SF_6 Nameplate Inaccuracies Impact on Greenhouse Gas Reporting

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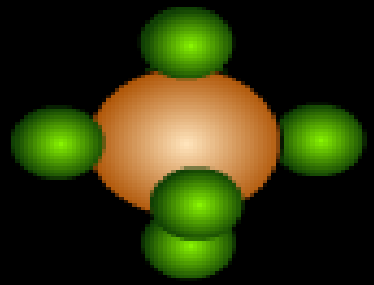
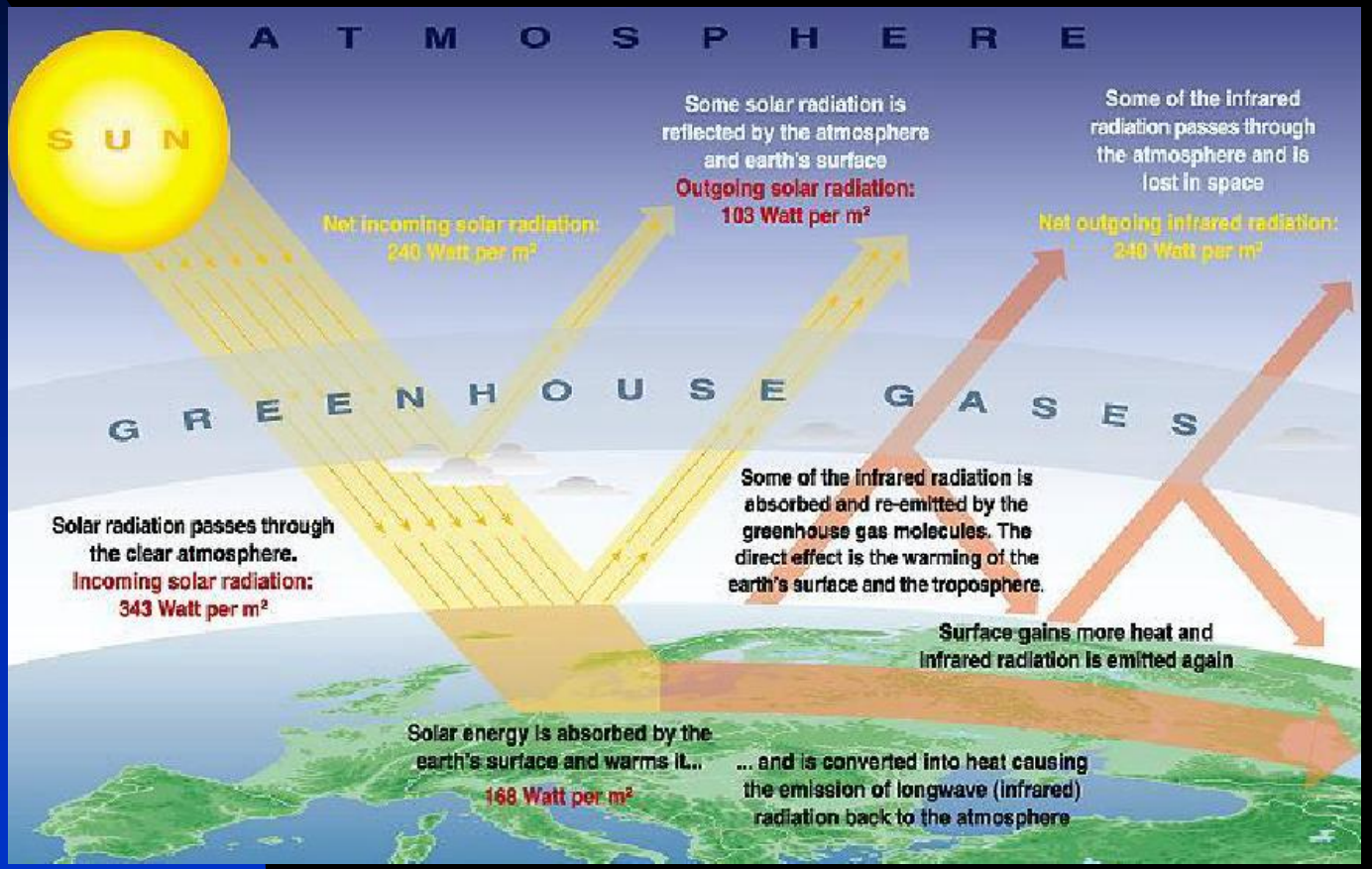
EPA SF6 Workshop
Long Beach, CA
May 7, 2014



