

# **SF6 Alternatives**

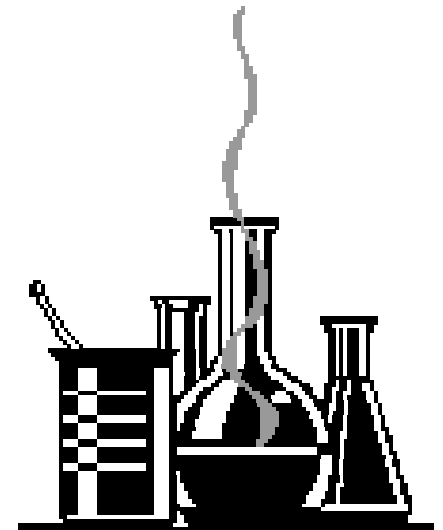
Patrick Avery  
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# SF6 Characteristics

In spite of its advantages of high dielectric strength, thermal stability, and facilitation of production of spacing-saving equipment

SF6 has significant disadvantages:

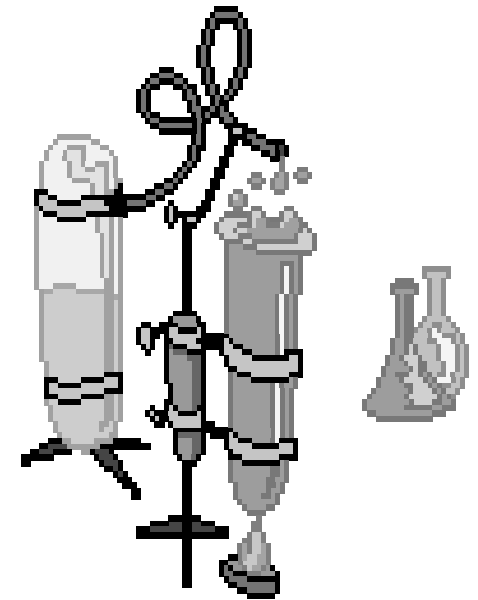
- Very expensive
- Leaks from equipment overtime causing potential harm to both the environment and humans.
- Decomposes into other compounds, including deadly S2F10, when exposed to heat
- Pyrolizes or changes chemically at 440 degrees Fahrenheit, into several new gases or powders like a fine dust



# SF6 Characteristics

- Heated or "sparked" produces a sulfurous, rotten egg smell.
- Inhalation of the S2F10 by-product can cause nausea, lung and organ damage, or death.
- Federal Occupational Health and Safety Administration standards for exposure to S2F10 are set at **10 parts per billion**.
- OSHA recommends that, when handling SF6, the gas "should not be subject to high energy input, such as cigarette smoking, electric heater filaments, welding or cutting torches, or electrical discharges or arcs"

(Citizens Education Project article, dated November 19, 2000).



# SF6 Characteristics

- Clayton found no mortality in rats exposed to SF6 (176,000 ppm) for 18 hours
- Troshikhin and Issakyan observed increased respiration in rats exposed to 80% SF6 and 20% O<sub>2</sub>.



SF6 can be an asphyxiant in acute high exposure conditions

However, these levels are so high it's unlikely that humans will be exposed to these levels

JW Clayton, Occup. Med. 1962; T&I, 1975

# SF6 Uses

SF6 has been used worldwide as an arc interruption, cooling and insulating medium by the electric utility industry in the following main types of electrical equipment:

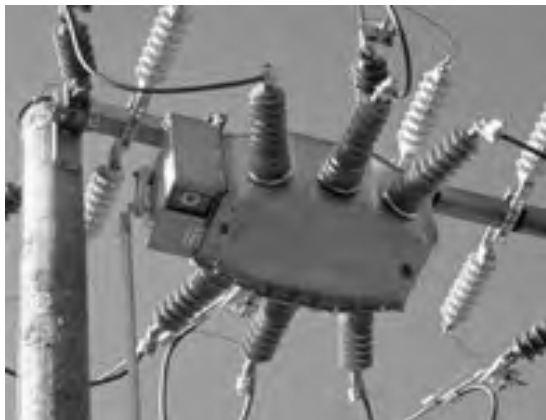
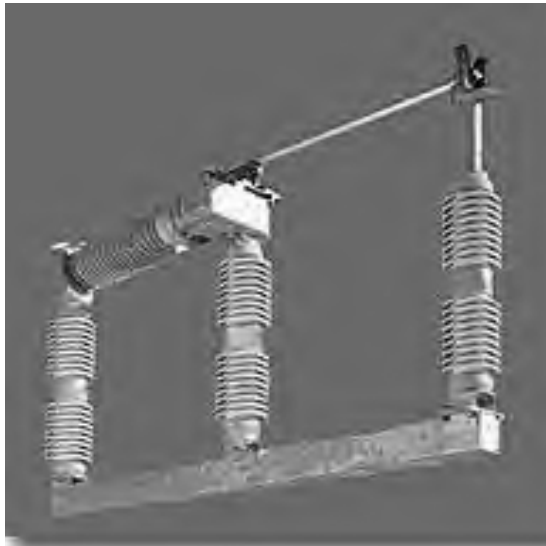
- GIS
- Disconnect switches
- Arresters
- Cutouts
- Circuit breakers
- Reclosers
- Switchgear
- Transformers
- Capacitors
- Coaxial cable

