DILO Certified Gas: Reconditioning, SF_6 Gas Inventory, & Cylinder Management

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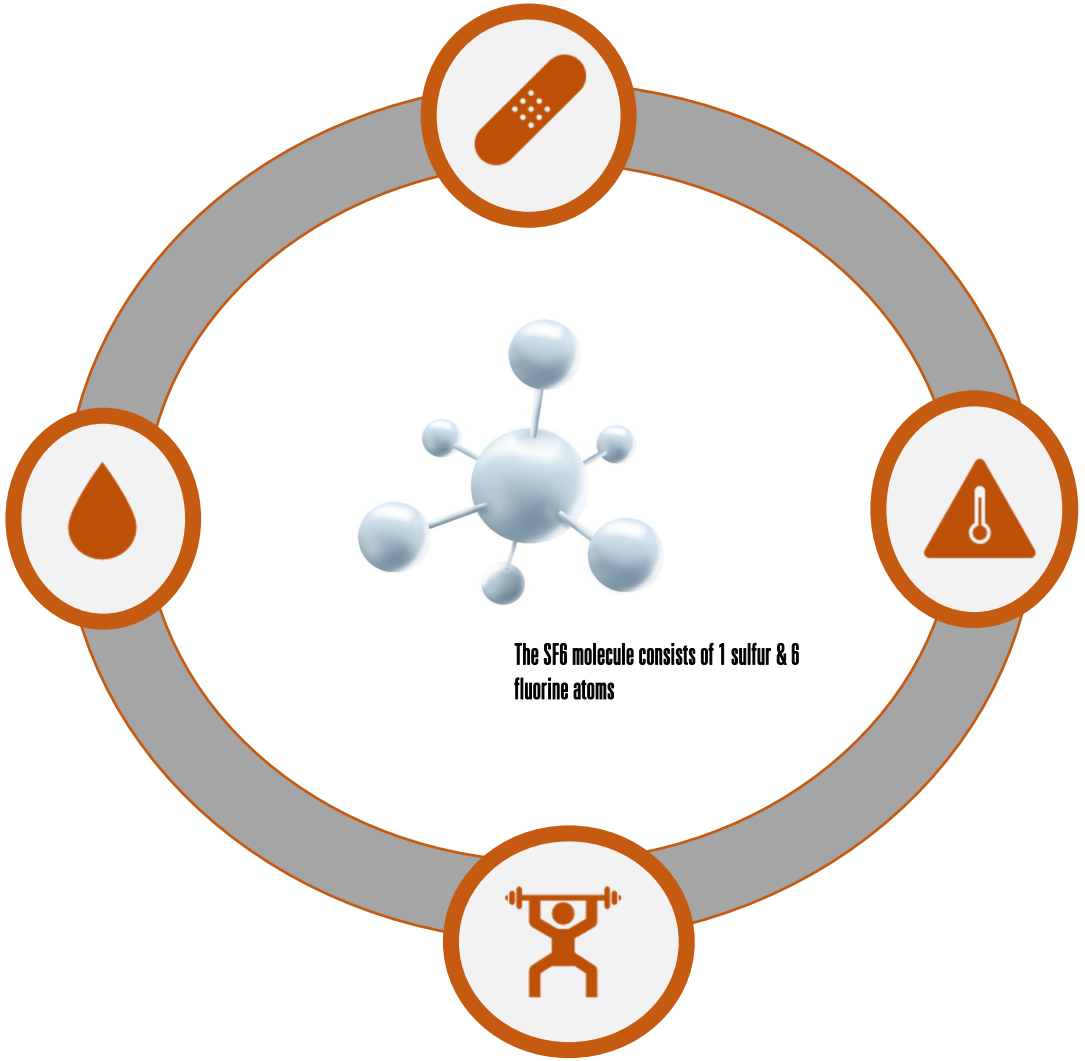
Learning Outcomes

- List the benefits of using reconditioned SF_6 gas
- Describe the specifications of reconditioned gas for use and supply with GIE
- Recognize the difference between reconditioned SF_6 gas and following the Three R's Protocol
- Perform accounting of gas inventory and cylinder management

