

SF₆ and Alternatives
Frequently Asked Questions
NEMA US 80015-2022

ALTERNATIVES MARKET

Q: Will there be an industry-accepted/defined common gas?

A: Currently, there is no directive or industry initiative to define a single, alternative gas for SF₆.

Q: Why don't all the manufacturers standardize on a single non-SF₆ solution?

A: SF₆ is the most common solution for interruption and switching, and has been for decades. The relatively recent focus on environmental performance compels the industry to research and develop alternatives. Manufacturers are pursuing multiple solutions in order to reach a new balance between technical and environmental performance. Some of the more important factors under consideration:

- Global Warming Potential (GWP)
- Health and Safety (Toxicity)
- Regulatory Exposure
- Interrupting and Switching Performance
- Insulating Performance
- Long-Term Stability
- Influence on Size and Cost of Equipment

Manufacturers pursuing multiple solutions will expose the strengths and weaknesses of each technology such that end users will be the beneficiaries of a technology (technologies) that provide both the technical and environmental performance demanded by society. For more information on this question, please see the Coalition's white paper on [Alternative Insulation Technologies](#).

Q: Can the SF₆ in an existing gas insulated switchgear be replaced with a non-SF₆ alternative?

A: Previously manufactured SF₆ switchgear was not designed to work with replacement insulations. There are a number of reasons for this; some include:

- The change in insulation media may impact the speed at which the mechanisms operate (or prohibit operation entirely).
- For switchgear where the insulation media is used to extinguish an arc, the new media may not flow through the interrupter properly to extinguish the arc.
- The tanks, gaskets, and other materials selected may not be compatible with the chosen replacement.
- The tank and overall equipment design may not be suitable for the pressure requirements of the alternative.

Q: Can the SF₆ in an existing gas insulated circuit breaker be replaced with a non-SF₆ alternative?

A: Previously manufactured SF₆ circuit breakers were not designed to work with replacement insulations. There are a number of reasons for this; some include:

- An SF₆ interrupter is specifically designed to clear system faults using the inherent thermodynamic and dielectric characteristics of SF₆. Non-SF₆ gas mixtures have significantly different properties than SF₆, requiring tailored design and dimensioning in order to achieve their rating.
- Gas sealing of non-SF₆ mixtures requires qualification and application of improved elastomeric sealing compounds in order to achieve reliable, long-term sealing performance.
- The pressure vessel (including bushing insulators) may need to carry higher gas pressure, leading to modification of the design in order to maintain acceptable mechanical stress levels.
- Oxygen is a common component of alternative gas mixtures. Therefore, materials, coatings, and lubricants used within the gas enclosure must be qualified for such service.

PERFORMANCE AND PROPERTIES OF ALTERNATIVES

Q: What will happen if the wrong gas is installed in the equipment?

A: If the equipment is not rated for alternative gases, there is no guarantee of performance unless testing has been performed and certified.

Q: Will a switch manufactured with an alternative be the same size as my current SF₆ switch?

A: It depends on many things, such as the function of the insulating gas (Does it only insulate bus bar or is it used to extinguish the arc?), the temperature ratings of the switchgear, the interrupting ratings of the switchgear, and the pressure requirements of the alternative gas. While some styles and ratings of switchgear are able to be manufactured in a similar size to their SF₆ equivalents, in many cases, the alternative insulated switchgear is larger in size.

Q: Will an alternative gas be suitable for the same temperature rating?

A: It depends on the specific mixture, though some have limitations starting at -5°C and below. This may require the addition of heaters, if applicable for the product type and use.

Q: Does an alternative gas mixture have the same lifecycle as SF₆?

A: As there are many alternatives for use in distribution switchgear below 38 kV, it is not yet clear if the alternative gas will have the same lifecycle, or if it will require maintenance at a given interval to be replaced. In addition, the lifecycle will be impacted by whether the insulating gas is used for arc quenching in addition to dielectrics.

Q: Will alternative gas require higher operating pressures?

A: This will be manufacturer dependent. Each equipment manufacturer will have to certify their designs with the alternative gas. This gas will provide different performance based on many different factors, including the size and shape of the gas tank, the sizes and shapes of the conductors, properties of the gas, etc. Users may not always achieve the same ratings with an alternative gas without a pressure increase, but it is possible.

Q: Will the SF₆ equipment have the same capabilities and characteristics when using the alternative gas?