Topics of Discussion

- General Information
- Mandatory Greenhouse Gas Reporting Rule
- Possible Reasons for Nameplate Inaccuracies
- Eliminating Emissions
- Determining Exact amount of SF_6 in any Vessel

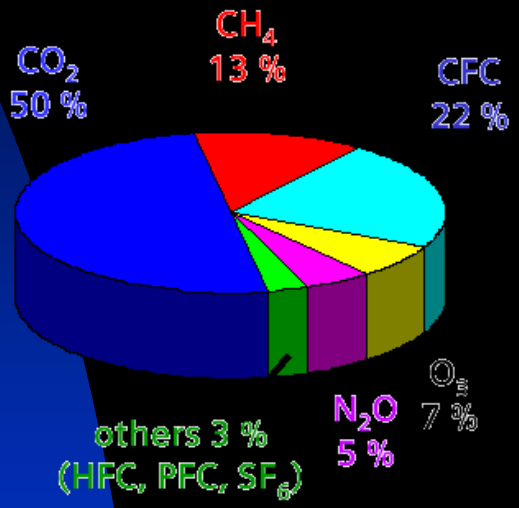
Environmental Considerations



Environmental Considerations
GHG Comparison

Compound	Atmospheric Lifetime (Years)	Global Warming Potential (100-year time horizon)*
CO_2	200	1
CH_4	12	21
HFC-134a	14.6	1,300
CF_4	50,000	6,500
SF_6	3,200	**23,900**

Environmental Considerations GHG Emissions



Contribution of various gases to the greenhouse effect

(Source: BMU, Kyoto summit on climate change 1997)

Kyoto summit on climate change:

- *1st group of greenhouse gases:*
  - **Carbon dioxide (CO_2)** from burning of fossil fuels
  - **Methane (CH_4)** from intensive cattle farming
  - **Dinitrogen monoxide (N_2O)** from nitrogen fertilization
- *2nd group of greenhouse gases:*
  - **Hydrofluor carbons (HFC)**
  - **Perfluor carbons (PFC)**
  - **Sulfur hexafluoride (SF_6)**

Reduction of the emission in Europe: 8 % (basis 1990/95) until 2010

Environmental Regulations

- Mandatory Greenhouse Gas Reporting Rule (40 CFR Part 98) Subpart DD (Users of Electrical Equipment) Subpart SS (OEM's)
- USEPA Requires users with at least 17,820 lbs nameplate capacity to report emissions annually
- Certain States have similar mandatory reporting requirements
  - CA (Air Resources Board)
  - MA (Proposed)

State of California / CARB

- Establishes an annual maximum emission rate at 10% of nameplate capacity
- Requires GIE owners to reduce their annual emission rate by 1% per year over a ten year period from 2011 to 2020
- Beginning in 2020, sets maximum emission rate not to exceed 1%

Mass Balance Equation

- User Emissions = (Decrease in Storage Inventory) + (Acquisitions) – (Disbursements) – (Net increase in Total Nameplate Capacity of Equipment Operated)
- *Nameplate capacity refers to the full and proper charge of equipment, in pounds (lbs) of SF_6, rather than actual charge, which may (amongst other things) reflect leakage*

Under / Over Estimation

- Underestimation
  - True value is 300 lbs / Nameplate is 280 lbs = Negative emission of 20 lbs
- Overestimation
  - True value is 280 lbs / Nameplate is 300 lbs = “Phantom Emission” of 20 lbs

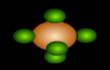
Anecdotal evidence suggests that a large percentage of GIE will fall into either of the above categories

Incorrect Nameplate?