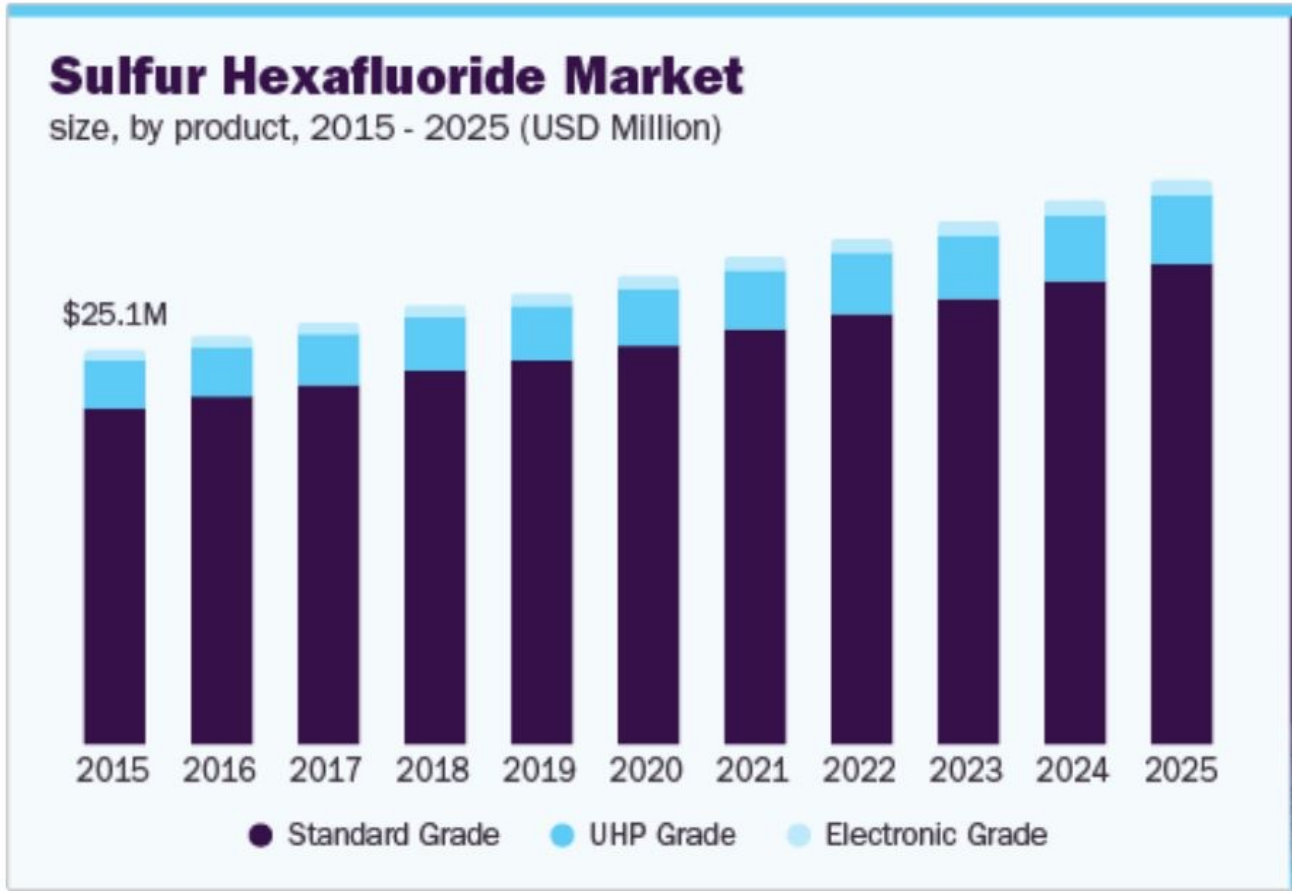
SF_6 History & General Overview

- Discovered in 1901 by French chemists Henri Moissan and Paul Labeau. The special properties of Sulfur Hexafluoride have contributed to its use in several applications, mainly high voltage equipment: circuit breakers, particle accelerators, etc.
- SF6 is manufactured by method of electrolysis
- In 1937 it was found that SF6 posses a much higher dielectric strength than air. This determination led to its primary use in the electrical industry ever since. SF6 soon became a preferred insulating medium over earlier insulators such as air, oil, and vacuum.
- Roughly 10,000 tons of SF6 is produced each year. 80% of this volume is used directly by the Electrical Industry.



Market Drivers & Trends

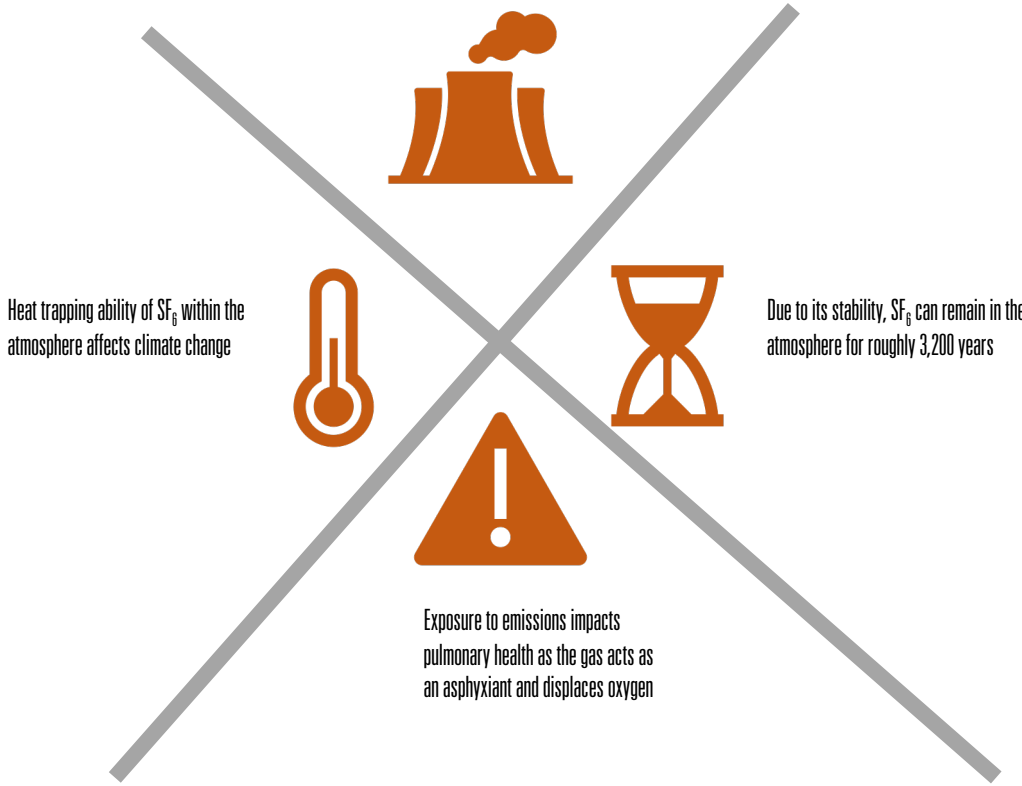
- Maintenance
- Leaks
- Failures
- New Purchase

