The Situation of Reduction in SF$_6$ Emissions from Gas-insulated Electrical Equipment In Japan

The Federation of Electric Power Companies
The Japan Electrical Manufacturers’ Association
Japan
Contents

• Joint study
• Voluntary Action Plan
• Emission Reduction Activity from 1998
• Future Perspective for SF$_6$ Emissions
Contents

• Joint study
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• Future Perspective for SF₆ Emissions
Joint Study on SF₆

Academic (Universities in Japan)

Electric Power Companies

Electric Equipment Manufacturers

Gas Producers

Electric Technology Research Association

Purpose
Technical standards for handling and recycling of SF₆ gas

Period
From 1996 to 1998
Joint Study on SF$_6$

- **Actual Usage in Japan**
  - Total SF$_6$ amount for Electric Industry
  - Actual Emissions within Electric Industry

- **Investigation on site**
  - Gas Leakage Rate
  - Gas Purity & Humidity
  - Decomposition Product

- **Requirements for Reused SF$_6$**
Averaged SF$_6$ Balance Sheet In Japan (From 1990 to 1995)

200t (emissions)

Gas Producers
Production: 2,300tons
Overseas Exports: 200tons
Domestic Use: 2,100tons

1,500t

Equipment Manufacturers

50t (emissions)

Electric Power Companies

550t

400t (emissions)

100t (Return)

Other Industries

Other Industries
## Actual Emissions at Electric Power Companies

*up to 1995*

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>Maintenance</th>
<th>Removal</th>
<th>Leakage</th>
</tr>
</thead>
<tbody>
<tr>
<td>110kV or higher</td>
<td>Recovery down to 0.05 MPa(gage)</td>
<td>Fully released</td>
<td>0.1%/year</td>
</tr>
<tr>
<td>Lower than 110kV</td>
<td>Fully released</td>
<td>Fully released</td>
<td></td>
</tr>
</tbody>
</table>
Investigation on site
(300 points on 40 Circuit Breakers in operation)

<table>
<thead>
<tr>
<th>Leakage Rate</th>
<th>[g/m·year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Leakage from O-ring</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Purity</th>
<th>Above 98.7 vol%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity</td>
<td>Below 118 volppm</td>
</tr>
<tr>
<td>Decomposition Products</td>
<td>Not detected</td>
</tr>
</tbody>
</table>

The detectable levels of measurement are HF>0.25volppm, SO2>0.05volppm, SOF2>10volppm and SO2F2>10volppm

Below 0.1%/year

1%/year

0.1%/year

0.01%/year

Gas Volume per O-ring Length

Below 0.1% year

0.1% year

1% year

[Graph showing leakage rates and measurements]
## Recovery Targets

<table>
<thead>
<tr>
<th>Item</th>
<th>Recovery terminal pressure</th>
<th>Recovery rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower than 110 kV</td>
<td>110 kV or higher</td>
</tr>
<tr>
<td></td>
<td>Lower than 110 kV</td>
<td>110 kV or higher</td>
</tr>
<tr>
<td><strong>Before 1995</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>During testing</td>
<td>No Recovery</td>
<td>No Recovery</td>
</tr>
<tr>
<td>During manufacturing</td>
<td>0 - 0.05 MPa·G</td>
<td>Approx. 70%</td>
</tr>
<tr>
<td>During installation/maintenance</td>
<td>No Recovery</td>
<td>0 - 0.05 MPa·G</td>
</tr>
<tr>
<td>During removal</td>
<td>No Recovery</td>
<td>No Recovery</td>
</tr>
<tr>
<td><strong>In the future (from 2005 onward)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>During testing/Manufacturing/Installation</td>
<td>0.015 MPa·abs (114 Torr) or lower</td>
<td>97% or higher</td>
</tr>
<tr>
<td>During removal</td>
<td>0.005 MPa·abs (38 Torr) or lower</td>
<td>99% or higher</td>
</tr>
</tbody>
</table>
# Quality criteria for Recycle SF₆

<table>
<thead>
<tr>
<th>Item</th>
<th>Permissible limits</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SF₆ gas purity</strong></td>
<td>95 vol. %</td>
<td>97 vol. %</td>
</tr>
<tr>
<td>Air</td>
<td>(5 vol. %)</td>
<td>(3vol. %) includingCF₄</td>
</tr>
<tr>
<td>Water content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment without Current Interruption</td>
<td>1000 ppm (vol.)</td>
<td>500 ppm (vol.)</td>
</tr>
<tr>
<td>Equipment with Current Interruption</td>
<td>300 ppm (vol.)</td>
<td>150 ppm (vol.)</td>
</tr>
<tr>
<td>Dissolved gases/decomposition products</td>
<td>-</td>
<td>No color reaction in detecting tube</td>
</tr>
</tbody>
</table>

**To be Reused**
SF₆ Recycling flow & Standard

- SF₆ Producers
- Equipment Manufacturers
- Electric Power Co.

