

SF₆ By-products: Safety, Cleaning, and Disposal Concerns

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SF₆ Gas Properties

- Slow reacting with a relatively high molecular weight and extremely stable molecular structure.
- Excellent insulation properties, strong arc quenching abilities, and high dielectric strength
- Non-flammable and non-toxic to humans
- Colorless and Odorless
- Under high temperature conditions (> 350° F), SF₆ decomposes into products that are toxic and corrosive

SF₆ Decomposition and Contamination

- Reactive decomposition byproducts form when SF₆ is exposed to:
 1. *spark discharges,*
 2. *partial discharges,*
 3. *switching arcs, and*
 4. *failure arcing*
- Decomposition byproducts can take the form of gas or powders
- Other types of contaminants can include moisture and air (from handling or leakage), dust and particles (mechanical generation)

SF₆ Decomposition Byproducts

Chemical Name	Chemical Formula
<i>Gaseous Byproducts</i>	
Sulfur Dioxide	SO ₂
Thionyl Sulfide (sulfur tetrafluoride)	SOF ₂ (SF ₄)
Hydrogen Fluoride	HF
Disulfur Decafluoride (sulfur pentafluoride)	S ₂ F ₁₀ (SF ₅)
Sulfuryl Fluoride	SO ₂ F ₂
Sulfur Tetrafluoride Oxide	SOF ₄ (SF ₄) ^a
^a SF ₄ is readily hydrolyzed to SOF ₂ .	
<i>Powder Byproducts</i>	
Tungsten, aluminum, copper fluorides	WF ₆ , WO ₃ , AlF ₃ , CuF ₂

Human Health Concerns

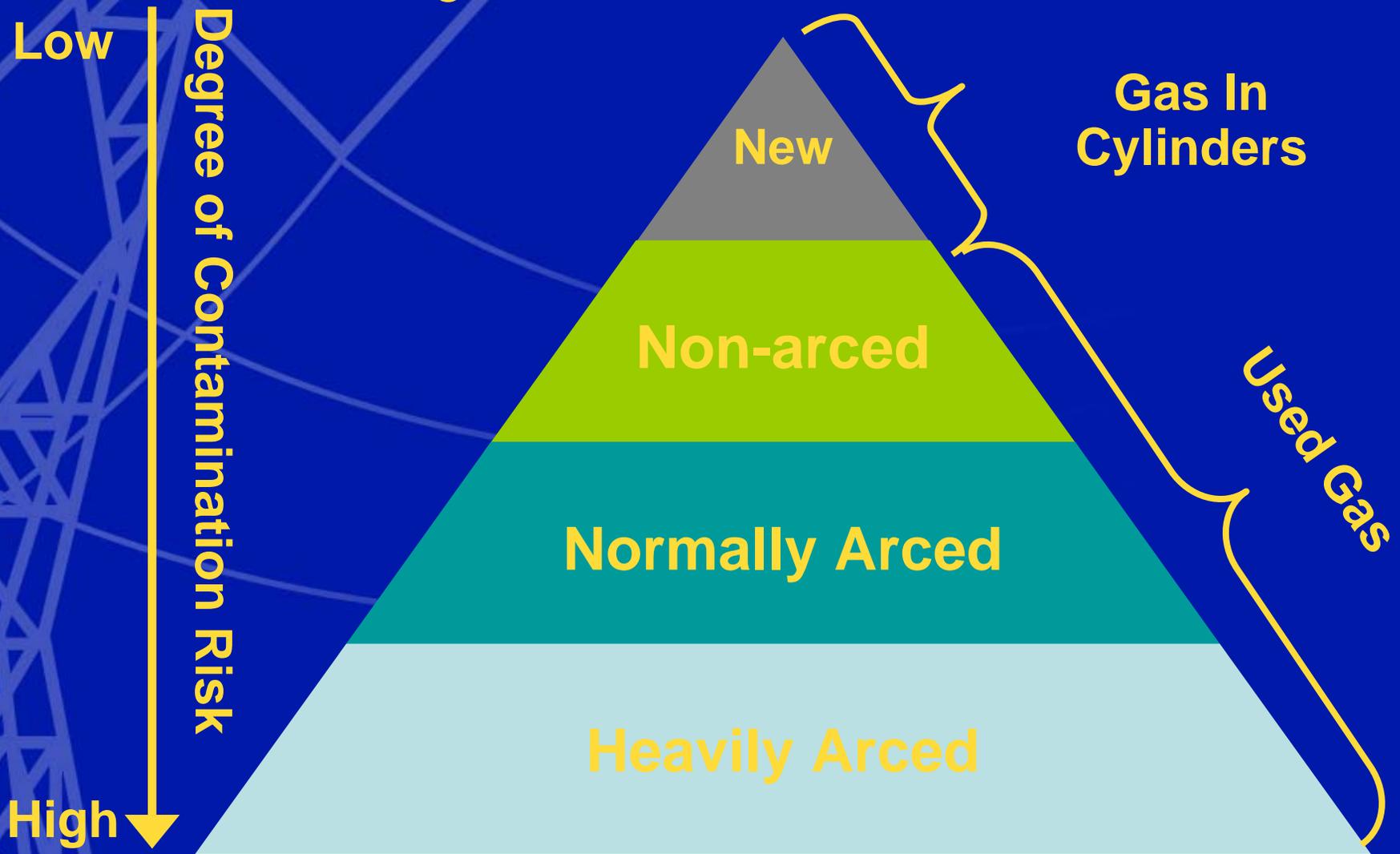
- Irritating to the eyes, nose, and throat, pulmonary edema and other lung damage, skin and eye burns, nasal congestion, bronchitis; powders may cause rashes
- Physical Indicators can include:
 - strong irritating “rotten egg” odor at low concentrations
 - Eyes, nose, throat and lung irritation at high concentrations
 - Presence of white, gray, or tan powders
- Toxic
 - Cell toxicity tests indicate S_2F_{10} is significantly more toxic to cell cultures than other byproducts