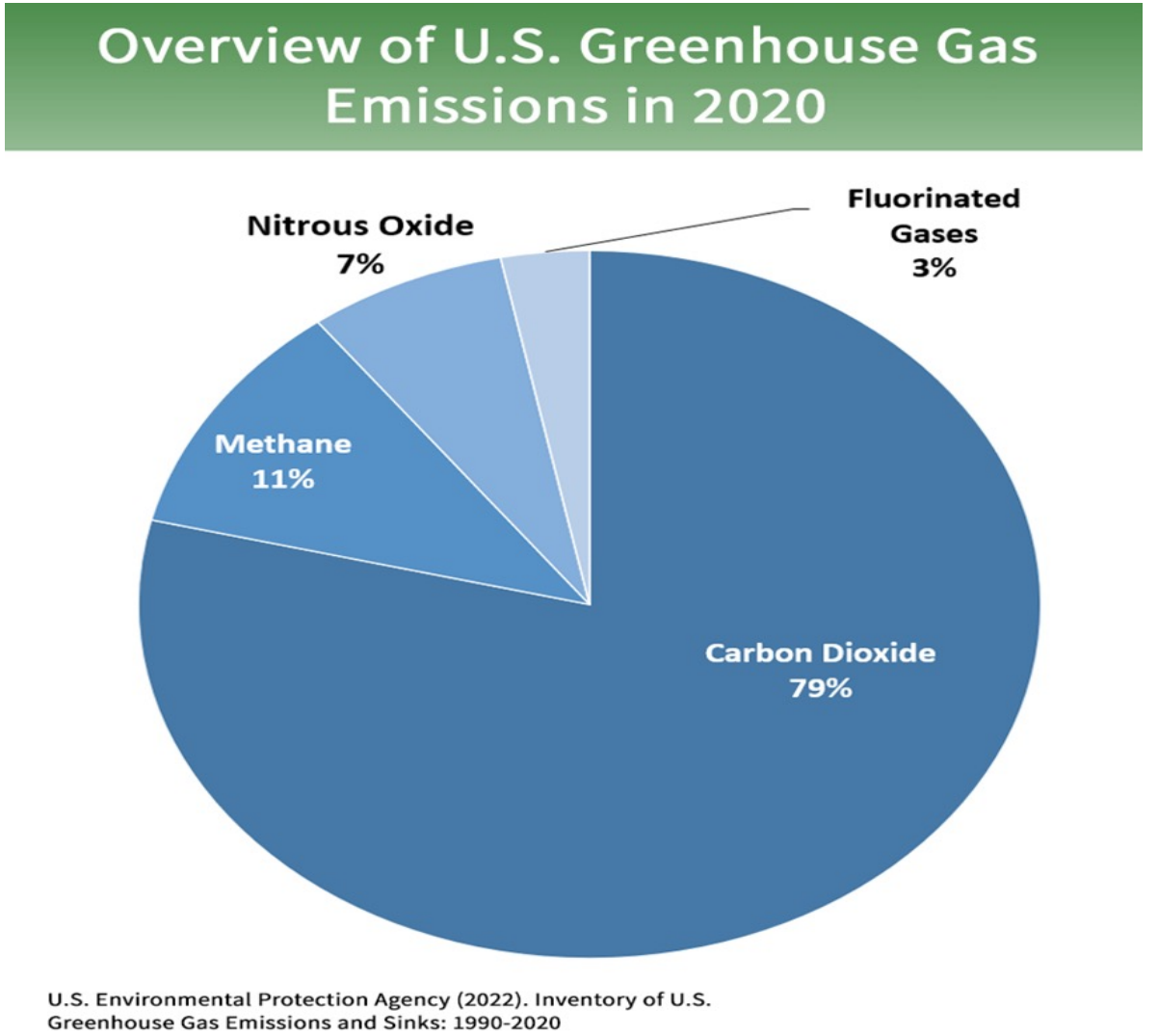


"The increasing export is expected to augment product prices over the forecast period."

Environmental Impact (Part 1)

SF6, regardless of quality or state, contributes to the following negative impacts once emitted into the atmosphere:



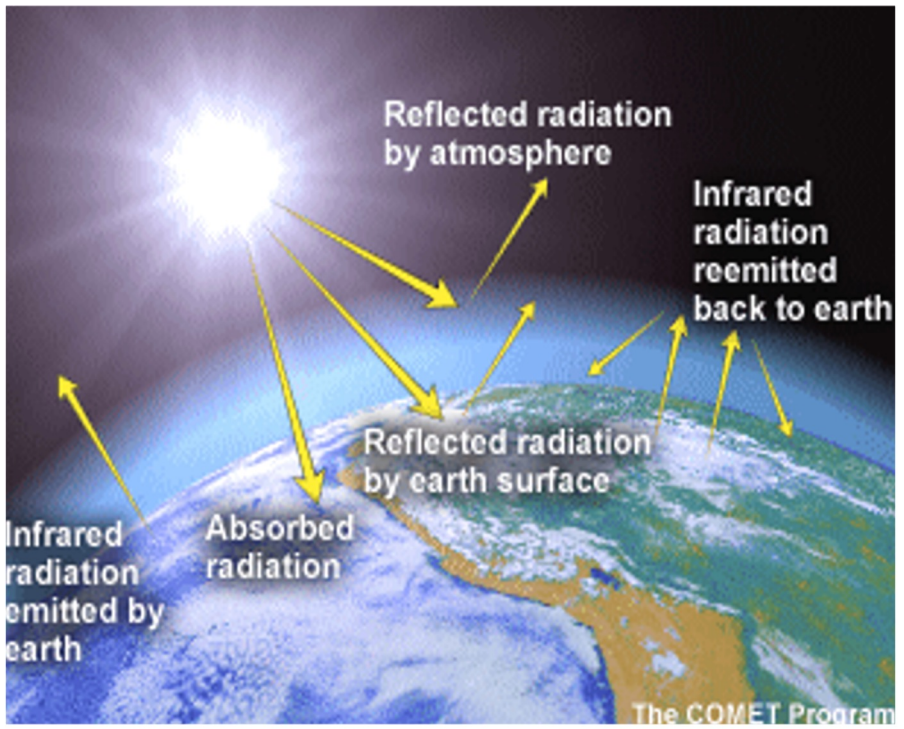


U.S. Environmental Protection Agency (2022). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020

Environmental Impact (Part 2)

The greenhouse effect is the planet's normal process of heating the environment to make life suitable for living things via natural greenhouse gases

- Artificial greenhouse gases which are industrially manufactured accelerate the greenhouse effect – especially **fluorinated gases**
- Satellites in space measure and trace the origins of greenhouse gases
- Strengthening of the greenhouse effect increases **global warming**. Global warming is associated with stronger storms, rising sea levels, increased droughts, etc.



