Questions & Misconceptions about GIS SF6 Gas & Systems

K6 GIS Users Groups

IEEE
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How does a manufacturer/user view these ratings?

Rated 60Hz Withstand Voltage (kV, rms)

At rated pressure_____

At Minimum functional pressure_____

At 0 psig_____

Impulse Withstand Voltage 1.2/50µs (kV, rms)

At rated pressure_____

At Minimum functional pressure_____

At 0 psig_____

Switching Surge Withstand Voltage (kV, rms)

At rated pressure_____

At Minimum functional pressure_____

At 0 psig_____

What misconceptions could these ratings cause?

Do ratings such as these confuse the response to gas alarms?

C37.122 Table 1-Rated insulation values:

Rated max. voltage V (U_r) kV rms	Rated power frequency withstand voltage U_d kV rms		Rated switching impulse withstand Voltage U_s kV peak			Rated lightning impulse withstand voltage U_p kV peak		
	Test levels	Disconnect Switch Open Gap	Test levels (phase to ground)	Test levels (phase to phase)	Disconnect Switch Open Gap (+ bias)	Test levels	Disconnect Switch Open Gap	Disconnect Switch Open Gap (+ bias)
72.5	140	160				325	375	
100	185	210				450	520	
123	230	265				550	630	
145	275	315				650	750	
170	325	375				750	860	
245[a]	425	490				900	1035	

C37.100.1 Common Requirements for High-Voltage Power Switchgear:

6.2.3 …For switchgear using compressed gas for insulation, dielectric tests shall be performed at minimum functional pressure (density) for insulation as specified by the manufacturer. The temperature and pressure of the gas during the tests shall be noted and recorded in the test report….

Minimum Functional Pressure definition (from C37.122)

Minimum functional pressure p_{me} (or density ρ_{me}): Insulation and/or switching pressure at and above which rated characteristics of switchgear are maintained.

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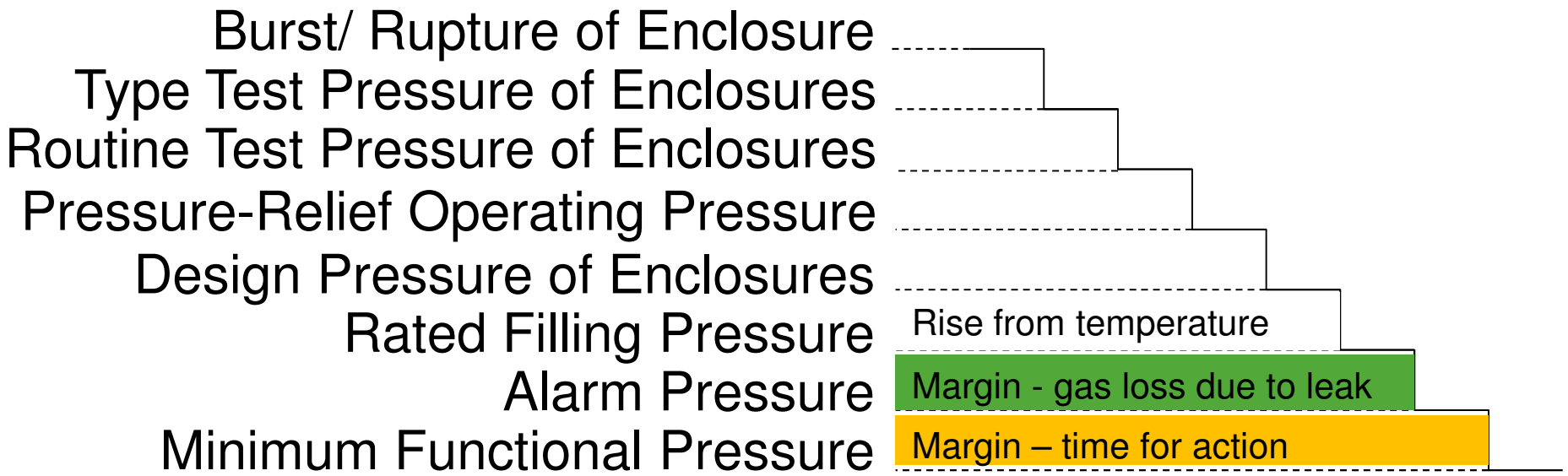
Do ratings such as these confuse the response to gas alarms?