# Manufacturers' Response

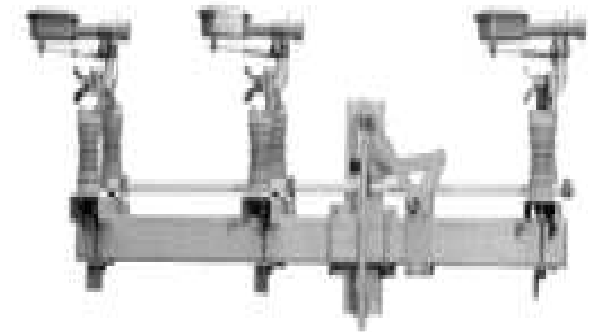
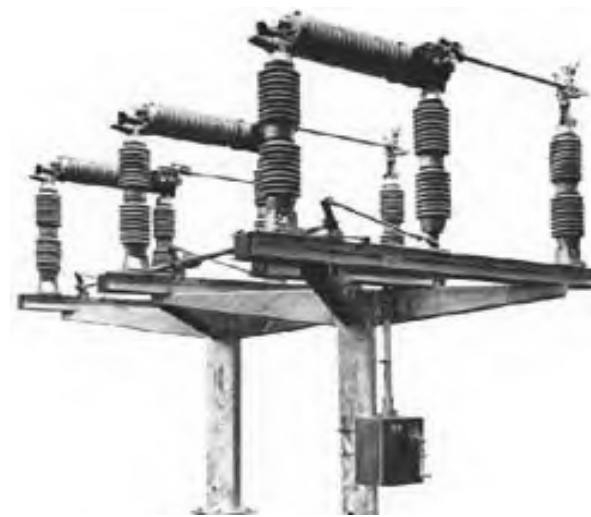
- Manufacturers have developed many environmentally-friendly alternatives to help utilities eliminate the use of SF6 in response to both regulatory agencies' and consumers' concerns about the use of SF6 in transmission and distribution equipment.
- This presentation exhibits some of these products that are available to customers **TODAY** and the benefits that can be gained compared to SF6-based products.

# Disconnect Switches

SF6



AIR



# Disconnect Switches

- Air break switches have proven reliability with over 90 years service history.
  - Lower maintenance costs
  - Non - Toxic
  - Less flammability
  - Less severe catastrophic failures
- Switches are available with voltage ratings of 15kV to 242kV. The rated continuous current is 600A to 2000A. The load break ratings are 1200kA to 2000kA. The BIL ratings are 95kV to 900kV.