Without the greenhouse effect, the Earth's surface temperature would be cooler by 60 degrees F causing many life forms to freeze Greenhouse Effect | National Geographic Society

Requirements for Reuse

	IEC 60376 Specification for new SF_6 gas	IEC 60376 Specification for used SF_6 gas
SF_6	> 98.5 Vol.-% For gas mixtures: > 99.7 Vol.-%	> 97 Vol.-% For gas mixtures: ±5% from the normal value
Air/CF_4	Air: < 10,000 µl/l (i.e 1 Vol.-%) for pure SF_6 gas For gas mixtures: < 2,000 µl/l (i.e. 0.2 Vol.-%) CF_4: < 4,000 µl/l (i.e. 0.4 Vol.- %) for pure SF_6 gas For gas mixtures: < 800 µl/l (i.e. 0.08 Vol.-%)	< 30,000 µl/l (i.e 3% Vol.) For gas mixtures: SF6/N2 mixtures: < 30,000 µl/l (air and/or CF4) SF6/N2 mixtures: < 30,000 µl/l (air and/or N4)
Moisture (dew point)	< 200 µl/l (i.e. 200 ppm_v: -36°C frost point @ atm)	< 200 µl/l (i.e. 200 ppm_v: -36°C frost point @ atm)
Oil	< 10 mg/kg (i.e. 10 ppm_w)	< 10 mg/kg (i.e. 10 ppm_w)
HF, SO_2	< 7 µl/l (I.e. 7 ppm_v) total	< 50 µl/l total (i.e. 50ppm_w) or 12 µl/l (i.e. 12ppm_v) For (SO_2+SOF_2) or 25 µl/l (i.e. 25 ppm_v) HF

Virgin vs. Reconditioned SF_6 (part 1)

Manufactured overseas, roughly 10,000 tons of gas produced each year

01 Production of fluorine thru electrolysis

02 Fluorination of sulfur to produce SF_6

03 Purification of crude product

04 Recovery of final product into liquid for storage

Removal of O_2, H_2O, CO_2 (naturally forming during production process)

Virgin vs. Reconditioned SF_6 (part 2)

Contaminant	Threshold	Location
Air (other vapors)	<97%	Purification @ supplier site
Moisture	>200 ppm	On-site filtration possible
By-product (SO_2)	>12 ppm	On-site filtration possible

The process for reconditioning SF6 starts and ends with analysis and documentation. Analysis is key for understanding contaminant levels and verifying reconditioned gas.

DILO Certified Gas

Verified SF_6 product that stands behind our emission-free philosophy . . .

- Consulting services available
- Incoming & Outgoing reports provided
- Bi-coastal centers
- Loaner cylinders available
- Third party analysis with certification available upon request

Maximum Acceptable Purity Levels:

	IEC 60480*	DILO Certified SF_6 Gas
O_2 and/or CF_4	3%	<0.9% ✓
H_2O	25 ppmW/200 ppmV (-36°C dew point)	<99.5 ppmV (-41.5°C dew point) ✓
Mineral Oil	10 ppmW	<1 ppmW ✓
Reactive Gases	50µ/l total or 12µ/l for (So2 + SOF2) or 25 µ/l HF	0 ppmV ✓

*Values based on IEEE C37.122.3 and IEC 60480 standards.

Benefits of SF_6 Reuse

EPA United States Environmental Protection Agency

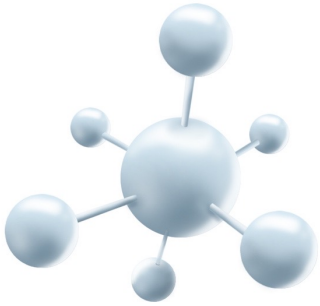
- Reduction in our carbon footprint
- Cost savings
- Reduction in lead times
- Increased accuracy with inventory management & reporting
- Increased grid reliability

The production of 100 lbs. of virgin SF_6 produces a 3-8 lbs. emission value

Reconditioning 100 lbs. of SF6 produces an emission value of <0.5 pounds*

Considerations

- Unable to verify electrical grade SF6 (**99.999% purity**) in the field due to limitations with portable testing devices
- **ASTM 2472 D standard** (currently in review) calls for the following:
  - **Moisture <8 ppmv**
  - Purity > 99%
  - HF < 0.3 ppmw
- **The manufacturing process for SF6 generates impurities** which are removed via cryogenic and filtration processes, similar to gas that is contaminated during the life cycle in GIE. **Both gas types can be refined without compromising insulating properties.**
- Consider markets where quality is critical i.e. the medical industry
- Current events and challenges with sourcing virgin SF6



Gas Reconditioning vs the 3 Rs

Learning Outcomes

- Testing
  - Importance of testing prior to handling
  - What are we looking for
- 3RS:
  - Recovery
    - Accountability
    - Key tools and Resources
  - Recycle
    - Types of Filtration
    - Filtration on site
  - Reuse
- Process of Reconditioning

Importance of Testing & What are we looking for

- Perform condition of the SF6 in the GIE
- Moisture Content
- Purity
- SO2 (by-products)

