Mr. Eiichi Sugimura , The Federation of Electric Power Companies(FEPC)
TEL: 03-3279-2186, E-MAIL: sugia@fepc.or.jp
Mr. Takanobu Aoyama , The Japan Electrical Manufacturers' Association(JEMA)
TEL: 0294-36-8175, E-MAIL: aoyama-takanobu@mb.jaeps.com

The Situation of Reduction in SF6 Emission from Gas-Insulated Electrical Equipment in Japan

Mr. Eiichi Sugimura , The Federation of Electric Power Companies(FEPC)
Mr. Takanobu Aoyama , The Japan Electrical Manufacturers' Association(JEMA)

ABSTRACT

In Japan during from 1996 to 1998,a joint study for technical standards for handling and recycling of SF6 gas by the representatives of Academy, Utilities, Equipment Manufacturers and Gas Producers under the coordination of the Electric Technology Research Association, and the voluntary action plan about SF6 emission reduction from electrical equipment was settled in 1998 in accordance with the criteria and agreement of the joint study. The emission rate in 2005 is targeted to 3% at manufacture, 3% at maintenance, and 1% at removal in this voluntary action plan, and this achievement is becoming reality by the actions being conducted to control emissions up to now. The emission rate in 2003 is so far decreasing steadily with 6%, 3%, and 2% respectively. This paper describes the contents of the measures of emission control adopted by users and by manufacturers.

1. SITUATION OF SF6 USAGE IN JAPAN

In Japan, since there has been a significant increase in electricity demand, substation equipment is coping with higher voltage and larger capacity ratings, requiring the equipment to be more reliable and compact. It is absolutely necessary to adjust to many demands, include small spaces, very severe environmental conditions such as earthquakes, and pollution. By application of sulfur hexafluoride (SF6) to substation equipment like circuit breakers and switchgears, downsizing remarkably and being more reliable can be achieved to greater degrees than conventional air-insulated substation in virtue of its excellent performance of SF6. Therefore, gas-insulated equipment like gas switchgear (GIS), gas insulated circuit breaker (GCB) and gas insulated transformer (GIT) are being widely and commonly applied because of the fact downsizing of substation equipment, correspond of environment and safety. Particularly in Japan where land acquisition is extremely difficult, there is a large demand for gas-insulated equipment as mentioned above. On the other hand, since SF6 was identified as a greenhouse gas at The 3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change in 1997, electric power companies and equipment manufactures in Japan have been studying countermeasures for limiting the release into the atmosphere. Since an economical solution with alternative measures has not been found yet in spite of great efforts in the concerned field, we have to continue to use SF6 with special considerations. Therefore, consideration and practical actions should be taken to keep SF6 emissions to a minimum so that we can make the best use of gas-insulated equipment.

2. SF6 HOLDING AND EMISSION IN JAPAN (Obtained by Joint Study)

The world's production of SF6 in 1995 was estimated to be approximately 8,500 tons. Some 30% of the total was produced in Japan. SF6 had mainly used for electric insulation by gas-insulated equipment manufacturers. From the results of surveys in Japan conducted by the joint study, on the amounts of SF6 handled by gas producers and gas-insulated equipment manufacturers, the amount of SF6 and the quantity of emissions from 1990 to 1995 are estimated as shown in Fig1.

Mr. Eiichi Sugimura , The Federation of Electric Power Companies(FEPC)
TEL: 03-3279-2186, E-MAIL: sugia@fepc.or.jp
Mr. Takanobu Aoyama , The Japan Electrical Manufacturers' Association(JEMA)
TEL: 0294-36-8175, E-MAIL: aoyama-takanobu@mb.jaeps.com

Generally, since SF6 for electric insulation purposes is used in enclosed vessels, the amount of SF6 holding increases in proportion to the quantity of facilities. According to the survey, the amount of SF6 possessed by the electric power companies had increased by 400 tons to 500tons 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 coming from their production processes and in the course of disposing of residual gas, which remains inside of retuned SF6 cylinders. Emissions at the equipment manufacturers occur in the testing stage both during development and production in the factory as well as during the installation work at the site. Emissions at the electric power companies correspond to the emissions at maintenance stage and removal stage as well as natural leakage from the equipment.