What is done upon receiving a gas alarm on a CB or GIS?

a) Is the response different if the alarm is coming from a CB or other vs. another zone?

b) Is the response procedure different for a Minimum gas alarm?

Pressure coordination of enclosures & pressure relief devices



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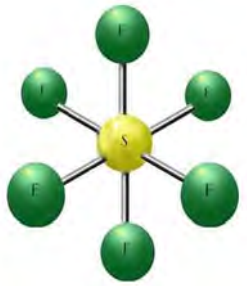
Moisture in SF6

How does an OEM or User measure moisture in SF6 during Installation and In-service?

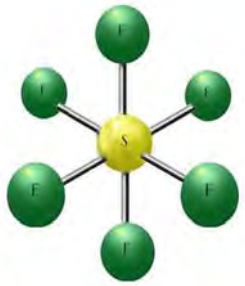
SF6 gas properties



9. Physical and Chemical Properties	
APPEARANCE:	Colorless gas
ODOR:	Irritating choking
ODOR THRESHOLD:	Not available.
PHYSICAL STATE:	Gas at normal temperature and pressure
pH:	Not applicable.
MELTING POINT at 1 atm:	-59°F (-50.7°C)
BOILING POINT at 1 atm:	Sublimes at -83°F (-63.9°C)
FLASH POINT (test method):	Not applicable.
EVAPORATION RATE (Butyl Acetate = 1):	Not available.
FLAMMABILITY:	Nonflammable
FLAMMABLE LIMITS IN AIR, % by volume:	**LOWER:** Not applicable. **UPPER:** Not applicable.
VAPOR PRESSURE at 70°F (21.1°C):	334.7 psia (2308 kPa abs)
VAPOR DENSITY at 70°F (21.1°C) and 1 atm:	0.3776 lb/ft^3 (6.049 kg/m^3)
SPECIFIC GRAVITY (H_2O = 1) at 19.4°F (-7°C):	Not available.
SPECIFIC GRAVITY (Air = 1) at 68°F (20°C) and 1 atm:	5.04
SOLUBILITY IN WATER 68°F (20°C):	Negligible
PARTITION COEFFICIENT: n-octanol/water:	Not available.
AUTOIGNITION TEMPERATURE:	32°F (0°C)
DECOMPOSITION TEMPERATURE:	Not available
PERCENT VOLATILES BY VOLUME:	100
MOLECULAR WEIGHT:	146.05
MOLECULAR FORMULA:	SF_6

Source: praxair.com

Typical SF6 gas supplied in cylinders



Transportation Information

UN Number: 1080

	United States of America	Canada	Mexico
Shipping Name	Sulfur Hexafluoride	Sulfur Hexafluoride	Sulfur Hexafluoride
Hazard Class	2.2	2.2	2.2
Label	Nonflammable Gas	Nonflammable Gas	Nonflammable Gas