IEC specifications (standards) for sulphur hexafluoride

	IEC 60376 specification for new SF6 gas	IEC 60480 specification for used SF6 gas	IEC 62271-4 SF6 reuse specification
Air / CF_4	Max. 1 vol.-%	< 3 vol.-%	< 30 vol-% air < 5 vol-% CF_4
Moisture (Dew point)	-36 °C* at p_a 1 bar < 25 ppm (mass)	-23 °C* at p_a 1 bar **(medium voltage)** -36 °C* at p_a 1 bar **(high voltage)**	< 1,000 ppm (mass) approx. +4.5 °C at p_a 1 bar
Oil	< 10 ppm (mass)	< 10 ppm (mass)	< 1,000 ppm (mass)
HF, SO_2	< 1 ppm_v	< 12 ppm_v SO_2 < 50 ppm_v total	> 12 ppm_v SO_2 > 50 ppm_v total

* measured at ambient pressure

Contaminant	In-service	Re-use
Non-reactive gases (air / N_2)	Up to 3%	Up to 3%
Reactive gases (SO_2, SOF_2)	500 PPM_v	12 PPM_v
Moisture – GCB only	200 PPM_v	200 PPM_v

The 3-Rs

- **Recovery** of gas**:** Capturing from a GIE through an emission free process that includes filtration of contaminants
- **Recycling** of gas through filtration: Process the gas through a prefilter system that removes contaminants

  - Activated charcoal: To adsorb oil in the gas

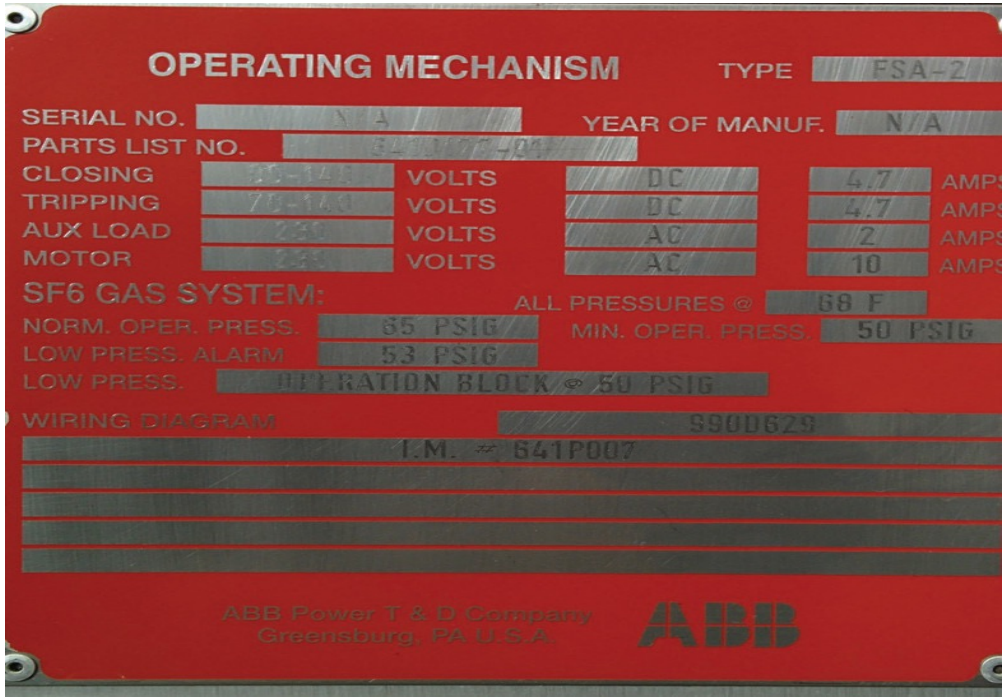
  - Aluminum Oxide: Separates moisture and by products from the vapor by acting as an absorbent attracting those compounds

  - Molecular Sieve: Uses dehydration to trap water molecules within them to achieve separation from SF6

  - Particle Filters: Designed to trap solid particles that may include solid decomposition material from SF6 gas by-products and other solids.
- **Reuse** of gas: Immediate fill into GIE or introduce into the supply stream for future reuse

Accountability

- Ensure GIE is filled to nameplate value
- Verify pressure vs temperature using OEM temp chart



Key Tools & Resources

- What is the quality of the gas?
- Is additional filtration required?
- Do we have the proper size recovery system required?
- Do we have enough storage?
- How do we account for the gas?
- Are adapters required?

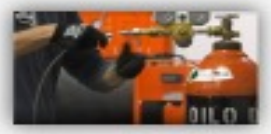
Reconditioning Process

ONE VISION. ZERO EMISSIONS.

DILO

Analysis of Used SF6

- Low Purity
- High H_2O*
- Presence of SO_2*



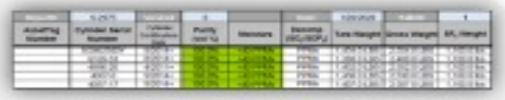
- Account for weight of SF_6 analyzed and to be reconditioned