- Remaining Gas
- Non Re-use Gas

Recycling and Destruction

Recycle Standard

<table>
<thead>
<tr>
<th>Requirement for Reused SF₆</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purity                    : 97vol%</td>
</tr>
<tr>
<td>Humidity                  : 150volppm</td>
</tr>
<tr>
<td>Decomposition Products    : Not Detected</td>
</tr>
</tbody>
</table>
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Organizations of Utilities and Manufacturers (FEPC) (JEMA)

The Voluntary Action plan in April 1998

Administrative Organizations

ME

MITI

Electric Technology Research Association

Recommend SF₆ Recycling Guide

Target of Recovery Rate

<table>
<thead>
<tr>
<th>During Manufacturing</th>
<th>During Maintenance</th>
<th>During Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>97%</td>
<td>97%</td>
<td>1%</td>
</tr>
</tbody>
</table>

ME : Ministry of Environment
MITI : Ministry of International Trade and Industry
Voluntary Actions  
by Electric Power Companies

Target of Recovery Rate

- **Usage (During Maintenance Work)**
  - 1990 – 1995: 60%  >>  by 2000: 90%
  - by 2005: 97%

- **Disposal (During Removal Work)**
  - 1990 – 1995: 0%  >>  by 2005: 99%
Voluntary Actions
by Equipment Manufacturers

Target of Recovery Rate (Manufacturing)
• 1990 – 1995  70% >> by 2000  85%
  by 2005  97%

Target of Gas Recovery & Usage
• Development of High Performance Gas Handling Equipment
• Development of Compact Gas-Insulated Equipment With Minimum SF₆ gas
Voluntary Actions by the Concerned Parties

- **Imports**
  - Purchase
  - A
  - B

- **Equipment Manufacturers**
  - C
  - D
  - Enclosure
  - E
  - F

- **SF₆ Producers**
  - G
  - H
  - Remaining Gas

- **Electric Power Co.**
  - I
  - Remaining Gas
  - Recovering Gas

- **Emissions**

**Industries Storing SF₆**
- A～G : Equipment Manufacturers
- M, N : Electric Power Co.
Recovery Rate from Equipment by Electric Power Companies

Year: 1995-2005

- **Recovery Rate**
- **Removal**
- **Maintenance**

Data Points:
- 1995: 0%
- 1996: 61%
- 1997: 66%
- 1998: 59%
- 1999: 77%
- 2000: 87%
- 2001: 93%
- 2002: 96%
- 2003: 97%
- 2004: 97%
- 2005: 99%
Recovery Rate by Equipment Manufacturers

Year

Recovery Rate


0 10 20 30 40 50 60 70 80 90 100

Development & Manufacturing

Recovery Rate


0 10 20 30 40 50 60 70 80 90 100

Development & Manufacturing
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Transition of Gas-recovery Equipment

Standardized Workflow of SF₆ handling

Gas-recovery Equipment
Improvement of Inventory system

- **Efficient use of SF$_6$ recovery equipment**
  - Share large-capacity recovery equipment among the electric companies
  - Coordinate the maintenance work schedule

- **Brush up the existing inventory system**
  - Standardized procedure for SF$_6$ handling
  - Standardized measuring method and equipment
  - Share the common understanding for recycle SF$_6$ handling
## SF₆ Inventory by Standardized work slip

- **Work slip for**
  - Initial Filling
  - Handling at maintenance
  - Recovery at Equipment disposal
  - Return to SF₆ producer
  - SF₆ disposal at gas producer
  - Remaining SF₆ in Container

###SF₆ Handling Volume

<table>
<thead>
<tr>
<th>Substation/Place</th>
<th>Date of Work</th>
<th>Design SF₆ Volume (kg)</th>
<th>Volume of gas compartment (m³)</th>
<th>Gas pressure before work (Mpa gage)</th>
<th>Gas pressure after work (Mpa gage)</th>
<th>Recovery terminal pressure (Mpa abs.)</th>
</tr>
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###Returned volume to Gas Manufacturer

<table>
<thead>
<tr>
<th>Name of Company (Retainer)</th>
<th>Date when SF₆ was recovered</th>
<th>Quantity</th>
<th>Remaining SF₆ volume (kg)</th>
<th>Classification of returned SF₆</th>
<th>Conform to Criteria / Non-conform to Criteria</th>
</tr>
</thead>
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###Banking volume at New installation & extention

<table>
<thead>
<tr>
<th>Type of Work</th>
<th>New installation/Extention/Others</th>
<th>Type of Unit</th>
<th>Unit No.</th>
<th>Typeform</th>
<th>Rated gas pressure (Mpa gage)</th>
<th>Ambient Temp. (degC)</th>
<th>Humidity (%)</th>
<th>Purity (Vol%)</th>
<th>Water Contents (Volppm)</th>
<th>Dissolved gas (HF) (Volppm)</th>
<th>Measuring Date</th>
<th>Type of Equipment</th>
<th>Measuring Instrument</th>
<th>Reg. No.</th>
<th>Measuring Values</th>
<th>Date</th>
<th>Ambient Temp. (degC)</th>
<th>RH/Humidity (%)</th>
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###Remarks:

- 50kg cylinder x _________(quantity)
- No. of Spare SF₆ container
- Returned SF₆ to OEM (in case of Non-comform SF₆)
- No notes/Remarks
- SO₂ Dissolved Gas (Vol%)
Compact Gas-Insulated Equipment
(550kV Circuit Breaker)

550kV GCB
4 break
SF₆ / phase:
1900kg

2 break
1000kg

1 break
850kg
SF₆ Recycling (240kV Hybrid GIS)

Existing GIS  ➔  Re-formed GIS

All remaining SF₆ gas was re-used.
New SF6 gas was added for replenishment.
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Estimation of \( \text{SF}_6 \) Emission from Electric Power Industry
Thank you for your attention