IMPROVEMENT OF INVENTORY SYSTEM

Another joint study among the representatives of the electric power companies, the equipment manufacturers and gas producer was set up to promote the recovery and reuse of SF_6 in electric power industry in Japan in October 1999.

Main issue of the said joint study is as follows.

(1) Efficient use of SF_6 recovery equipment among the electric industry

Electric power companies in Japan set up the plan to purchase the SF_6 recovery equipment for the gas insulated equipment with relatively small SF_6 quantity, which is for example suitable for 110kV GIS. However, Quite a lot of investment could be required if the recovery equipment which can handle the large amount of SF_6 for gas insulated equipment with much SF_6 volume, such as GIS of 300kV and above.

Under such background, electric power companies and equipment manufactures exchange the information relating to the numbers of units and their capability which they possess and share the

information when, where and how long periodical maintenance works will be carried out. By this cooperation, SF_6 recovery can be carried out efficiently without much investment for SF_6 recovery equipment with larger capability.

(2) Brush up the existing inventory system

As a result of the former joint study by Academy, Utilities, equipment manufacturers and gas producer, a concept of SF_6 recycle flow was established. However, standardization of procedure and common understanding for SF_6 handling are strongly required to secure the proper handling. Followings were intensively discussed intensively and common understandings were established.

a. Standardized procedure for SF_6 handling

As far as banking quantity of SF_6 in the equipment is concerned, SF_6 volume on the nameplate of respective gas insulated equipment is used. And as far as SF_6 emission from gas insulated equipment is concerned, the calculated values based on the SF_6 volume and its pressure are basically applied, while mass measuring method can be also applied if measuring equipment is available on site.

In addition, SF_6 quantity is added to the logbook of electric company, when the ownership is transferred, while sometime, the time of commencement of operation was applied.

Standardized slip is applied to all the gas handling work and record the SF_6 quantity including the emission. And responsible organ is nominated at every SF_6 handling works.

b. Standardized measuring method and equipment

Minimum requirement for measuring equipment was specified based on the results of former joint study and all the measuring equipment should be proofread every year. The SF_6 handling report should contain the standardized items such as manufacture, type form, registration number of measuring equipment and date, time, day, ambient temperature, relative humidity and result of measurement.

c. Common understanding for the handling of recycled gas

Followings understanding were established.

i. The electric power company who recovers the SF_6 should basically reuse recovered SF_6 that meets the recycling criteria.
ii. The electric power company who has a larger volume of SF_6 than he could use within the company, should ask the equipment manufacture if excess amount can be utilized or not, to promote the recycling and reuse of SF_6.
iii. SF_6 quantity from electric power company to equipment manufacturer should not exceed 500 kg per manufacture per month.

8. SF_6 EMISSIONS FROM ELECTRIC INDUSTRY IN JAPAN

Based on the aforementioned targets, securing the countermeasure for promoting SF_6 recovery, the amounts of SF_6 emissions by gas insulated equipment were estimated as follows.

Through the implementation of the said measures, the Japan Electrical Manufacturers' Association presumes that it may be possible to reduce the amount of discharge from gas insulated equipment manufacturers to less than one tenth of the current emissions of approximately 400 tons in the future. On the other hand, it is expected that the amount of leakage from the equipment in operation increase because of the growing amount of facilities. As a result, the number of equipment to be inspected and replaced increases which, in turn, creates new factors for increasing gas emissions. Even under such situation, it is considered possible to maintain the electric power companies' current emission level in future by increasing the recovery rate, namely by improving the performance of gas-recovery equipment and increasing the number of such equipment to offset increases in the amount of leakage. Through the implementation of these measures, it becomes possible to reduce the total amount of emissions from both gas-insulated equipment manufacturers and electric power companies as shown in Fig. 8-1.

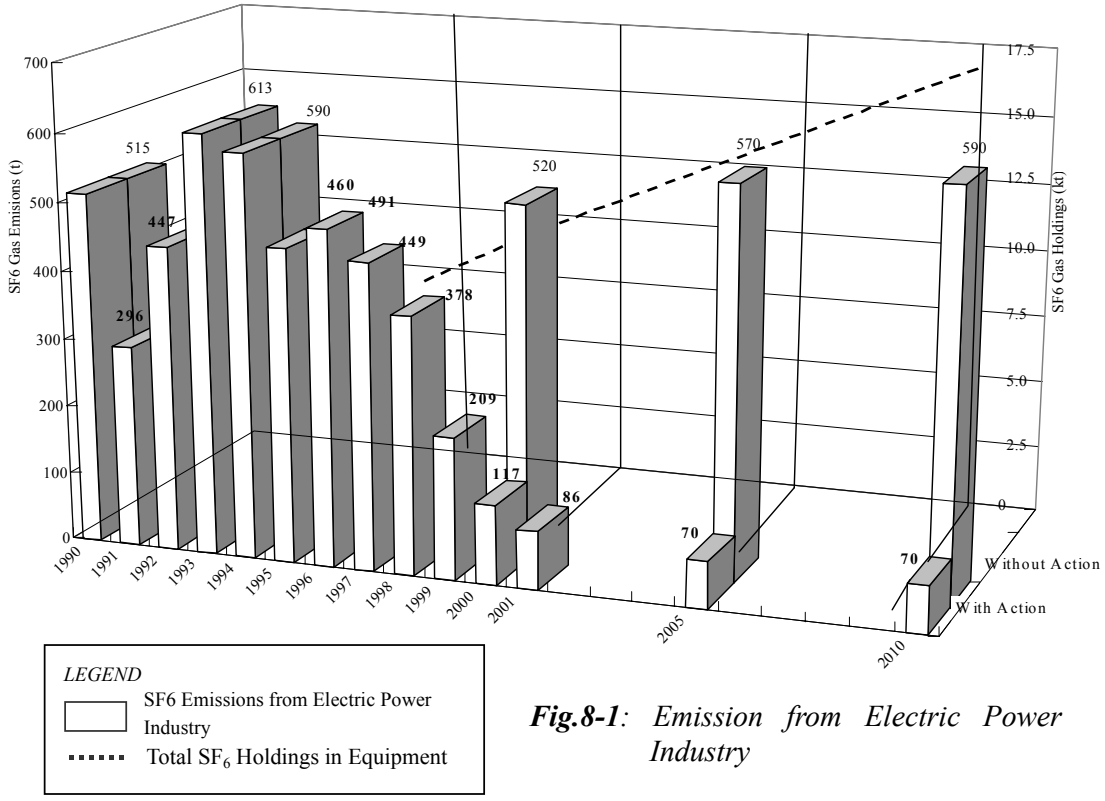

***Fig.8-1**: Emission from Electric Power Industry*

9. SF_6 EMISSION FROM THE OTHER INDUSTRY IN JAPAN

With the implementation of measures, the SF_6 gas production industry has set a quantitative reduction target for emissions of SF_6 as follows:

・Actual 2000 emissions : 23 kg/ton

In addition, it is reported that SF_6 is applied to the Magnesium casting process and approximately 20 tons of SF_6 is used in 1999 by Magnesium industry. However, from the standing point of environmental protection, substitute gas is now being researched and therefore, the quantity of SF_6 used in Magnesium industry will be reduced, thanks to substitute gas and other measures.

10. CLOSE/FUTURE PERSPECTIVE FOR SF_6 EMISSION

By setting up the recovery target, the recycling criteria and the closed recycle system concept, SF_6 emission from 1996 to 2001 was gradually reduced. In the future, we are confident that the further efforts by the continuing cooperation of relevant parties will be made to reduce SF_6 emissions in accordance with the guidelines established by this joint study.