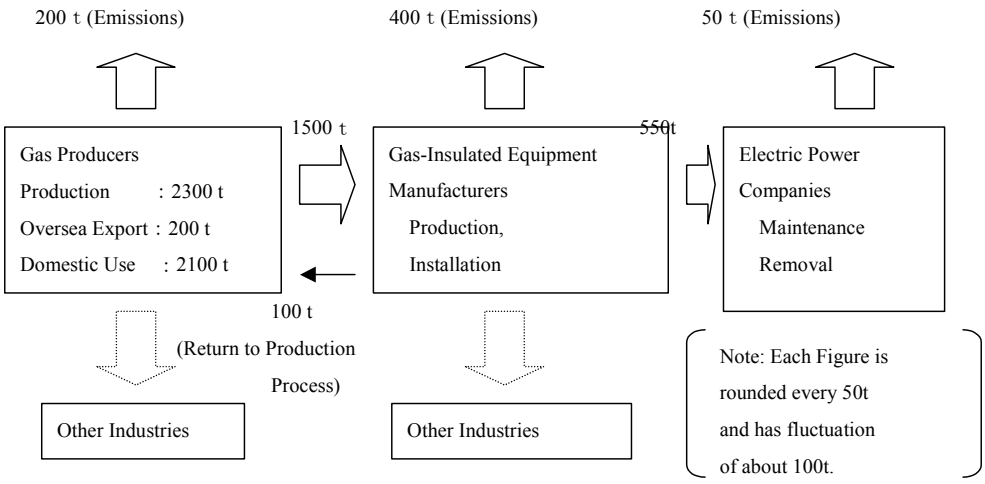

Fig. 1 Outlook of Annual SF6 Usage and Emissions(Average from 1990 to 1995)

3. VOLUNTARY ACTION PLANS OF ELECTRIC INDUSTRY

In 1998, The Federation of Electric Power Companies (FEPC) and Japan Electric Manufacturers' Association (JEMA) announced the voluntary action plan for the reduction of SF6 emissions from electric equipment. Since alternative gases to SF6 gas have not yet been found in spite of

great efforts in the concerned field, the voluntary action plan was issued based on the results of the joint study and the understanding that electric power companies and electric equipment manufactures must make every effort to keep the SF6 emission to minimum in order to continue to make use of gas-insulated equipment.

The items of action plan are as follows:

(1) SF6 emission reduction at development and manufacturing, at maintenance and at removal

Mr. Eiichi Sugimura , The Federation of Electric Power Companies(FEPC)
TEL: 03-3279-2186, E-MAIL: sugia@fepc.or.jp
Mr. Takanobu Aoyama , The Japan Electrical Manufacturers' Association(JEMA)
TEL: 0294-36-8175, E-MAIL: aoyama-takanobu@mb.jaeps.com

(2) Establishment of recycling system

(3) Review the current SF6 inventory system

(4) Development of new technology to minimize the use of SF6 in equipment

4. SET-UP THE RECOVERY GUIDELINE

As a research and conference of the joint study, the recovery goal was set as shown in table 1, which summarizes the current recovery rates and the future target values. The situation and countermeasures of the respective stages from equipment development to removal are as follows:

(1) During Equipment Development Stage

As interrupting tests or switching tests during the development stage generated dissolved gases, SF6 had not been fully recovered until now. However, we did carry out SF6 recycling for standard work and promoted the recovery by applying breathers, filters and the like so as to remove dissolved gases.

(2) During Equipment Manufacturing

Product testing and segment work of transporting parts during manufacturing are the only aspects related to SF6 handling. Though recovery is performed during manufacturing, further efficiency is required.

(3) During Equipment Installation

Length of time required to recover SF6 during equipment installation is lengthened due to the various procedures necessary to maximize the recovery rate, increasing the recovery goal shall be realized by the condition of work process and improvement of handling.

(4) During Maintenance Work

When an internal inspection is performed three procedures are required: the recovery of SF6 before opening the gas compartment, the vacuum up procedure, and the SF6 filling process after the internal inspection are required. When SF6 is recovered to a 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 areas, application of a recovery device with higher efficiency or improving the maintenance condition to extend maintenance intervals are required.

(5) During Equipment Removal

When SF6 gas-insulated equipment is removed, SF6 gas is recovered in the same manner as during maintenance work in order to open the equipment. The application of a recovery device with a higher efficiency rate is again required.

