

Cigre International Workshop

Alternative to SF₆ for high voltage substations

Stresa, August 26th 2015

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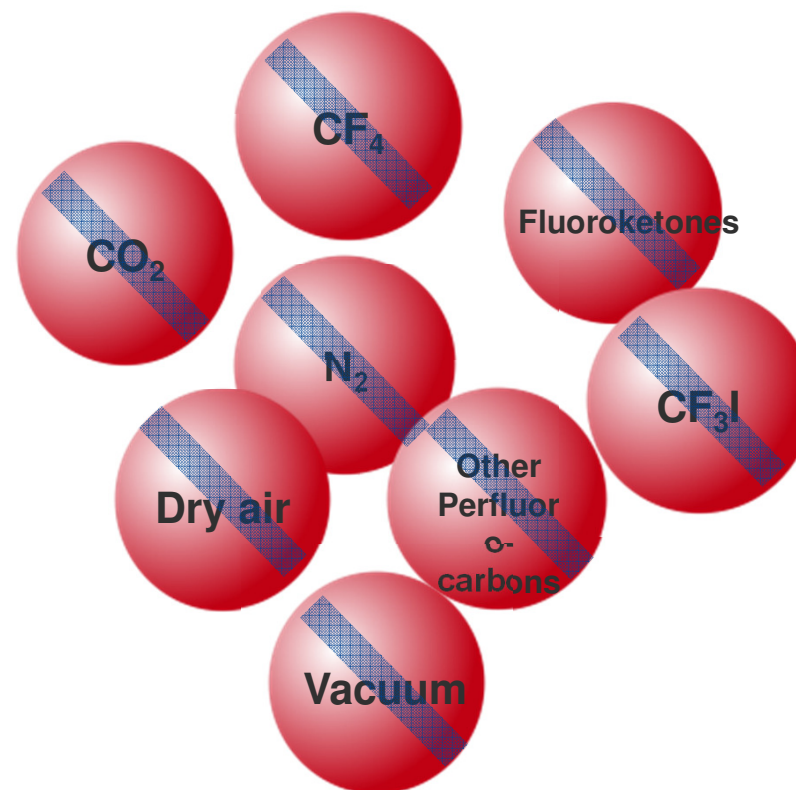


Candidates to SF₆ replacement - Up to g³ !



Molecule	Mol wt (gr)	Diel. Withstand vs. SF ₆	Boiling temp. (°C)	Global warming potential (GWP)	Toxicity
SF ₆	146	1	-63	23 500	☺
Dry air	29	~0,5	-194	0	☺
N ₂	14	~0,4	-196	0	☺
CO ₂	44	~0,45	-78.5	1	☺
CF ₄	88	~0,4	-128	7'400	☺
C ₂ F ₆	138	~0,8	-78	12'200	☺
C ₃ F ₈	188	~0,9	-37	8'800	☺
c-C ₄ F ₈	200	~1,25	-6	10'300	☺
CF ₃ I	196	~1,2	-22,5	5	☹
C5 Ketone	266	~1,4	+25	1	☺

- Low dielectric strength
- Voltage limitation
- High boiling point
- Toxicity
- High Global Warming Potential

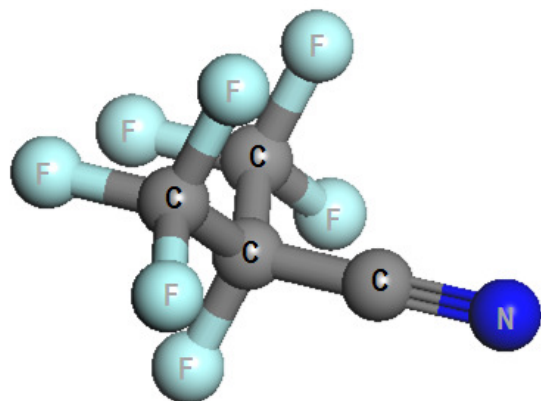


Up to now, no economical green alternative to SF₆ for HV

New gas mixture with a new compound for a SF₆-free solution for HV applications



A new compound developed specifically for dielectric applications



Fluorinated nitrile

2,3,3,3-tetrafluoro-2-(trifluoromethyl)