Formula

SF_6

MSDS Reference

P-4657

CAS Number

2551 - 62 - 4

General Description

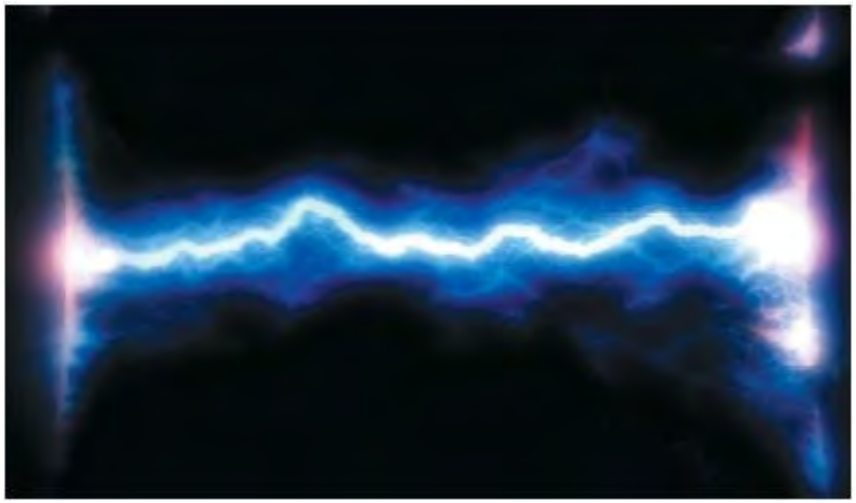
Colorless, odorless, nonflammable, liquified gas.

SH 3.0	3.0	99.9% H_2O < 0.65 ppm/w Air as Nitrogen < 400 ppm/w Acidity (HF) < 0.3 ppm/w CF_4 < 400 ppm/w Oil < 5 ppm/w	K	115 lb/52.2 kg	3000 Series: Non-corrosive 2000 Series: Non-corrosive

Source: praxair.com

Why do we care about moisture in SF6?

Moisture (particularly in the liquid stage) affects dielectric withstand strength of GIS.



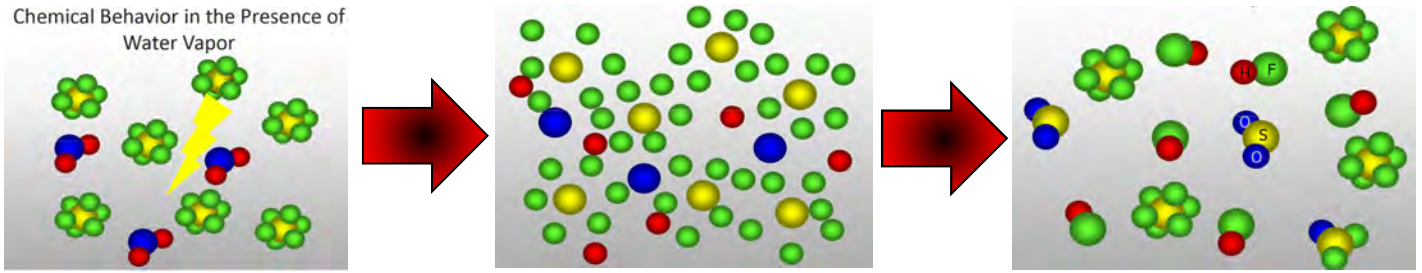
Why do we care about moisture in SF6?

Chemical Behavior in the Presence of Water Vapor

- SF_6 decomposition products combine with water to form secondary products

$$SF_6 + H_2O \longrightarrow 2\ HF + SOF_2 + 2\ F$$

- Hydrofluoric Acid (HF) is a highly corrosive substance that attacks glass and porcelain



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Standards:

WG K8: IEEE Std. C37.122.5 (prev. P1125): Guide for Moisture Measurement and Control in SF6

Other common reference standards:

IEEE Std. C37.122.3 (prev. P1712): Guide for Sulfur Hexafluoride (SF6) Gas Handling for High Voltage (over 1000 Vac) Equipment

IEC 60376: Specification of Technical Grade Sulfur Hexafluoride (SF6) for use in Electrical Equipment

IEC 60480: Guidelines for the Checking and Treatment of Sulfur Hexafluoride (SF6) taken from Electrical Equipment and Specification for its Re-use

IEC 62271-1: High-voltage switchgear and control gear - Part 1 - Common specifications.

CIGRE Brochure No. 276: Guide for preparation of Customized "Practical SF6 Handling Instructions", Study Committee B3, Task Force B3.02.01

ASTM D2472: Standard Specification for Sulfur Hexafluoride

Common terms/definitions:

Dewpoint: The temperature (in Degrees ° C or ° F) at which moisture (water vapor) in the gas begins to condense as liquid (droplets or dew) or solid (ice).