Mr. Eiichi Sugimura , The Federation of Electric Power Companies(FEPC)
TEL: 03-3279-2186, E-MAIL: sugia@fepc.or.jp
Mr. Takanobu Aoyama , The Japan Electrical Manufacturers' Association(JEMA)
TEL: 0294-36-8175, E-MAIL: aoyama-takanobu@mb.jaeps.com

Table 1: Current recovery rates and future gas recovery guidelines

Time	Stage	Recovery terminal pressure		Recovery rate	
		Lower than 110kV	110kV or higher	Lower than 110kV	110kV or higher
Before 1995	During testing	—（No recovery）		—（No recovery）	
	During manufacture	0～0.05Mpa・Gage		Approx.70%	
	During installation	—（No recovery）	0～0.05Mpa・Gage	—（No recovery）	Approx.70%
	During maintenance	—（No recovery）	0～0.05Mpa・Gage	—（No recovery）	Approx.70%
	During maintenance	—（No recovery）		—（No recovery）	
Future (Not Later than 2005)	During testing	0.015Mpa・abs(114Torr) or lower		97% or higher	
	During manufacture				
	During installation				
	During maintenance				
	During maintenance	0. 005Mpa・abs(38Torr) or lower		99% or higher	

(Note: The indicated recovery rates apply to cases where recovery is performed on equipment/facilities with a rated gas pressure of 0.4Mpa・Gage)

5. SF6 GAS QUALITY CRITERIA

Concerning SF6 gas purity, new quality criteria were set up as shown in table 2. These criteria are considered to influence equipment performance by the joint study standing on conventional quality criteria. It will be possible to recycle of SF6 gas.

Mr. Eiichi Sugimura , The Federation of Electric Power Companies(FEPC)
TEL: 03-3279-2186, E-MAIL: sugia@fepc.or.jp
Mr. Takanobu Aoyama , The Japan Electrical Manufacturers' Association(JEMA)
TEL: 0294-36-8175, E-MAIL: aoyama-takanobu@mb.jaeps.com

Table 2: Quality control criteria for SF6 gas

Item		Permissible limits	Criteria
SF6 gas purity		95vol.%	97vol%
Air		(5vol.%)	(3vol%)（including CF4）
Moisture Content	Equipment without current interruption	1000ppm(vol.)	500ppm(vol.)
	Equipment with current interruption	300ppm(vol.)	150ppm(vol.)
Decomposition product・Dissolved gases		—	No color reaction in detecting tube

6. SF6 GAS RECYCLING FLOW

Since gas recycling was required so as to considerably reduce SF6 emissions, the joint study proposed a closed recycling program the SF6 circulation between Utilities, Equipment Manufacturers and Gas Producers. The recycling flow for SF6 is shown in Fig.2.

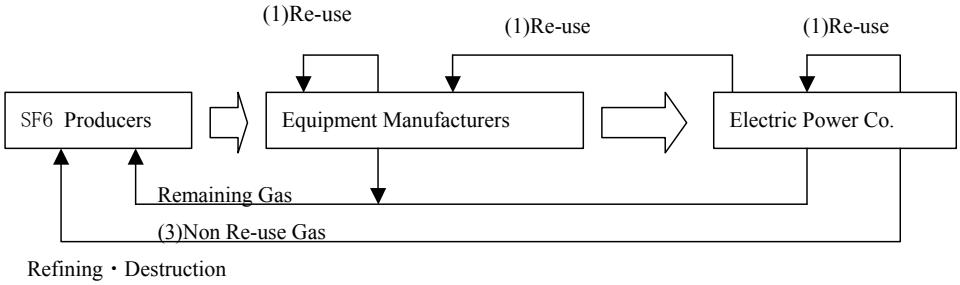

Fig 2: SF6 recycling flow

To make efficient gas-recovery operations possible, and to control the gas inventory system, the following principles should be observed:

1.Recovered SF6 that meets the required quality control level should be reused by electric power companies and gas-insulated equipment manufacturers.
2.Even when SF6 recovered from removed equipment satisfies the required quality control level, its reuse in electric power companies is not efficient if the SF6 is available in large quantities. If this is the case, recovered SF6 should be brought in to gas-insulated equipment manufacturers.

Mr. Eiichi Sugimura , The Federation of Electric Power Companies(FEPC)
TEL: 03-3279-2186, E-MAIL: sugia@fepc.or.jp
Mr. Takanobu Aoyama , The Japan Electrical Manufacturers' Association(JEMA)
TEL: 0294-36-8175, E-MAIL: aoyama-takanobu@mb.jaeps.com

3.If recovered SF6 fails to reach the required quality control level, the SF6 should be returned to its producers for refining or destruction.