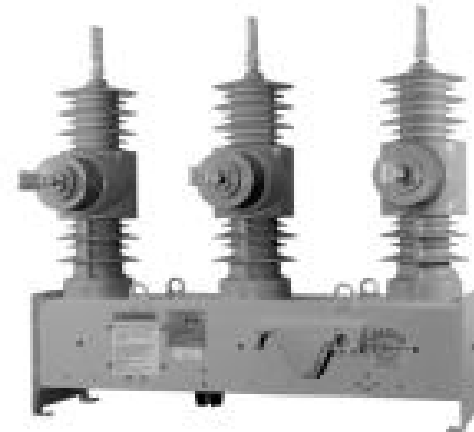


# Reclosers

SF6



Solid Dielectric

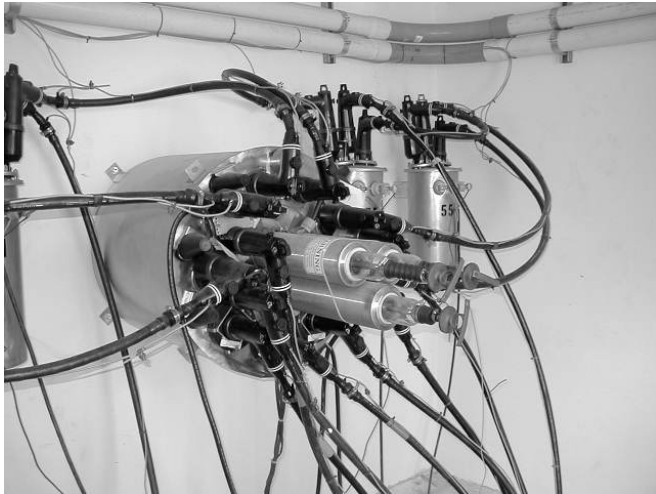


# Solid Dielectric Reclosers

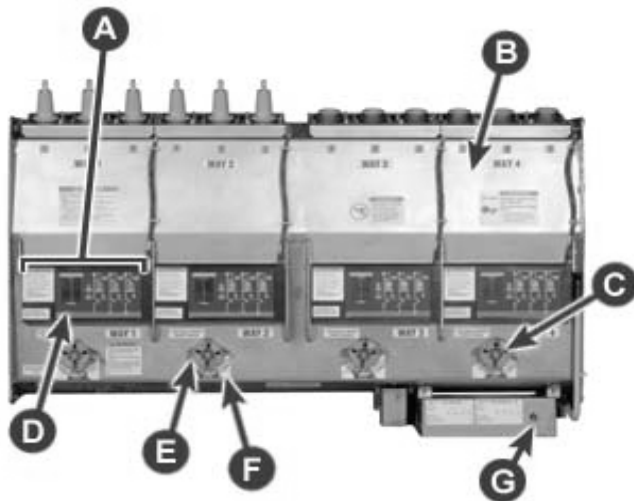
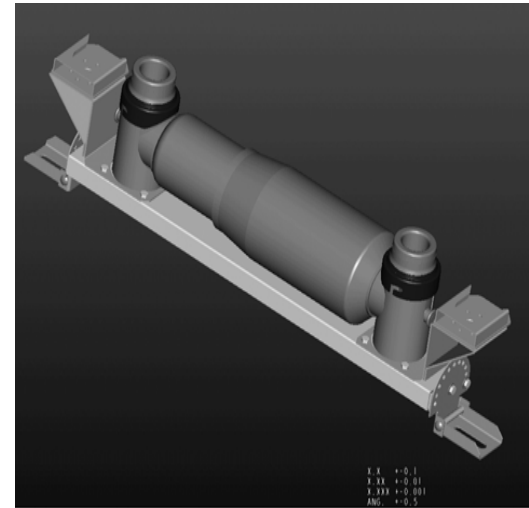
- The solid polymer insulation system does not rely on a gaseous or liquid dielectric. These reclosers are maintenance-free and highly resistant to ozone, oxygen, moisture, contamination, and ultraviolet light.
- These reclosers are available with voltage ratings of 15kV, 27kV, and 38kV. The rated continuous current is 630A and 800A. The interruption ratings are 12.5kA and 16kA. The BIL ratings are 95kV to 170kV.

# Distribution Switchgear

SF6



Solid Dielectric



# Solid Dielectric Switchgear

- Lightweight modular design facilitates assembly into any configuration. Maintenance free and weather resistant design allows installation in coastal and vault applications.
- This switchgear is available with voltage ratings of 15kV, 27kV, and 38kV. The rated continuous current is 600 and 900 Amps. The interruption ratings are 12.5kA to 20kA. The BIL ratings are 95kV to 150kV.

# Alternative Fluids



- Transformers
- Retro fill existing equipment
- Padmount Switchgear
- Regulators

# Benefits of Seed-Based Fluids

- Fire Safety Characteristics
- Performance Characteristics
  - Enhanced Asset Life
- Environmental Characteristics
- Reducing Fire Risk & Hazard
- Reducing Oil Spill Hazard

# Fire Safety



# Less Flammable Fluids

- Fire Points

Mineral Oil:	155 C
Rtemp:	312 C
Silicone Fluid:	340 C
Seed-Based Fluid:	360 C
SF6	444 C



# FM Global Recognition of Fire Safety Power Transformers

- Approved Fluid:
  - $\leq$  10K gallons, only 5 ft vs. 15 ft clearance to non-combustible buildings and other equipment w/o suppression system based on FM fire resistance testing
  - $>$  10K gallons, only 25 ft vs. 50-100 ft
  - Eliminates deluge system (~\$250k)
  - Previously only 1000 gal. or less eligible for 5 ft clearance if not FM Approved transformer

