



WHITE PAPER

Epoxy-based Hermetic Feedthroughs Boost Switchgear Reliability

The energy industry is seeing increased demand for stable, reliable, and sustainable power sources globally. A leading concern relates to greenhouse gases and climate change. In power distribution, attention remains focused on finding alternatives to the use of sulfur hexafluoride (SF_6) in gas-insulated electrical switchgear. SF_6 is a synthetic fluorinated compound used in both high-voltage and medium-voltage switchgear including ring main units (RMU's) due to its exceptional performance as an electrical insulator; it enables more compact equipment designs compared to oil or vacuum insulated switchgear.

SF_6 GAS INSULATED SWITCHGEAR (GIS)

Despite its usefulness in gas insulated switchgear since the 1950's, SF_6 is one of the most potent greenhouse gases with a global warming potential of 23,500 times that of CO_2 according to the Intergovernmental Panel on Climate Change. The insulated switchgear market currently accounts for 80% of the world's SF_6 usage. Due to its extreme potency and lifespan, the Kyoto Protocol has listed SF_6 among the major substances whose use and emissions should be minimized. In the US, various states are partnering to transition and retire the use of SF_6 . Europe has banned in practically all applications except high-voltage switchgear, and this is only allowed because alternative technologies are not yet economically

viable. Containing SF_6 in gas insulated switchgear remains important for both system function and environmental protection.

One of the most important components of a switchgear assembly is the electrical feedthrough used to carry conductor wires in and out of the gas-insulated cavity.

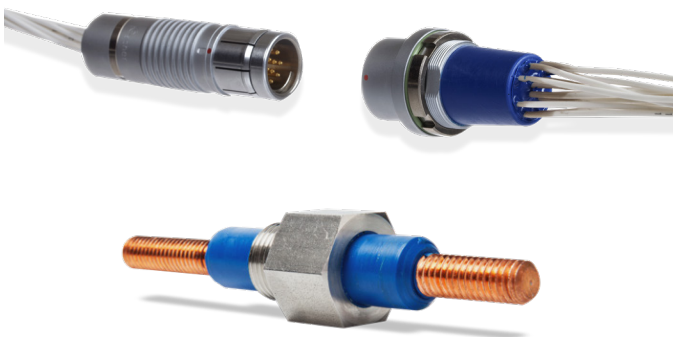


Hermetic feedthroughs ensure that water and moisture stay outside of the switchgear while insulating greenhouse gases stay inside, even if the switchgear were to be submerged in water. This is especially critical for subsurface switchgear installed underground, yet above ground equipment must also be storm-hardened for submersion in flood prone areas. Epoxy-based hermetic feedthroughs are the dominant choice for switchgear applications for a few reasons.

1. Epoxy is chemically inert, making it compatible with the different gases used as switchgear insulation.
2. It also offers both robust mechanical properties and resistance to temperature extremes. Less capable materials often cannot maintain long-lasting hermetic seals around wires and connectors when exposed to switchgear operating environments.
3. Hermetic wire feedthroughs offer higher density, thus reducing the number of mechanical interfaces required to penetrate the bulkhead.

COMMON CONNECTIONS IN SF₆ GIS

- Wire feedthroughs
- Full cable harnessing with integral feedthroughs
- Connector-to-wire feedthroughs including metric circular connectors
- High power feedthroughs up to 30,000 VAC



SENSING A CHANGE

To show improvements are being made, requires measurement. The IEC has developed standards for the measurement of both new (IEC 60376) and used (IEC 60480) SF₆ gas. According to the EPA, California “imposes an annual maximum rate of SF₆ emissions that is reduced by 1 percent over a ten-year period from 2011 to 2020. From 2020 onwards, the maximum emission rate is not to exceed 1 percent. CARB is also proposing regulatory amendments to phase out use of SF₆ in gas-insulated equipment (GIE) starting in 2025.”¹

Sensor technology has advanced to measure multiple properties from a single sensing element such as pressure, temperature, and moisture or humidity. While the sensing element is exposed to gases, the challenge is to seal the electronics used to amplify the signal within a housing. Epoxy-based designs can ensure that the sensing element is able to penetrate the measurement area with a leak-tight seal.

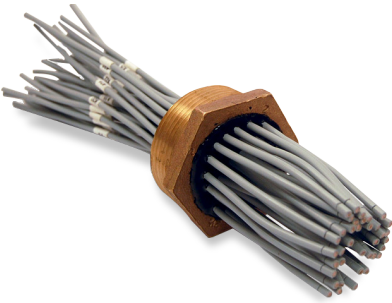
Hermetic feedthroughs interface between the sensor/transducer and the monitoring system, HMI, or telemetry unit. A hermetic electrical connector, wire, or cable can protect the sensor in gas and liquid environments. Hermetic bulkhead connectors protect monitoring equipment while simplifying the installation or on-site usage.

With the decrease in cost of wireless signal transmission and commercialization of many wireless transmission components, the IoT (Internet of Things) industry has seen growth in various industries. In switchgear applications, customers transmit the wired signal from the sealed, SF₆ environment to a non-hazardous area with a telemetry unit to wirelessly monitor the gas condition.



SF₆ ALTERNATIVES

With medium-voltage switchgear, greater progress is being made regarding SF₆ alternatives. Europe has seen the greatest adoption of SF₆ free switchgear and ring main units to date. To match SF₆ performance while reducing environmental risks, new gases, such as 3M's Novec™ 4710 series, need to remain stable over temperature with a high dielectric strength. SF₆ alternative gases are less toxic in new and used mixtures, reducing operator risk and environmental impact. While the environmental impact is less, the requirement for hermetic and water-tight feedthroughs remains critical to the function and reliability of switchgear equipment.