7. IMPROVEMENT OF SF6 INVENTORY SYSTEM

As to the SF6 circulation between Utilities, Equipment Manufacturers and Gas Producers, measure and approach of the gas inventory system were proposed by the joint study. In the measure and approach, inventory items and storage parson were desired at the each work of Gas producers, Equipment manufacturers, and Utilities. SF6 gas flow and control centered at Equipment Manufacturers are shown in Fig.3. As gas quantity was grasped on gas delivery, report formats using gas inventory were prepared.

Thereafter, in October 1999 another joint study among the representatives of the electric power companies, the equipment manufacturers and gas producers was set up to promote the recovery and reuse of SF6 in the electric power industry in Japan. As the countermeasure of the recovery and reuse of SF6 were concretely proposed, the reduction of SF6 gas emissions is definitely progressing.

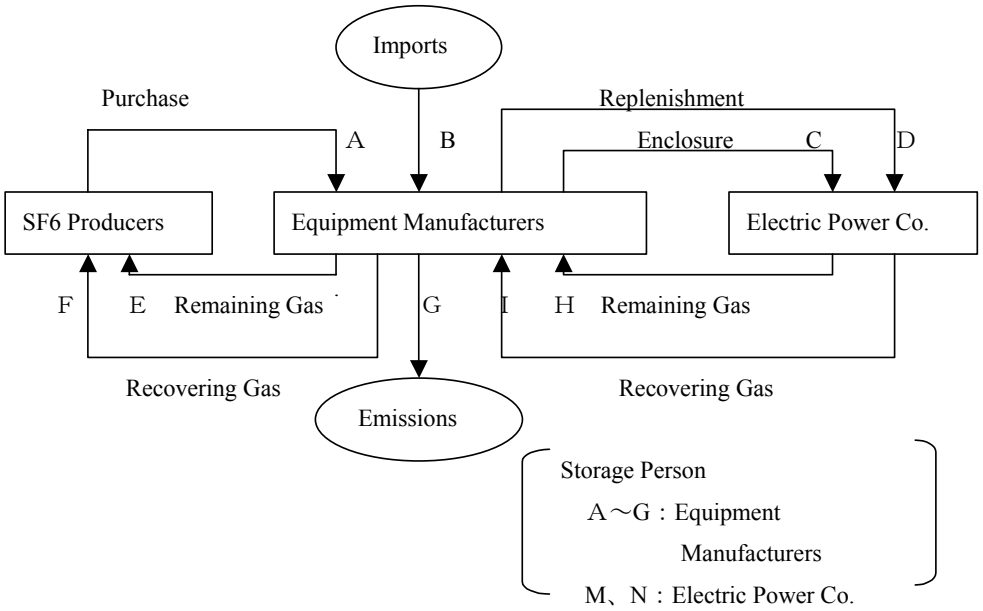

Fig. 3 SF6 flow and control centered on equipment manufacturers

8. SITUATION OF THE VOLUNTARY ACTION PLAN IN ELECTRIC INDUSTRY

According to the voluntary action plans of the Electric Power Companies (FEPC) and the Japan Electric Manufacturers' Association (JEMA), electric power companies and electric equipment manufacturers must make great efforts to reduce SF6 emissions. Based on the aforementioned targets, and securing the countermeasure for promoting SF6 recovery, the amounts of SF6 emitted by gas-insulated equipment were estimated as follows:

The Situation of Reduction in SF6 Emission from Gas-Insulated Electrical Equipment in Japan

Mr. Eiichi Sugimura , The Federation of Electric Power Companies(FEPC)
TEL: 03-3279-2186, E-MAIL: sugia@fepc.or.jp
Mr. Takanobu Aoyama , The Japan Electrical Manufacturers' Association(JEMA)
TEL: 0294-36-8175, E-MAIL: aoyama-takanobu@mb.jaeps.com