A: The level of performance will be manufacturer dependent. If a user simply replaces SF₆ with an alternative gas at the same pressure, the dielectric and thermal characteristics often result in different capabilities. The capabilities depend on both the gas properties and the design of the equipment. For example, with some designs, an alternative gas mixture will result in improved

continuous current carrying capabilities, and in other designs the same alternative gas will result in reduced continuous current carrying capabilities due to the shape and size of the gas tank, and the differences in gas circulation.

OPERATIONS

Q: Will a new gas handling procedure and/or gas handling equipment be required if I begin using alternative gases?

A: Very likely. The new gas may be required to be filled to a different pressure, and it may be required to either mix with oxygen or be purchased pre-mixed. Disposal procedures may vary based on the nature of the alternative gas, and the design of the switchgear. Gas replacement could be required at certain intervals depending on the alternative gas.

Q: Is there a training requirement for handling of SF₆ gas alternatives?

A: No federal, state, or local specific training requirements are in place at this time. However, because of the differences on handling pre-mixed gases, or if performing on-site mixing and/or performing recovery of mixed gases, we recommend formal training for individuals tasked with handling, managing, and tracking the use of SF₆ gas alternatives.

Q: How might field gas handling differ from SF₆ to non-SF₆ equipment?

A: The answer depends upon the gas mixture employed and whether the filling gas mixture is pre-mixed or not:

- Technical air (binary mixture of N₂ and O₂) may be bottle or cart filled from either pre-mixed bottles or individual bottles. Technical air may be expelled to the atmosphere except in the case of an internal failure resulting in arc byproducts. In this case, the gas should be recovered and properly disposed of according to the manufacturer's recommendations.
- Binary mixtures of CO₂ and O₂ may be bottle or cart filled, preferably from pre-mixed bottles or alternatively from individual bottles. Virgin mixed gas may be released to the atmosphere, whereas used gas should be recovered and filtered similar to SF₆.
- Ternary mixtures of CO₂, O₂, and a fluorinated component are typically filled from individual bottles via a dedicated gas cart. Pre-heating and mixture control are managed by the cart. Gas recovery is accomplished in a closed system using the same cart.

Q: What is the process for SF₆ gas alternative decomposition handling and disposal?

A: The varied options for SF₆ gas alternatives are not all the same and have different decomposition characteristics. As a result, different approaches are required. But in general, the process is very similar to SF₆ gas. Filtration and capture of decomposition products for 3M™ Novec™ 5110 and 4710 Insulating Gases is possible by use of specifically designed recovery systems. However, the processes and filtration are being researched further. To date there has not been a process defined for disposal and/or reconditioning of alternative gases that have been exposed to decomposition.

Q: How do we know the long-term reliability/performance of alternative gases since they have not been in use in transmission and distribution applications for as long as SF₆?

A: A single answer is not possible at this time. The long-term stability and reliability of the gas will be dependent upon the specific gas mixture in use. The equipment manufacturer will need to provide this information for the specific formulation used in their equipment.

Q: Are hose and cart connections for alternative gases the same as for SF₆?

A: No. Equipment such as recovery and filling equipment for GIE that use an alternative gas as a dielectric or arc quenching medium use different thread and different color coding.

Q: How might field leak detection differ from SF₆ to non-SF₆ equipment?

A: The answer depends upon the gas mixture employed:

- Any CO₂-based mixture may use a commercial hand-held CO₂ detector to localize gas leaks in the field. The manufacturer should be able to recommend specific devices based upon their experience.
- Thermal imaging cameras may also be used to detect large CO₂ leaks on energized equipment. Information from the camera manufacturers indicates that these cameras may be different than those used for SF₆. More study is required before manufacturers are able to make a formal recommendation.
- Leaks of CO₂-based gas mixtures that include a fluorinated component may be localized with traditional hand-held refrigerant (halogen) detectors.
- New technologies are emerging to detect other insulating gases. The equipment manufacturer should be able to provide specific and useful guidance for effective leak detection.

REGULATORY

Q: In the U.S. are there regulations and reporting requirements for gas alternatives?

A: There is no specific reporting regulations for vacuum GIE. However, there are regulations in some states that address reporting requirements for greenhouse gases (including SF₆ alternatives). California is an example of this.

Each of the 3M™ Novec™ Insulating Gases are subject to a U.S. EPA Significant New Use Rule (SNUR). Please see product SDS for further information; they are available at www.3M.com/SDS.

In addition, O₂ (oxygen) also has a specific OSHA safety standard that must be reviewed and adhered to, although it does not specifically address its use in GIE. The OSHA regulation is 1910.104 - Oxygen.