- SF_6 Leakage from GIE
- GIE Under/Over filled
- SF_6 Emission during Recovery
- GIE Inaccurate Nameplate

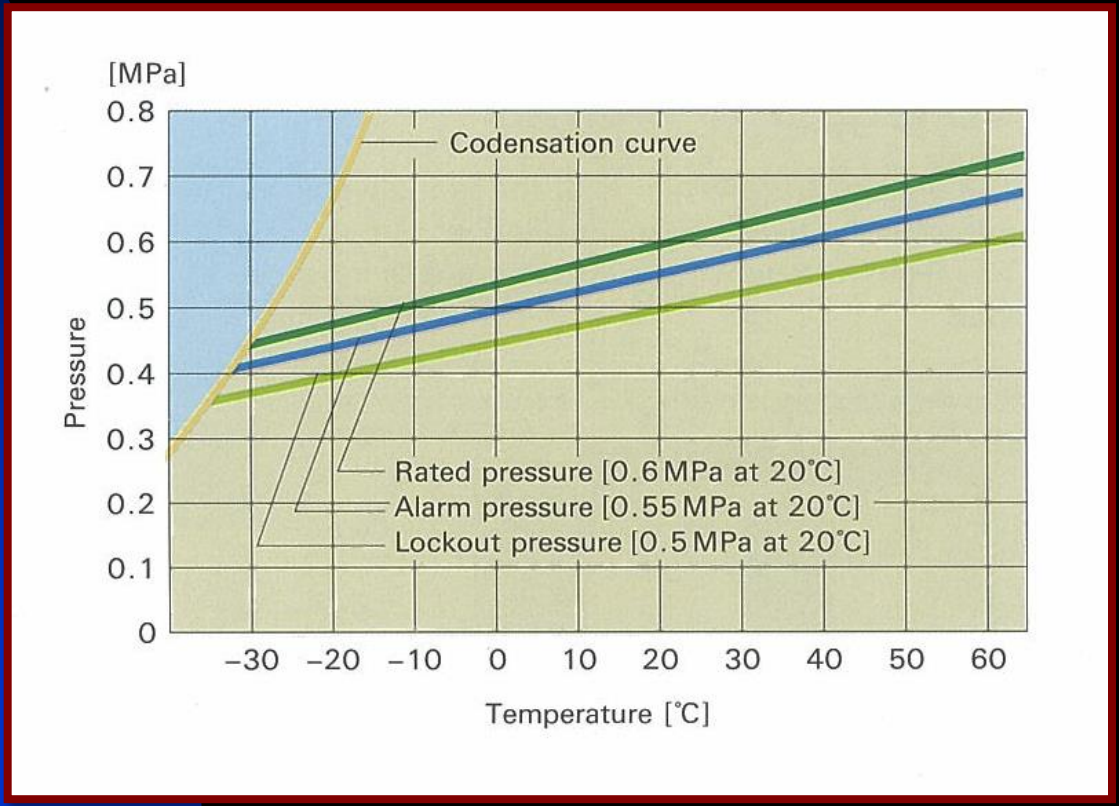
SF_6 Leakage from GIE

- Leakage will result in GIE containing lower amount of SF_6 compared to nameplate
- Actual leak will/should be reported as emission
- Will create issue if user isn't aware of leak
  - Slow leak on large volume vessel
  - Leak hasn't resulted in noticeable pressure drop or low pressure alarm



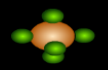
Under/Over Fill

- GIE is generally filled using temperature/pressure curve



Under/Over Fill

- Accidental or Intentional (Over Fill Only)
- Any deviation of temperature/pressure reading will lead to discrepancy
  - Example: Vessel containing 200 lbs @ 87 PSIG – if originally only filled to 85 PSIG = 4 lbs Phantom Emission.
- Result of inaccurate temperature or pressure measurement
- Direct vs Equipment assisted fill