Before setting up the voluntary action plan, the Japan Electric Manufacturers' Association presumes that it may be possible to reduce the amount of discharge from gas-insulated equipment
manufactures to less than one tenth of the current emissions of approximately 400 tons on average from 1990 to 1995 in the future. On the other hand, as to increasing facilities, it is expected that the amount of natural leakage, emissions during maintenance and removal from equipment in operation will increase. As a result, the amount of equipment to be inspected and replaced, in turn, creates new factors for increasing gas emissions. Therefore it is indispensable to revel up the recovery rate of SF6, to improve the performance of gas-recovery equipment and to increase the amount of such equipment to offset increases in the amount of leakage. Under such a situation, it is considered possible to maintain the electric power companies' current emission levels in the future. Through the implementation of these measures, it will become possible to reduce the total amount of emissions from both gas-insulated equipment manufacturers and electric power companies. The amount of SF6 emissions from the electric industry until now and its future expectations are shown in Fig.4. The amount of SF6 gas holdings in the electric industry increased 4.3% on average from 6600 tons in 1996 to 8600 tons in 2003. On the other hand, the amount of SF6 gas emissions decreased sharply from 493 tons in 1996 to 50 tons in 2003. Importantly, after setting up the voluntary action plan, the reduction of SF6 emissions progressed greatly due to the implementation of these measures. In addition, the recovery rates are shown in Fig.5, Fig.6. Since the SF6 emission rate was 30% at manufacture and 40% at maintenance before the voluntary action plan, its rate in 2003 is so far progressing steadily at 6%, 3%, and 2% respectively. This achievement is becoming reality by the actions being conducted for the control of emissions up to now.

Mr. Eiichi Sugimura , The Federation of Electric Power Companies(FEPC)
TEL: 03-3279-2186, E-MAIL: sugia@fepc.or.jp
Mr. Takanobu Aoyama , The Japan Electrical Manufacturers' Association(JEMA)
TEL: 0294-36-8175, E-MAIL: aoyama-takanobu@mb.jaeps.com