Oil, vacuum, nitrogen, oxygen, and CO₂ are other common alternatives to SF₆. CO₂ seems the most promising future material with claims that it will eliminate 10 tons of greenhouse gases over the switchgear's lifecycle. Regardless of the type of gas used, it is important that all individual components used within the switchgear assembly are compatible. Further, they must be robust and reliable enough to withstand harsh environments, temperature extremes and regular submersion in water.

RELIABLE FEEDTHROUGHS FOR POWER EQUIPMENT

In fact, epoxy-based feedthroughs and connectors meet a range of stringent performance requirements to serve in switchgear applications. These include:

Hermetic with leakage rates less than 1×10^{-9} cc-He/sec per MIL-STD-883 testing

- Vacuum to 1×10^8 Torr
- Pressure to 15,000 PSI
- Temperatures from -100° to 350°F

- Wire gauges from 38 AWG to 500 MCM
- Conductor counts from one wire to 3200 in a single feedthrough
- Cable lengths to 2000 meters
- High-voltage solutions available, greater than 30kV

These hermetically sealed feedthroughs and connectors are widely specified in demanding applications such as medium- and high-voltage electric switchgear used for power distribution, switchgear used in communication networks and military equipment requiring 100% uptime in the most demanding environments.



BEYOND SWITCHGEAR: FEEDTHROUGHS FOR POWER DISTRIBUTION

With reliability and stability foundational elements of the power generation and transmission industries, Douglas Electrical Components focuses on the value of high-quality connections and product availability.

Applications where our hermetic feedthroughs are frequently used:

- Transformers
- Network protectors
- Magnetic bearing flywheels used in smart energy storage
- Steam and gas turbines
- Cryogenic gas generation and storage
- Hydrogen fuel cells and generators
- Lithium battery seals
- Oil & Gas instrumentation, compressors, and controls.

¹ [https://www.epa.gov/eps-partnership/state-and-regional-regulations-related-sf6-emissions-electric-transmission-and#:~:text=It%20imposes%20an%20annual%20maximum,\(GIE\)%20starting%20in%202025.](https://www.epa.gov/eps-partnership/state-and-regional-regulations-related-sf6-emissions-electric-transmission-and#:~:text=It%20imposes%20an%20annual%20maximum,(GIE)%20starting%20in%202025.)

*3M and Novec are trademarks

LEAKAGE RATE COMPARISON

Helium	Nitrogen	Water Vapor	Air		SF ₆		CO ₂	
cm ³ /sec	cm ³ /sec	cm ³ /sec	cm ³ /sec	grams/year	cm ³ /sec	grams/year	cm ³ /sec	grams/year
5.0E+00	5.6E+00	1.0E+01	5.4E+00	840,000	6.4E+00	1,207,546	6.7E+00	380,681
1.0E+00	1.1E+00	2.1E+00	1.1E+00	168,000	1.3E+00	241,509	1.3E+00	76,136
5.0E-01	5.6E-01	1.0E+00	5.4E-01	84,000	6.4E-01	120,755	6.7E-01	38,068
1.0E-01	1.1E-01	2.1E-01	1.1E-01	16,800	1.3E-01	24,151	1.3E-01	7,614
5.0E-02	5.6E-02	1.0E-01	5.4E-02	8,400	6.4E-02	12,075	6.7E-02	3,807
1.0E-02	1.1E-02	2.1E-02	1.1E-02	1,680	1.3E-02	2,415	1.3E-02	761
5.0E-03	5.6E-03	1.0E-02	5.4E-03	840	6.4E-03	1,208	6.7E-03	381
1.0E-03	1.1E-03	2.1E-03	1.1E-03	168	1.3E-03	242	1.3E-03	76
5.0E-04	5.6E-04	1.0E-03	5.4E-04	84	6.4E-04	121	6.7E-04	38
1.0E-04	1.1E-04	2.1E-04	1.1E-04	17	1.3E-04	24	1.3E-04	8
5.0E-05	1.9E-05	2.3E-05	1.9E-05	3	1.9E-05	4	2.0E-05	1
1.0E-05	3.7E-06	4.7E-06	3.7E-06	5.8E-01	3.9E-06	7.3E-01	4.0E-06	2.2E-01
5.0E-06	1.9E-06	2.3E-06	1.9E-06	2.9E-01	1.9E-06	3.6E-01	2.0E-06	1.1E-01
1.0E-06	3.7E-07	4.7E-07	3.7E-07	5.8E-02	3.9E-07	7.3E-02	4.0E-07	2.2E-02
5.0E-07	1.9E-07	2.3E-07	1.9E-07	2.9E-02	1.9E-07	3.6E-02	2.0E-07	1.1E-02
1.0E-07	3.7E-08	4.7E-08	3.7E-08	5.8E-03	3.9E-08	7.3E-03	4.0E-08	2.2E-03
5.0E-08	1.9E-08	2.3E-08	1.9E-08	2.9E-03	1.9E-08	3.6E-03	2.0E-08	1.1E-03
1.0E-08	3.7E-09	4.7E-09	3.7E-09	5.8E-04	3.9E-09	7.3E-04	4.0E-09	2.2E-04
5.0E-09	1.9E-09	2.3E-09	1.9E-09	2.9E-04	1.9E-09	3.6E-04	2.0E-09	1.1E-04
1.0E-09	3.7E-10	4.7E-10	3.7E-10	5.8E-05	3.9E-10	7.3E-05	4.0E-10	2.2E-05