* CIGRE ; IEEE; ANSI; IEC; ASTM

- Perform SF_6 reconditioning

Analysis of Reconditioned SF_6

- Confirm analysis of reconditioned SF6 meets/exceeds standards for re-use*



- Fill into clean (non-contaminated) SF_6 storage containers

- Account for weight of SF_6 analyzed and reconditioned

- Introduce into SF_6 supply stream

www.dilo.com

Accountability- Delivery of Reconditioned SF6

Delivery of reconditioned SF_6 gas with the following criteria

Report#:	AIR#191017	Service#	S-2878		Date:	10/17/2019	Pallet#	1
AssetTag Number	Cylinder Serial Number	Cylinder Certification Date	Purity (vol %)	Moisture	Decomp (SO_2/SOF_2)	Tare Weight	Gross Weight	SF_6 Weight
EHR603	N-339679	07/17*	99.9%	<40 PPMv	PPMv	119.0 LBS	233.8 LBS	114.8 lbs
GTE931	419416	11/16+	99.9%	<40 PPMv	PPMv	121.8 LBS	236.3 LBS	114.5 lbs
HLY311	73251805	11/17+*	99.9%	<40 PPMv	PPMv	110.7 LBS	225.3 LBS	114.6 lbs
FKN258	SG2095B	7/14+*	99.9%	<40 PPMv	PPMv	123.0 LBS	238.3 LBS	115.3 lbs
HLY301	U36035	11/17+	99.9%	<40 PPMv	PPMv	117.4 LBS	232.7 LBS	115.3 lbs
HKV358	32	03/17+	99.9%	<40 PPMv	PPMv	118.0 LBS	233.2 LBS	115.2 lbs
GTC978	OX-4-408947	12/16+	99.9%	<40 PPMv	PPMv	114.0 LBS	228.8 LBS	114.8 lbs
FKP274	C6657014	08/16+*	99.9%	<40 PPMv	PPMv	121.0 LBS	235.9 LBS	114.9 lbs
HAW447	179273	08/17+	99.9%	<40 PPMv	PPMv	127.0 LBS	242.2 LBS	115.2 lbs
DJT090	N-278340	07/14+	99.9%	<40 PPMv	PPMv	118.0 LBS	232.9 LBS	114.9 lbs
JCU279	X-379544	07/18+	99.9%	<40 PPMv	PPMv	113.6 LBS	228.9 LBS	115.3 lbs

Each cylinder must be weighed, analyzed and documented

Cylinders must be tagged with S/N, tare weight, gross weight & gas condition

Conclusion

Re-use of SF_6 contributes to reduction of greenhouse gas emissions and reduces the need for manufacturing of virgin gas. In turn thus reducing Greenhouse gas emissions globally.

SF6 Inventory Management

Danielle White & Robert Cardenas

RSMs

DILO Company, Inc.

Learning Outcomes

- Understand how to account for SF6 Inventory
- Recognize labeling and marking of SF6 containers
- List steps for recovery and filling of SF6 that allow user to account for SF6 by weight
- Perform accounting of gas inventory and cylinder management

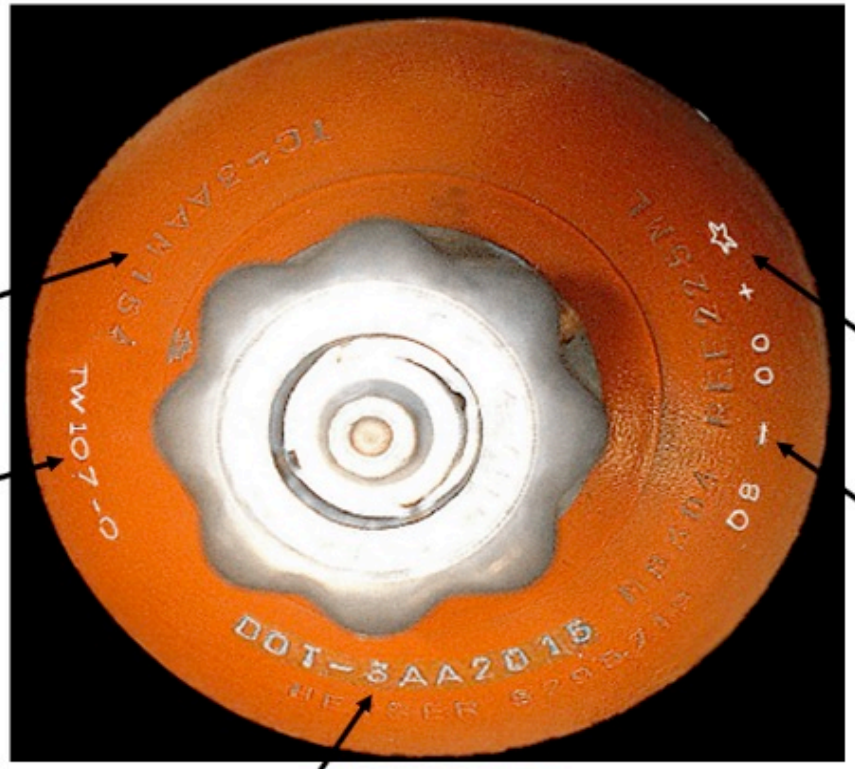
SF6 is accounted for in weight

- The volume of SF_6 can only be accounted for by weighing gas. It is not possible to rely on gas pressure.
- Cylinder and Scale
  - Gross weight – tare weight = SF6 volume (lbs./kgs.)
  - Cylinder Should be weighed without cap
  - Safety scale (low profile, secured with chain)
- Mass Flow Meter
  - Fewer steps
  - Less handling required

Logging SF6

- It is best that SF6 weights are consistently tracked and documented when moving gas (filling, recovery, return to supplier, etc.).
- Internal log improves SF6 accountability and can help track emissions.
- Log SF6 weight when:
  - Filling GIE/GIS
  - Recovering GIE/GIS
  - Consolidating Cylinders
  - Shipping SF6 to supplier