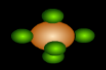


Direct vs Equipment Assisted Filling

- GIE is filled either directly from cylinders or through Recovery System that may contain heaters/evaporators
- Operators utilizing GIE OEM temperature/pressure curve generally assume ambient = gas temperature
- Controlled tests using the following equipment:
  - 1,000 l ASME Pressure Tank
  - Precision Pressure Gauge K040R13
  - Mass flow scale B152R41
  - Cylinder weighing scale D-230-R002

Filling Procedure

- 1,000 l tank filled to 80 PSIG
- Filling directly from cylinder required 88.97 lbs SF_6 gas
  - Heat loss during vaporization
  - Temperatures < 25 F possible
- Filling through heater/evaporator required 87.50 lbs SF_6 gas
  - Gas temperature 90 F
- Alternate equipment use resulted potential phantom emission of 1.47 lbs / 1.66 %



Measuring / Weighing Issues

- Weight Scale Inaccuracies
  - Use Weight Scales with specified accuracy and calibrate at required intervals
- Residual Recovery System Pressure
  - Utilize Mass Flow Scales at GIE
- Incorrect Cylinder TW Stamps
  - Weigh and re-stamp empties during re-test

Residual Recovery System Pressure

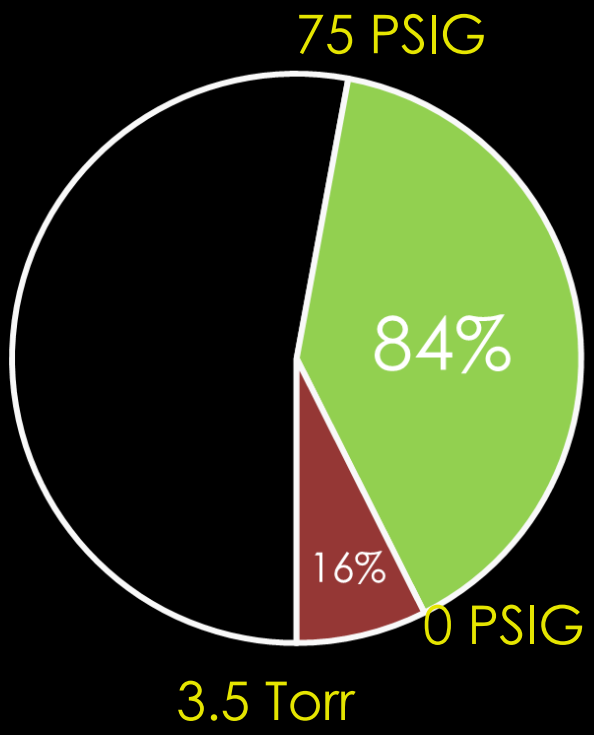
Measuring / Weighing Issues

- Gauges without displayed value
  - Requires external gauge for exact/accurate measurement
  - Commonly used on HV and MV Equipment
  - Gauges providing PSIG / bar / kPa reading preferred

SF_6 Recovery Emission

- Failure to reach an acceptable blank off pressure (Recovery System limitation or operator error) will result in SF_6 emission
- Resulting emission easy to calculate
- Recommended blank off pressure 3.5 Torr / mmHg minimum
  - Guarantees > 99.9% SF_6 Recovery

SF_6 Recovery Emission Residual Pressure



SF_6 Recovery Emission Determining Recovery %

- Circuit breaker containing 200 lbs of SF_6 @ 80 PSIG
- Blank-off pressure 3.5 Torr
  - 99.93% recovery / SF_6 emission = 0.14 lbs
- Blank-off pressure 200 Torr
  - 95.92% recovery / SF_6 emission = 8.16 lbs