# FM Global Recognition of Fire Safety – Distribution

- Approved (Labeled) Transformer Up To 10 MVA, 35 kV:
  - Only 3 ft clearance required to buildings and other equipment
  - Includes over current, ground fault & tank rupture protection
  - Easier for commercial/industrial customers to meet NEC & verify compliance

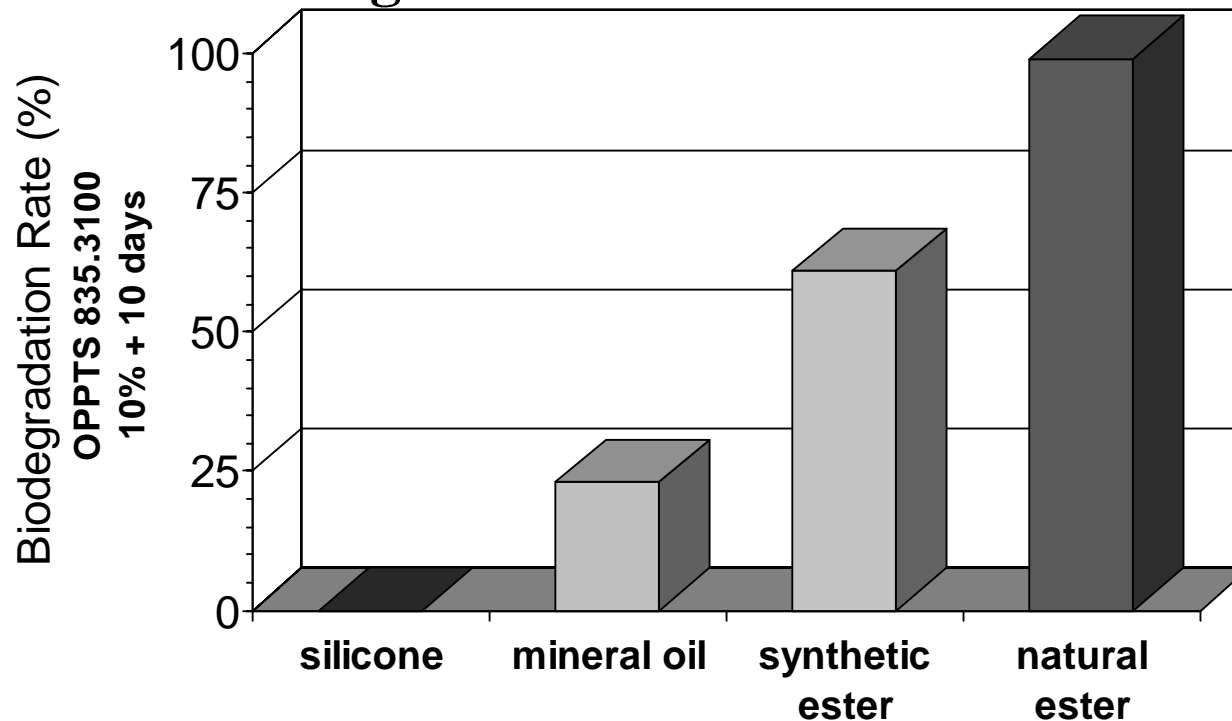
# Environmental

## Acute Aquatic Toxicity Testing

### Natural Ester

**OECD Procedure 203 Fish Acute Toxicity**  
**Results: - zero mortality, No Observable Effect**  
**Concentration  $\geq 1000$  mg/l**

### Biodegradation Rate of Dielectric Fluids



# Environmentally Responsible

- Renewable Resource (Soy) Based
- Rapid and Complete Biodegradation
- Non-Toxic Base & Additives
- Qualifies Under Edible Oil Act
- US/California EPA “ETV” Certified
- Eligible for regulatory relief
- Does Not Contain Petroleum, \* PCB’s, SF6, CFC, PERC, etc. Silicones, or Halogens\*

# Environmental Regulations



- Not Subject to Federal Regulation of Used Oils (Title 40, No. 279)
- Covered by the Edible Oil Regulatory Reform Act (Public Law 104-55)
- Eligible for current and future regulatory relief
- Alternative spill response procedures may be possible (Bioremediation)