Cylinder Markings



DOT3AA2015

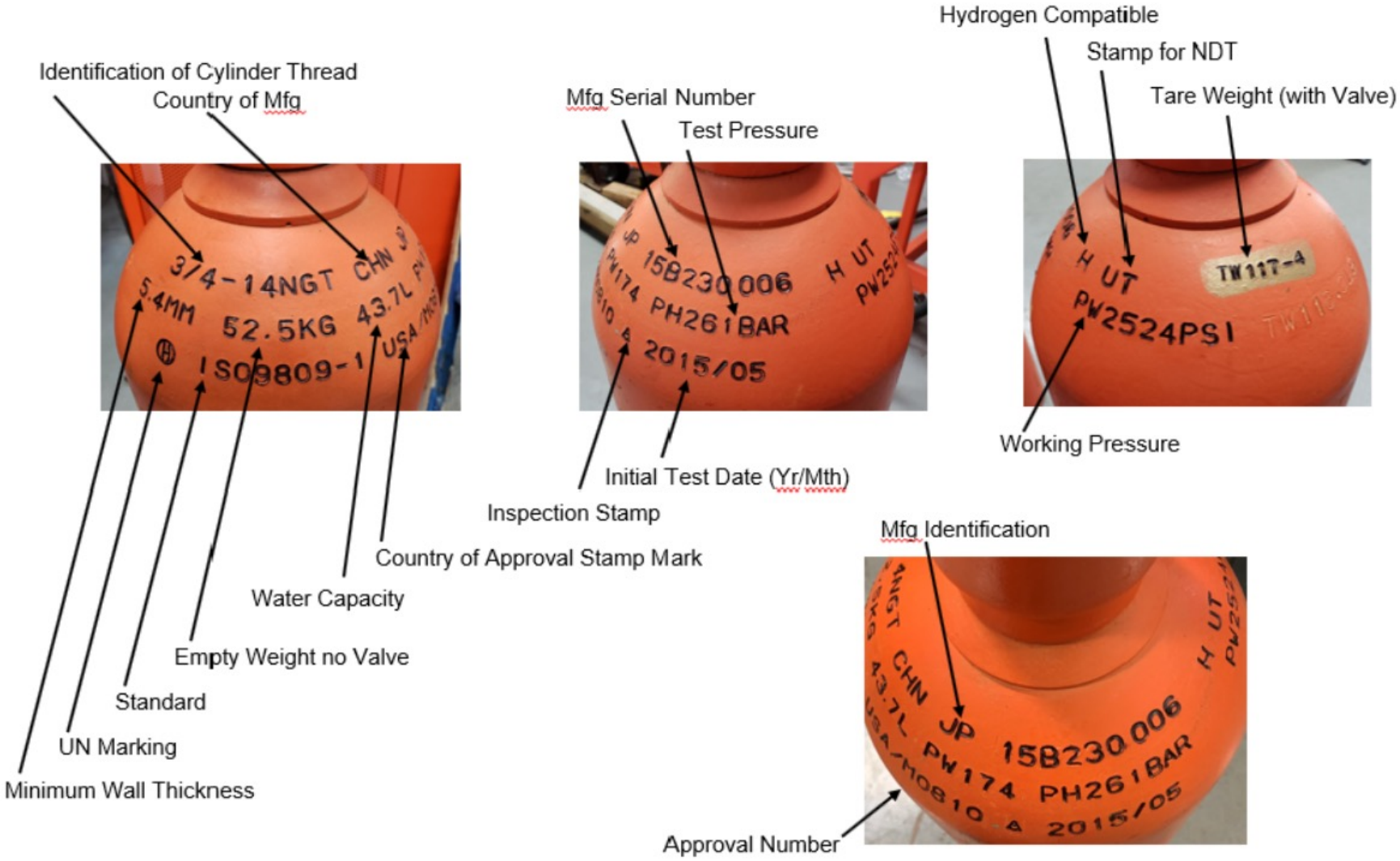
DOT3: Seamless
DOT4: Welded

AA: Steel
AL: Aluminum

Working pressure (**NOT** max.)

You may also find the manufacturers stamp or marking

ISO Cylinder Markings



Logging SF6

Starting Weight

SN	Certification Date	Tare Weight	Gross Weight	Net Weight
D555555	10/2022 +*	115 Lbs.	115 Lbs.	0 Lbs.

Ending Weight

SN	Certification Date	Tare Weight	Gross Weight	Net Weight
D555555	10/2022 +*	115 Lbs.	230 Lbs.	115 Lbs.

Cylinder Reports

- Allow organizations to track SF6 movement from:
  - Inventory
  - Suppliers
  - Between storage vessels

- Incoming Cylinder Report
  - Log of cylinders received by warehouse

- Outgoing Cylinder Report
  - Log of cylinders leaving warehouse

Incoming/Outgoing Cylinder Report

Order Totals Report

DILO DIRECT SERVICE LINE

Customer:	State Electric Co.		INCOMING/OUTGOING	INCOMING	
Report#	S-5555	Service#	S-5555	Date:	10/11/2022

Pallet #	Total SF6 Weight	Cylinder Count		Comments
1	115.0 lbs	1	Cyls	Cylinder Receieved for Recycling
2	0.0 lbs	0	Cyls	
3	0.0 lbs	0	Cyls	
4	0.0 lbs	0	Cyls	
5	0.0 lbs	0	Cyls	
6	0.0 lbs	0	Cyls	
7	0.0 lbs	0	Cyls	
8	0.0 lbs	0	Cyls	
9	0.0 lbs	0	Cyls	
10	0.0 lbs	0	Cyls	
11	0.0 lbs	0	Cyls	
12	0.0 lbs	0	Cyls	
13	0.0 lbs	0	Cyls	
14	0.0 lbs	0	Cyls	
15	0.0 lbs	0	Cyls	
16	0.0 lbs	0	Cyls	
17	0.0 lbs	0	Cyls	
18	0.0 lbs	0	Cyls	
19	0.0 lbs	0	Cyls	
20	0.0 lbs	0	Cyls	
SF6 Total:	115	1		

Analyzer Model:	3-038		
Analyzer Serial No:	390		
Analyzer Cal Date:	Jun-20		
Scale Model:	D-230-R002		
Scale Serial No & Cal:	1301435	Mar-20	
DILO Technician:	TP	10/11/2022	

CIGRE Maximum Impurity Levels:

Moisture:	<200 PPMv (breakers/switches)
	<750 PPMv (gas bus)
Decomp:	<12 PPMv SO2/SOF2
Purity:	>97% volume percentage