$$\left(\frac{P_I - P_F}{P_I}\right) \times 100 = \%recovered$$

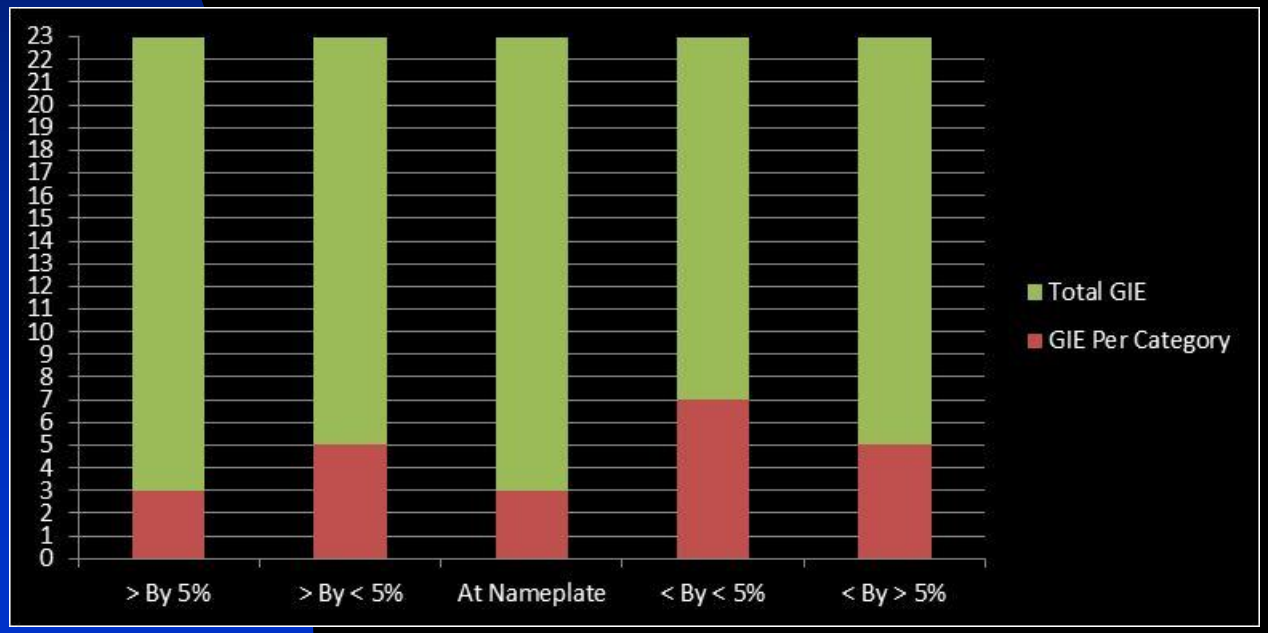
P_I = Initial breaker pressure in mmHg(absolute)
P_F = Final breaker pressure in mmHg(absolute)

Verifying Nameplate Test Subjects

- Sample group 23 HV Circuit Breakers
  - Temperature/Pressure deviation < 1%
  - Non leaking
    - > 2 years in service w/o top off
    - Verified by blanking off < 1 Torr and performing raise test
  - OEM Specified Nameplate capacity
  - Minimum Nameplate capacity 25 lbs

Inaccurate Nameplate

- Under/Over Fill, Leakage, Recovery Emission were all eliminated for testing
- Possible reasons for wrong nameplate:
- Inaccurate calculation / measurement
- Design change affecting internal volume
- Human error



Determine Exact SF_6 Weight

- Variables needed:
  - Initial System Pressure / PI - a
  - Final System Pressure / PF - b
  - Amount (in lbs) of SF6 Recovered - c
- Formula:

$$\left(\frac{a-b}{a}\right) \times 100 = \%\ recovered\ (y)$$

$$\frac{c \times 100}{y} = lbs\ of\ SF_6$$

Required Equipment

- Precision gauge, mass flow scale, compressor, sample cylinder
- Recovery < 2 lbs or 2 PSIG
- 15 min per GIE – Equipment to be de-energized
- Temperature Irrelevant

Conclusions / Recommendations

- Discrepancies in installed GIE highly likely
- Actual discrepancies > 1% very likely the norm
- Current data (Emission rate compared to Nameplate) questionable at best
- Entities required to report need ability to correct baseline numbers
- Convert all SF6 handling (Receiving, filling/top off) to True Mass Monitoring
- Check Temperature/Pressure before degassing
- Retest cylinders to include accurate TW stamps

Questions?

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