Occupational Exposure Limits

Substance	PEL-TWA	PEL-Ceiling	TLV-TWA	TLV-C
HF	3 ppm			
SO ₂ F ₄ (SF ₄)		0.1 ppm		0.1 ppm
S₂F₁₀ (SF₅)	0.025 ppm*	0.01 ppm		0.01 ppm
SO ₂ F ₂	5 ppm			
SO ₂	2 ppm		2 ppm	
SF ₆	1,000 ppm		1,000 ppm	

*Revised in 1989 to a PEL-ceiling value of 0.01 ppm; enforcement of the new limit stayed by OSHA, until available sampling and analytical technique is published a notice in the Federal Register.

SF₆ Gas Categories



Safe Handling Procedures

- **Low Risk (new, non-arc'd SF₆)**
 - Work in well-ventilated areas
 - No smoking, refrain from welding, avoid open flame or outdoor heaters
- **Intermediate Risk (normally arc'd SF₆)**
 - Same as above
- **High Risk (heavily arc'd SF₆)**
 - Use of personal protective equipment (i.e., respiratory device, protective clothing such as rubber gloves, footwear, goggles) for removal/handling of solid SF₆ byproducts
 - Ventilate and test enclosed areas for adequate O₂ prior to initiating clean up

Safeguarding the Work Area

- Post warning signs provided with emergency instructions strategically
- Post evacuation maps and plans
- Provide personnel with written instructions for safe handling of SF₆-filled equipment, including:
 - Procedures for low, intermediate, and high risk situations
- Train personnel on cleaning procedures

Cleaning Procedures

- Contaminated Work Area
 - Use of Personal Protective Equipment
 - Removal of powdery deposits with vacuum cleaner equipment (HEPA filters), wipes
 - Removal of disposable protective equipment and waste bags into a properly labeled hazardous waste drum
- Contaminated SF₆ Gas
 - Onsite purification unit for acceptable levels
 - Off-site reclamation methods for non-acceptable levels (i.e., heavily arced gas)

Cleaning Contaminated SF₆ Gas On-Site

- Determine gas category
- Select appropriate filters
- Purify gas by filtering
- Perform quality checks
- Handle gas that results as non-reusable

Select Appropriate Filters

Filter Type	Function	SF ₆ Gas
Particle Filter	Removes solid decomposition products and other particles	Non-arc'd, normally arc'd, heavily arc'd
Gas/Moisture Filter	Removes gaseous decomposition products and moisture	Non-arc'd, normally arc'd, heavily arc'd
Prefilter	Reduces concentrations of solid and gaseous decomposition products	Heavily arc'd
Detoxification Filter	Reduces reactive gaseous decomposition products to below 200 ppmv for transport	Heavily arc'd