Incoming/Outgoing Cylinder Report

Cylinder Report

DILO DIRECT SERVICE LINE

Customer	State Electric Co.		INCOMING						
Report#:	S-5555	Service#	S-5555		Date:	10/11/2022	Pallet#	1	
AssetTag Number	Cylinder Serial Number	Cylinder Certification Date	Purity (vol %)	Moisture	Decomp (SO_2/SOF_2)	Tare Weight	Gross Weight	SF_6 Weight	Comments
K5555	D-555555	Oct-22	95.0%	<300 PPMv	PPMv	115.0 LBS	230.0 LBS	115.0 lbs	Full cylinder / low purity

Cylinder Count	1

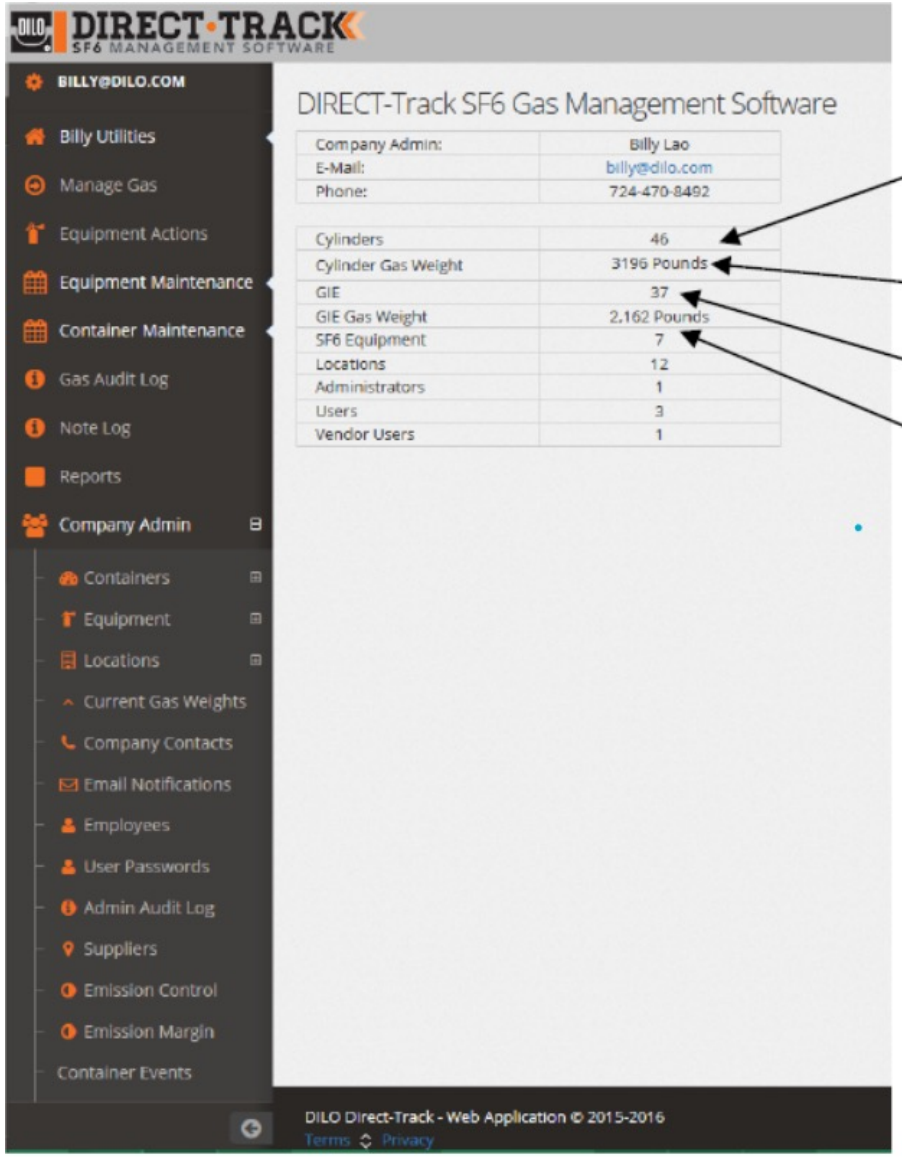
Total SF6 Weight: **115.0 lbs**

This report certifies as found/as left condition of the SF6 in the serialized SF6 Gas cylinder.

DILO Technician: TP

CIGRE Maximum Impurity Levels:
Moisture: <200 PPMv (breakers/switches)
<750 PPMv (gas bus)
Decomp: <12 PPMv SO2/SOF2
Purity: >97% volume percentage

Direct Track



Example of summarized SF6 count in cylinders

Example of total SF6 quantity in stored cylinders

Example of total GIE inventory

Example of total SF6 quantity in GIE

Personalized summery page which includes a quick shot of total SF6 gas in inventory including gas in cylinders and gas in GIE. The user can also see how many locations are accounted for in the system, as well as other pertinent account information such as number of users, company administrators and vendor users active in their system.

Labeling Cylinders

- Reduce the risk of cross contamination
- Improve shop efficiency and workflow
- Reduce risk of contaminating GIE/GIS

Full	New/High purity	Contaminated
Partial	Tag for consolidation/Use for fill / top off	Return for disposal
Empty	Suitable for Re-Use	Return for Recert./Disposal

- **Color Code Example:**
  - Red
    - Less than 97% SF6
    - Contaminated with arc-bryproducts – do not use
  - Blue
    - Full cylinder virgin or reconditioned SF6
  - Green
    - Partially filled – clean SF6
    - Consolidate or use for top-off
  - White
    - Empty in vacuum

Recovery/Filling with Cylinder and Scale

1. Note cylinder SN and TW
2. Weigh cylinder before starting
3. Weigh cylinder after recovery is complete
4. Difference in weight is net gas recovered/filled
5. Repeat each step for every new gas compartment/GIE

Recovery/Filling with Mass Flow Meter

1. Note cylinder SN and TW
2. Zero out mass flow meter before starting
3. Complete recovery/filling
4. Recover remaining gas in hoses
5. Write down weight in gas as displayed on screen
6. Repeat each step for every new gas compartment/GIE

THANK YOU!