As the industry advances with the research and application of alternative arc quenching and insulation materials, industry regulators will advise on reporting and environmental health and safety regulations, policies, and processes that will apply.

STANDARDS

Q: Do any standards for gas insulated equipment contain leak limits?

A: Yes, see the table below for a non-exhaustive list.

Product Type	Voltage Class	Standard	Clause	Applicability	Leak Rate
Gas Insulated Substations	>52 kV	IEEE C37.122-2021	6.15	SF ₆	0.1%/year (confirmed by type testing) 0.5%/year (confirmed by routine testing)
AC High-Voltage Circuit Breakers	>1 kV	IEEE C37.04-2018	7.11	Closed Pressure Systems—Any Insulating Gas	Maximum leak rate <1%/year. Alternate preferred leak rates are 0.5% and 0.1%/year.
Metal-Enclosed Switchgear	1 kV – 52 kV	IEEE C37.20.9-2019	6.13	Refillable Compartments—Any Insulating Gas	0.5%/year
				Sealed Compartments—Any Insulating Gas	0.1%/year
				Vertical Sections of Gas-Filled Compartments—Any Insulating Gas	0.5%/year
Metal-Enclosed Switchgear	>52 kV	IEC 62271:2021	6.16.3	IEC 62271-1 Clause 6.16.3 Is Applicable Except as Noted:	
				Any Single Compartment to Atmosphere and Between Compartments—Any Insulating Gas	≤0.5%/year

				Any Single Compartment to Atmosphere and Between Compartments—SF ₆ , SF ₆ Mixtures, and Other Gas Mixtures with GWP >1000	≤0.1%/year
				Any Single Compartment to Atmosphere and Between Compartments—Gas Mixtures with GWP ≤1000	≤0.5%/year
				Any Single Compartment to Atmosphere and Between Compartments, for Containing Less than 1 kg of Gas—SF ₆ , SF ₆ Mixtures, and Other Gas Mixtures with GWP >1000	≤0.2%/year
High Voltage Switchgear—Alternating-Current Circuit Breakers	>1 kV	IEC 62271-100:2021	6.16		
High Voltage Switchgear—Alternating Current Disconnectors and Earthing Switches	>1 kV	IEC 62271-102:2018	6.16		
High Voltage Switchgear—Alternating Current Switches	1 kV – 52 kV	IEC 62271-103:2021	6.16		

High Voltage Switchgear—Common Specifications	As applic.	IEC 62271-1:2017	6.17	Controlled Pressure Systems—Insulating Gases Except Ambient Air, SF ₆ , and SF ₆ Mixtures	Specified by the number of replenishments per day or by the pressure drop per day.
	As applic.			Closed Pressure Systems—Insulating Gases—SF ₆ and SF ₆ Mixtures	≤0.5%/year
	As applic.			Closed Pressure Systems—Insulating Gases Except Ambient Air, SF ₆ , and SF ₆ Mixtures	≤1%/year
	As applic.			Sealed Pressure Systems—Insulating Gases Except Ambient Air	Specified by the expected operating duration. Shall be designed in a way to ensure that the minimum functional pressure (density) shall not be attained before the expected end of life. The manufacturer shall specify a permissible leakage rate.
High Voltage Switchgear—Alternating Current Switch-Fuse Combinations	1 kV – 52 kV	IEC 62271-105:2021	6.16		
Subsurface, Vault, and Pad-Mounted Load-Interrupter Switchgear and Fused Load-Interrupter Switchgear for Alternating-Current Systems Up to 38 kV	≤38 kV	IEEE C37.74-2014	7.4		

Pad-Mounted Dry Vault, Submersible, and Overhead Fault Interrupters for Alternating-Current Systems	≤38 kV	IEEE C37.62-2020	6.16	Controlled Pressure Systems—Any Insulating Gases	Specified by the number of replenishments per day or by the pressure drop per day.
				Closed Pressure Systems—Insulating Gases—SF ₆ and SF ₆ Mixtures	≤0.5% or <1.0%/year
				Closed Pressure Systems—Insulating Gases Except SF ₆ and SF ₆ Mixtures	≤0.5% or 1% or 3%/year
				Sealed Pressure Systems—Any Insulating Gases	The tightness of sealed pressure systems is specified by their expected operating life. The expected operating life with regard to leakage performance shall be specified by the manufacturer.
High Voltage Switchgear—Automatic Circuit Reclosers for Alternating-Current Systems	≤38 kV	IEEE C37.60-2018 IEC 62271-111:2019	6.16		

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