propanenitrile

heptafluoroisobutyronitrile

CAS # 42532-60-5

Reach registered

3M's NOVEC 4710 reference



A gas mixture of 3M™ Novec™ compound and CO₂

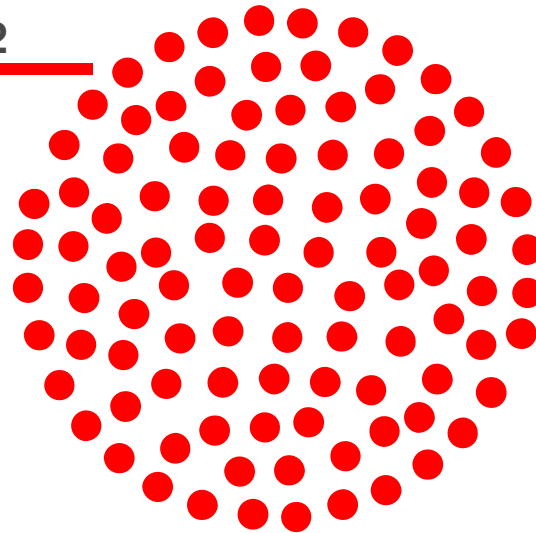
Reduced Global Warming Potential



Low Global Warming Potential: 98% reduction versus SF₆

Alstom  technology
380 kg eq. CO₂

SF₆ technology
23,500 kg eq. CO₂



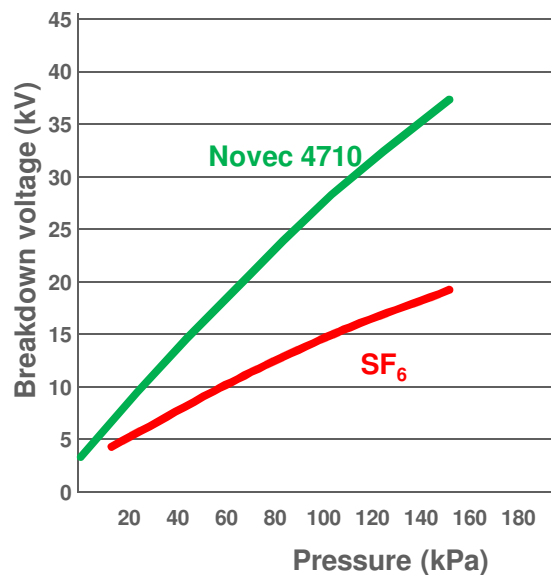
Calculation method

- 100-yr ITH
- IPCC 2013

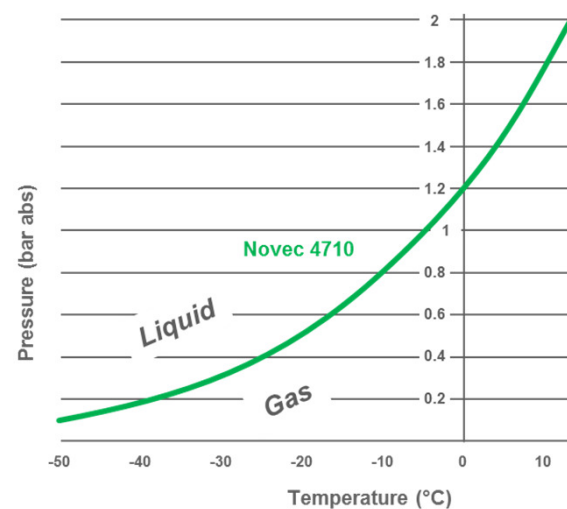
Why a gas mixture? High dielectric performance



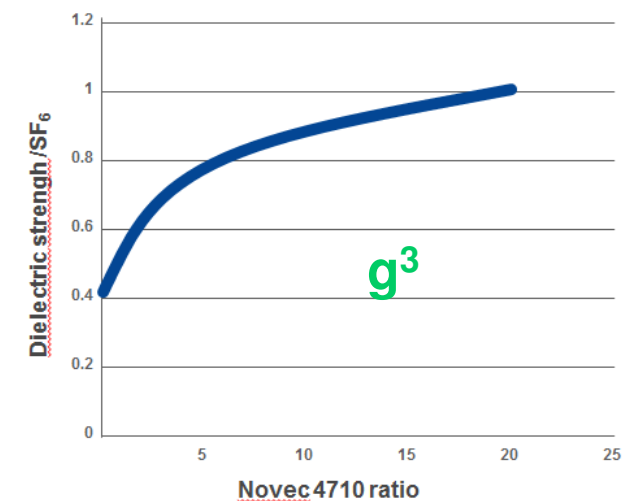
Dielectric withstand is 85 to 100 % that of SF₆



Pure Novec:
Diel. withstand = ~2 x SF₆



Pure Novec:
Boiling temp. = -5° C
@ atmosph. P



For g³:

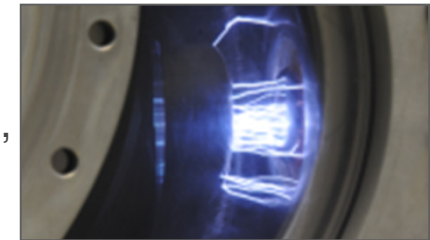
- Ratio of Novec in g³ = f(Temp.)
- @ same pres. diel withs. = 0.85 to 1 x SF₆ for -25° C
- CO₂ overpressure allows to reach the SF₆ dielectric strength.