Typical dewpoint in SF6 equipment ranges from -60C to -5C. Common operating pressures are 100-755 kPa abs. (0-95 psig).

ppmv: Moisture Volume concentration (parts per million by Volume). One million times the ratio of the volume of moisture (water vapor) present in the gas to the total volume of the gas (including water vapor).

ppmw: Moisture Mass concentration (parts per million by Mass). For SF6 gas, conversion to ppmw = ppmv/8.1.

What criteria is used?

Dewpoint (from IEC standard):

Excerpt from IEC 62271-1:

5.2 Requirements for gases in switchgear and controlgear

The manufacturer shall specify the type and the required quantity, quality and density of the gas to be used in switchgear and controlgear and provide the user with necessary instructions for renewing the gas and maintaining its required quantity and quality (refer to item a) of 10.4.1), except for sealed pressure systems.

For sulphur hexafluoride (SF_6) filled switchgear and controlgear, SF_6 in accordance with either IEC 60376 or IEC 60480 can be used. In order to prevent condensation, the maximum allowable moisture content within gas-filled switchgear and controlgear filled with gas at the rated filling density for insulation ρ_{re} shall be such that the dew-point is not higher than –5 °C for a measurement at 20 °C. Adequate correction shall be made for measurement made at other temperatures. For the measurement and determination of the dew-point, refer to IEC 60376 and IEC 60480.

Note, the above is often only considered in absence of manufacturer's recommendations as it is equivalent at 574 ppmv at 700 kPa (102 psia = 87 psig)

What if measurement is not taken at 20C (68 degrees F)?

Recognize that moisture measurements will vary depending on temperature at which the measurement is taken, so they are typically related back to 20 degrees C.

The relationship of temperature to moisture is based on the quantities of epoxy which are present in a gas compartment. As the ratio of epoxy to gas increases, the ratio of moisture to temperature will also increase