Purify Gas by Filtering

- 50 ppmv - maximum tolerable impurity level for reuse

which translates into a reading of

- 12 ppmv if the sum concentration of SO_2 and SOF_2 is measured

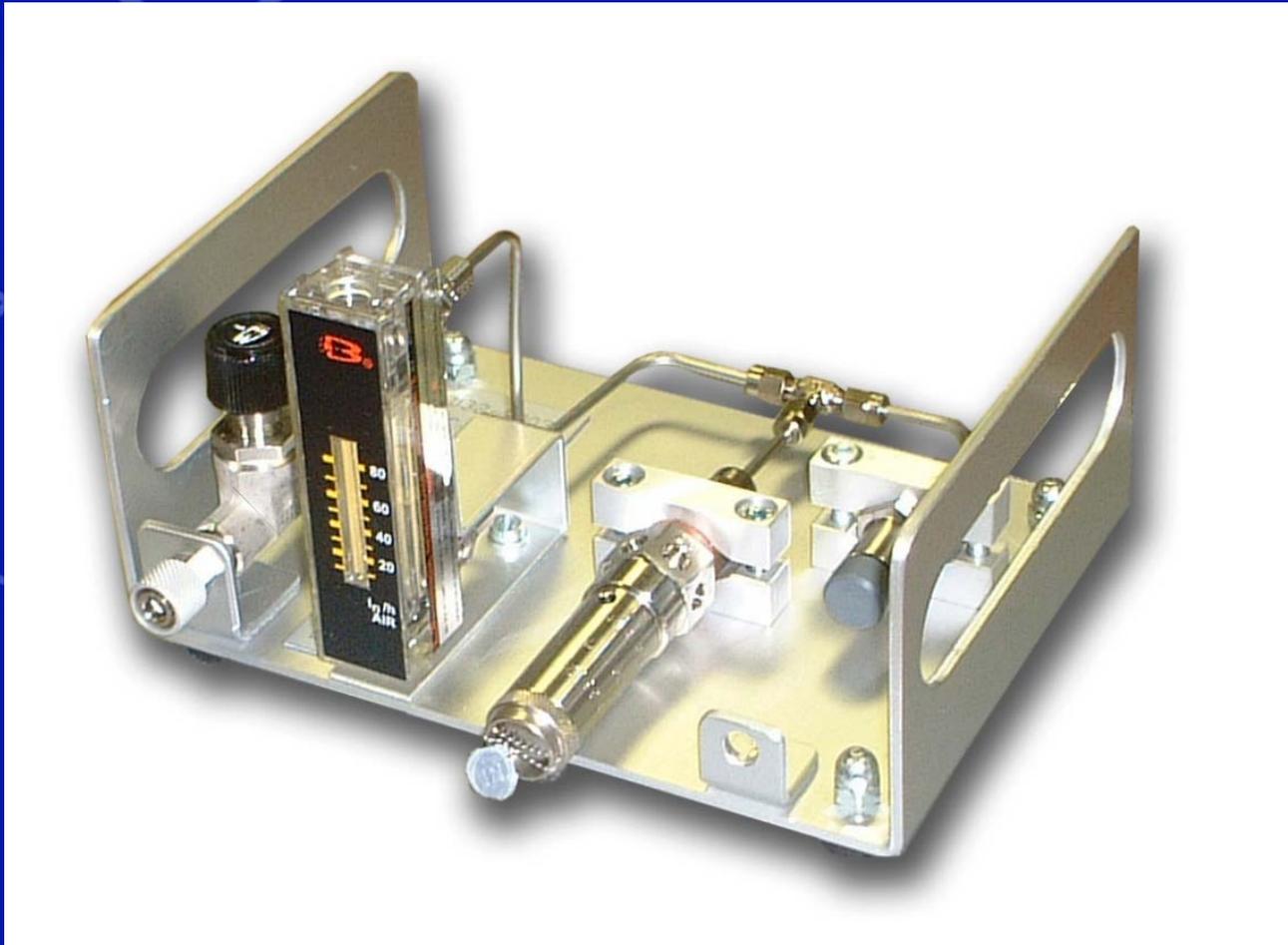
(IEC 60480 and CIGRE TFB3.01.01/2004)

Perform Quality Checks

Methods include:

- Portable Analyzers
 - Electrochemical sensors
 - Spectrometer
 - Tester using reactive tubes
- Gas chromatograph (not suitable for field testing and expensive)

Portable Analyzer



Used SF₆ Storage and Transportation

- Generally need to store and transport used SF₆ gas for
 - disposal of non-reusable gas
 - off-site purification
- Procedures include:
 - Clearly label cylinder as used gas (Apply danger labels and/or use a different color)
 - Follow local transport regulations
 - Arrange for disposal of waste that complies with federal and state regulations



SULPHUR HEXAFLUORIDE USED



C - Corrosive

T+ - Very toxic

R 26/27/28 - Very toxic by inhalation, in contact with skin and if swallowed

S 7/9 - keep container tightly closed and in a well-ventilated place

S 38 - in case of insufficient ventilation, wear suitable respiratory equipment

S 45 - in case of accident or if you feel unwell, seek medical advice immediately
(show the label where possible)

UN 3308 : Toxic, corrosive liquefied gas, N.O.S

Contains : Sulfur hexafluoride - class 2

Source: Bessede, Huet, Montillet - AREVA T&D
and Barbier and Micozzi, - AVANTEC

Used SF₆ Disposal Procedures

- Incineration plants offer destruction services for used SF₆ gas
- SF₆ gas can be destroyed at a thermal process operating at 2100 degrees F
 - Dissociates into reaction products that are passed through wet scrubbers to form gypsum, fluospar minerals
 - Gypsum CaSO₂ used in construction
 - Fluorospar CaF₂ used as an additive in toothpaste

Resources

- SF₆ Recycling Guide (CIGRE Report, August 2003)
- IEC TR 61634 (SF₆ Handling)
- IEC TR 60480 (Used SF₆)
- EPA's EPS Partnership Web site
 - Byproducts of SF₆ Use in the Electric Power Industry, January, 2002
 - Partner SF₆ Handling Procedures
 - Service Provider Directory
 - Catalog of Guidelines and Standards for the Handling and Management of SF₆