Switching and Thermal Test results



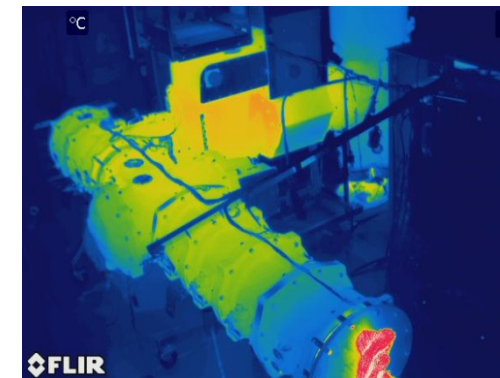
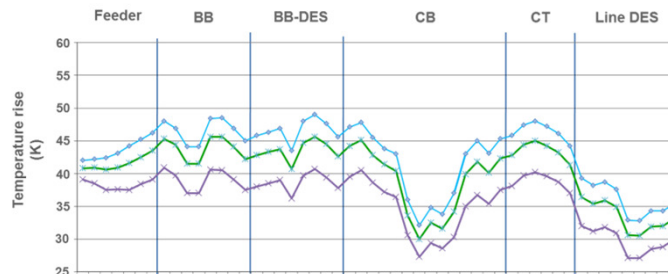
g³ is suitable for GIS disconnectors

- Busbar transfer switching:
 - IEC perfo. demonstrated,
 - No adaptation needed
- Capacitive switching:
 - Slightly better performance for SF₆,
 - Design adaptation needed for g³



Thermal performance is equivalent to CO₂

- Design improvement or de-rating needed versus SF₆



Interrupting Technology



g³ is suitable for interrupting technology

- g³ circuit breaker developed on the basis of existing SF₆ self-blast design
- Parameters and designs need to be adapted
- Test duties performed on 145kV/40kA prototype (Terminal faults T10-T100, SLF, Cap., OP, ...)



For new and polluted gas g³ has same toxicity class gas as SF₆

Characterized through a range of toxicological tests:

- **Low** acute and repeat-dose inhalation **toxicity**
- **Not mutagenic** in vitro
- Occupation Exposure Guideline
- New gas classified in the **lowest hazard category**
- Tests performed by Alstom also on polluted gas after interruption in circuit breaker: **same toxicity class as SF₆**



Corrosion: compatible with usual materials of high voltage equipment



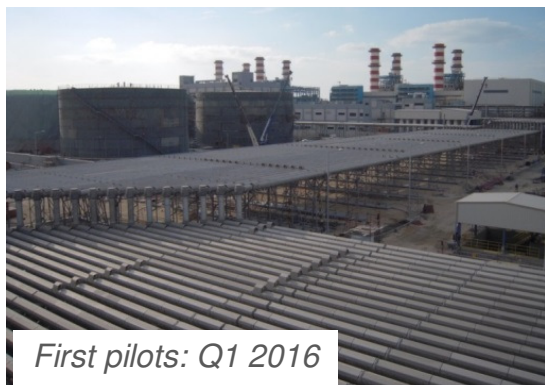
Flammability: similar to SF₆

First Products & applications



Gas Insulated Lines 420kV

Solutions with g³
for -25 °C applications



Current Transformer 245kV

Solution with g³
for -30 °C applications



420kV CMU, CT & VT
available soon

GIS 145kV incl. CB

Solution with g³
for -25 °C applications



Perspectives



- g³ suitable for **most common performances & ambient conditions**, SF₆ still necessary for extreme one,
- **> 98% reduction** on Global Warming Potential,
- Technical and economical **performances & dimensions similar** to existing ranges,
- Direct **substitute** possible in **specific cases** only & with necessary adaptation. Not for circuit breakers,
- **Important developments** necessary.
- First product launched by **mid 2015** & pilots for end 2015/beginning 2016





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