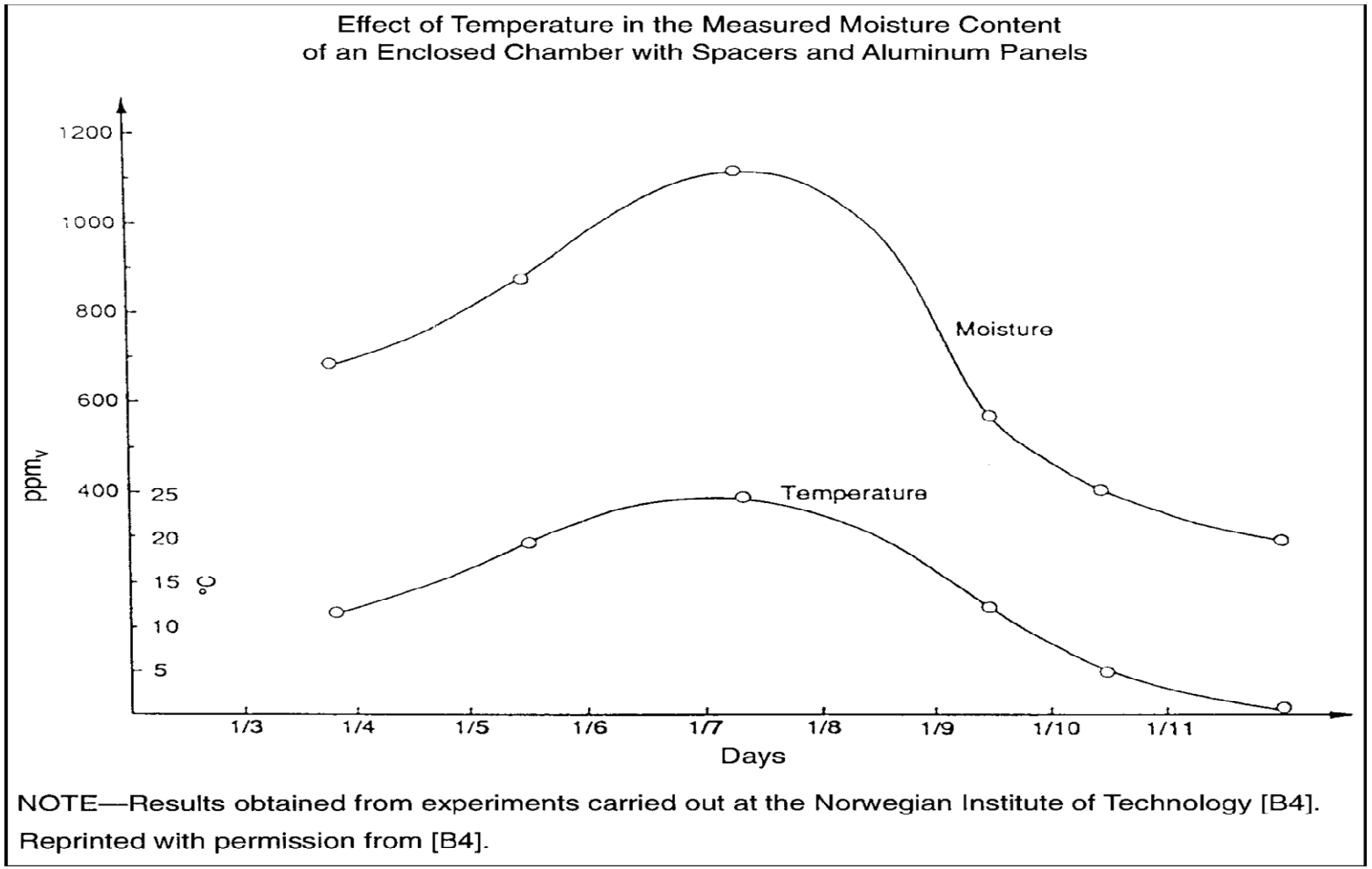


Figure 1-1 —Seasonal variation of moisture content in a typical GIS compartment

What if measurement in ppmv is desired (commonly specified by GIS mfrs) and only dewpoint is known or measured?

Convert from dewpoint to ppmv.

Does pressure need to be taken into account?

Yes, to convert dewpoint to ppmv, pressure needs to be known as dewpoint is pressure dependent. ppmv is pressure independent.

What criteria is used?

ppmv (examples of values provided by OEMs)

Moisture Limits (in ppmv)			
	Circuit Breakers	Other Equipment	Remarks
Standards - GIS Manufacturer			
A	400	550	
B	100		**Dead Tank Puffer-1**
	400		**Dead Tank Puffer-2**
	810		**Live Tank Puffer**
		800	**Bus**
C	120	600	
D	300	300	
E	70		**Two Pressure Type**
		150	**Bus with Disconnect Switch**
		500	**Bus w/o Disconnect Switch**
F	150	1000	
SF6 Manufacturer			
A	11	11	**Typical New Gas Specifications**
Standards			
IEC 60376 (2005-06)	120	120	**New SF6 Gas**
ASTM D2472-00	71	71	**New SF6 Gas**

Excerpt from C37.122.5 - Table 1 [B4]

What equipment is used to measure moisture in GIS?

Capacitive polymer type device

Chilled mirror type device

Is moisture measured directly from SF6 gas cylinders?

a) **SF6 gas suppliers desire measurement to be taken from the cylinder in liquid phase. To accomplish this, cylinder must be inverted.**

b) **If cylinder <u>is not</u> inverted, then initial measurements (in the vapor phase) will be worst case and may not be representative of moisture content in the cylinder.**

Are moisture measurements taken at same time of year?

a) **If moisture measurements are taken at different time of year (when temperature is different) and compared for consistency, then they may show higher moisture in the summer than in the winter. Try to measure at same time of year or close to temperature of previously taken measurement.**