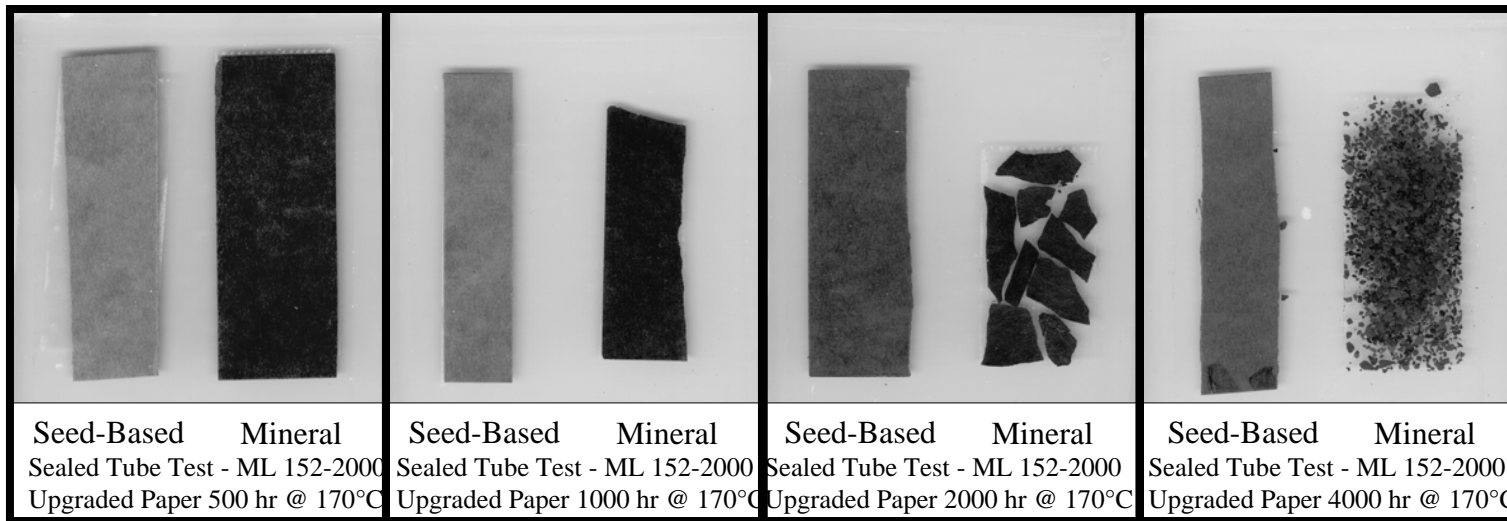
# Performance Advantages

- Extends Paper Insulation Thermal Life in New Transformers
- Dries and Extends Life of Aged Paper
- Tested Sludge-Free per Doble PFVO & Other Accelerated Aging Methods

# Accelerated Insulation Life Tests

- Lockie Tests
- Thermal sealed vessel tests
- Field performance
  - New units
  - Retro fill units

# *Results of the Lockie Tests*



*Aging of paper depends primarily on temperature and water content.*

*Paper Aged in the Seed-Oil based fluid took 5-8 times longer to reach end of life parameters than paper aged in Mineral Oil.*



# Enhanced Life

- Benefit of Longer Paper Life
  - Increased Loading/Overloading – 20%
  - Longer Transformer Life – 5 to 8 times
- Enables transformer manufacturer to get more kVA output per dollar of material.
- Excellent for retrofilling existing liquid filled transformers. Will extract moisture from paper, enhancing remaining thermal insulation life.

# Seed-Oil Based Fluid-Filled Transformers: Field Proven



- Initial Units in Seventh Year of Operation (Installed in July, 1996)
- First External Customer Installation April 1998
- >6000 Transformers in Service
- Frequent Fluid Sample Testing has Confirmed Excellent Fluid Condition Including Key Properties, Dissolved Gas, and Dissolved Metals Data
- Flawless Performance

# Early Adopters

## Sacramento (SMUD)

- 8000 distribution transformers per year
- Cost justified with combination of environmental, paper thermal life and fire safety benefits
- Joint California & US EPA ETV Certification
- Proactive decision to embrace seed oil as the future of distribution transformers

US Navy specifies seed oil as standard

# Key Retrofill Benefits

- Paper Moisture Reduction
- Extension of Remaining Insulation Life/Unit Life
- Essentially Eliminates Risks of Pool Fire and Fire Propagation.
- Improved Environmental Profile

# Retro filling Power Transformers



50MVA 69kV  
Installed in 1957  
Retro filled in 2001

200MVA 161kV  
Installed in 1966  
Retro filled in 2004



# Industrial/Commercial Installations

- Water Treatment
- Schools/Colleges/Universities
- Petrochemical
- Food & Pharmaceutical
- Pulp & Paper
- Military Bases
- Shopping Malls

# SF6 Alternatives Summary

- Industry is concerned about SF6 health and environmental risks
- SF6 use is declining
- Environmentally friendly solutions are increasing
  - Solid dielectrics
  - Seed based fluids



**Questions?**