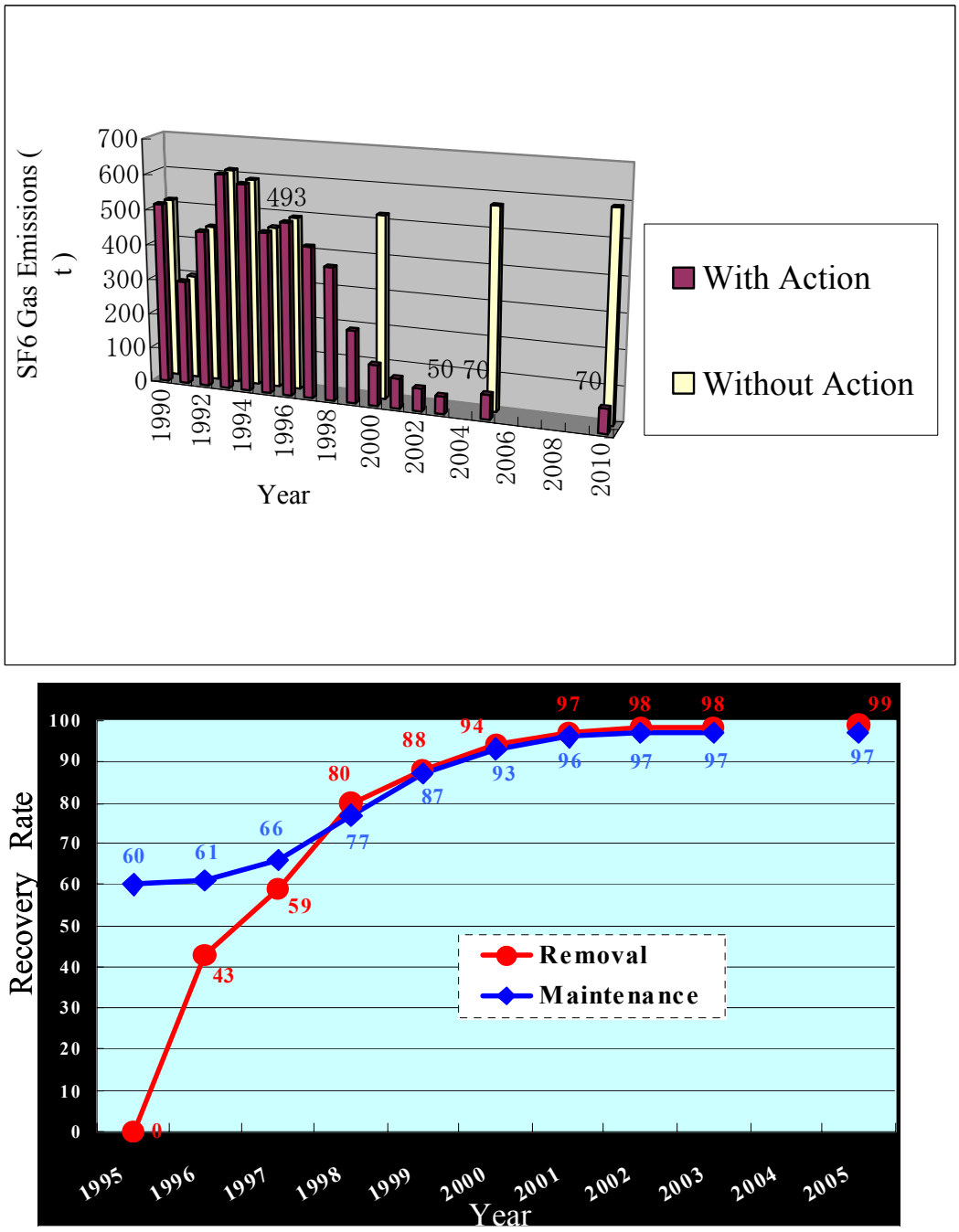

Fig.5 Recovery Rate from Equipment by Electric Power Companies

Mr. Eiichi Sugimura , The Federation of Electric Power Companies(FEPC)
TEL: 03-3279-2186, E-MAIL: sugia@fepc.or.jp
Mr. Takanobu Aoyama , The Japan Electrical Manufacturers' Association(JEMA)
TEL: 0294-36-8175, E-MAIL: aoyama-takanobu@mb.jaeps.com

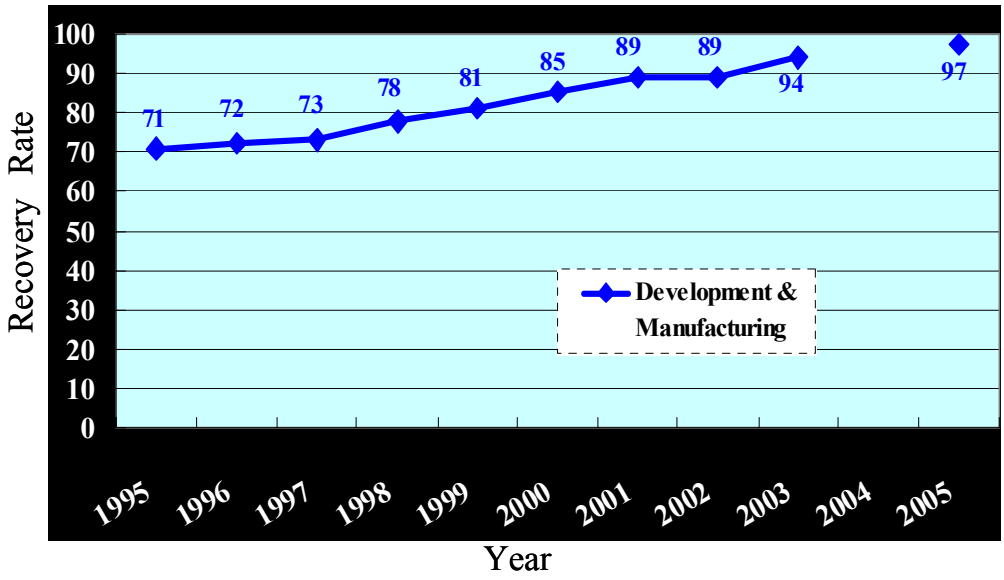

Fig.6 Recovery Rate by Equipment Manufacturers

9. CLOSE/FUTURE PERSPECTIVE FOR SF6 EMISSION

In Japan, a joint study for the objective of the reduction of SF6 gas emission by the representatives of Academies, Utilities, Equipment Manufacturers and Gas Producers was conducted, and settled handling criteria, considered safety factors, and enabled recycling. By setting up the recovery target of the voluntary action plan, the recycling criteria and the closed recycle system concept, SF6 emissions from 1996 to 2003 were sharply reduced. This achievement is becoming reality by the actions being conducted to control emissions up to now. In the future, we are confident that the further efforts and the continuing cooperation of the relevant parties will allow for the reduction of SF6 emissions in accordance with the guidelines established by this joint study.

REFERENCES

1. M.Meguro and S.Maruyama, SF6 emission reduction from gas insulated electrical equipment in Japan; USEPA conference at San Diego, November (2000).
2. H.Yasutake and M.Meguro, SF6 emission reduction from gas insulated electrical equipment in Japan; USEPA conference at San Diago, November (2002).
3. Committee for criteria of SF6 gas handling for electric industry, Report of Electric Technology Research Association, Volume 54, No.3.