Open Discussion Topics (as time permits)

a) **How could OEMs make this easier? What features could be added?**

b) **What new equipment did you have to purchase (if any)?**

c) **What new procedures have been established by end users?**

d) **Does the end user perform moisture measurements once equipment is in service or have OEMs perform?**

SF6 Gas Mandatory Reporting Requirements

- U.S. EPA's Greenhouse Gas Mandatory Reporting Program (40 CFR Part 98)

- CARB (California Air Resource Board) Regulation for Reducing SF6 Emissions from GIS (AB 32), (CCR title 17, Subchapter 10, Article 4, Subarticle 3.1)

SF6 Gas Mandatory Reporting Requirements EPA

- ***Subpart OO: Industrial Suppliers of GHGs***
  - *(OEMs, importers, exporters, threshold - 2.306 lbs., annually on 3/31, first 9/30/2011)*
- ***Subpart SS: Manufacture of Electrical T&D Equipment***
  - *(OEMs, threshold – 23,000 lbs., annually on 3/31, first 9/28/2012)*
- ***Subpart DD: Use of Electrical T&D Equipment***
  - *(Users, threshold – 17,820 lbs., annually on 3/31, first 9/28/2012)*
- ***Subpart QQ: Imports and Exports of Equipment Pre-charged with Fluorinated GHGs***
  - *(OEMs, threshold - 2.306 lbs., annually on 3/31, first 9/28/2012)*

SF6 Gas Mandatory Reporting Requirements EPA

- Gather information
  - Nameplate capacities: existing, new & retired, gas acquired & disbursed
- Calculate emissions
  - Emissions = Decrease in SF6 inventory + Acquisitions of SF6 – Disbursements of SF6 – Net increase in Nameplate capacity
- Report on EPA website
  - e-EGRET Electronic Greenhouse Gas Reporting Tool
- Maintain records
  - 3 years

SF6 Gas Mandatory Reporting Requirements EPA

- **Purpose of the Rule**
  - Requires reporting of greenhouse gas (GHG) emissions from all sectors of the economy in the United States
  - Provides accurate and timely data to inform future climate change policies and programs
  - Does not require control of GHG emissions

SF6 Gas Mandatory Reporting Requirements EPA

- **Regulation of SF6 Emissions?**
  - No new legislation in Congress in near future
  - Legal authority to regulate GHGs under the Clean Air Act
  - Currently no proposed regulation applicable to SF6 emission sources

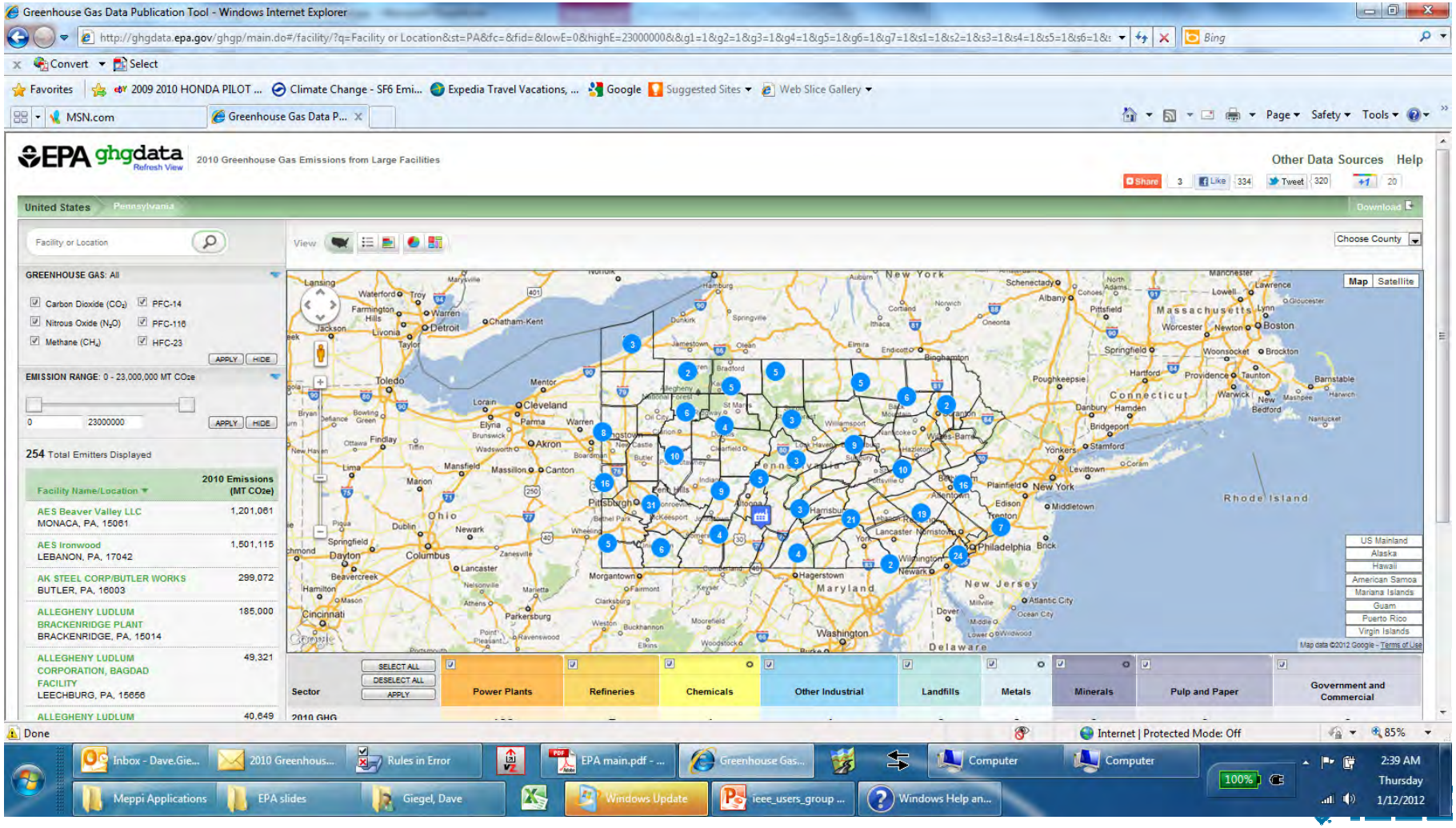
- **Penalties/fines**
  - None for emissions
  - Only for not reporting or fraudulent reporting
  - Initial emphasis is on understanding and accuracy

EPA

- Refer to EPA Webpage slides:

http://epa.gov/climatechange/emissions/ghgdata/

EPA



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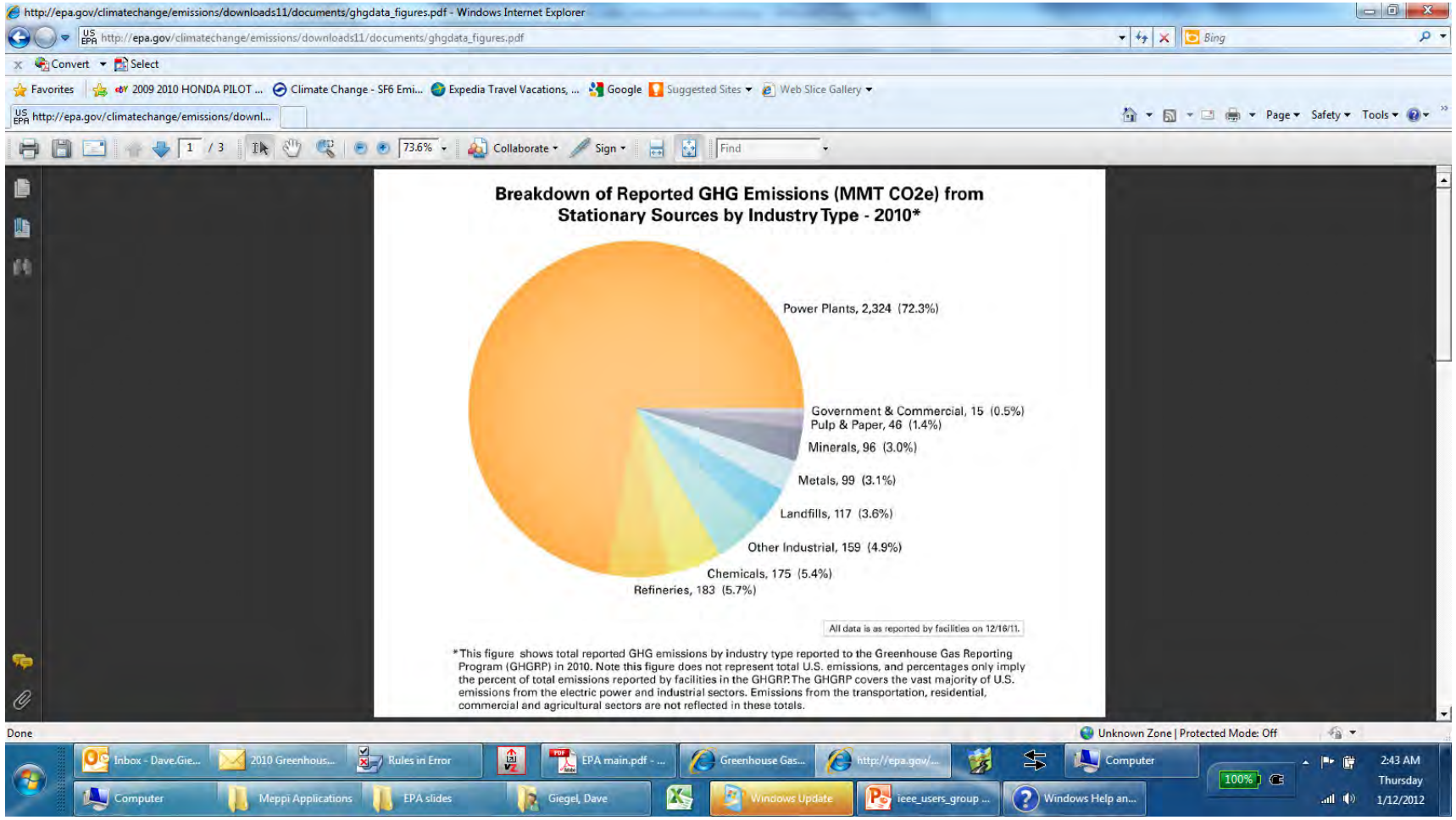
EPA



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SF6 Gas Mandatory Reporting Requirements CARB

Key Elements

- Establishes an annual maximum emission rate
- Sets initial emission rate at 10% of nameplate capacity
- Requires GIS owners to reduce their SF6 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%
- Applies only to "Active GIS Equipment"

SF6 Gas Mandatory Reporting Requirements CARB

Recordkeeping and Reporting Requirements:

- Demonstrate compliance through recordkeeping and reporting requirements
- Annual reports would include:
  - SF6 emissions
  - SF6 emission rate
- GIS owners must have available upon ARB request:
  - Current SF6 inventories
  - GIS SF6 nameplate capacity
- Retain all records for three years

SF6 Gas Mandatory Reporting Requirements CARB

	EPA	CARB
Applicability	Users, OEMs	Users (owners)
User reporting threshold	17,820 lbs.	Any amount
First year to report	2011	2011
Date for reports	March 31	June 1
Equation for determining emissions	same	same
Emission Regulation	none	10% in 2011 reducing by 1% per year until 1% in 2020 and thereafter
Record retention	3 years	3 years
Measuring equipment accuracy	1%	1%
Recalibration	Annually	Annually
Late or Fraudulent reporting Penalty	Yes	Yes
Exceeding allowable emissions Penalty	None	Yes – violation for each day of calendar year