

**New Method for Drying  
SF6 Insulated Substation Assets**

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Sulfur Hexafluoride (SF<sub>6</sub>) is a man-made gas that has remarkable properties for basic electrical insulation, arc extinction, and stability as a molecule. For these reasons, 80% of all substation assets in service today contain SF<sub>6</sub>. These same properties of SF<sub>6</sub> also make it the most potent greenhouse gas responsible for climate change by the greenhouse effect. Efforts to reduce gas leaks in assets and reduce the quantity in the waste stream help to keep SF<sub>6</sub> out of the atmosphere.

Beyond the general case of a small SF<sub>6</sub> leak, contamination of the SF<sub>6</sub> can have an avalanche effect. Contamination (particularly by moisture) reduces the basic insulation provided and reduces the effective tracking distance of internal insulation stand-offs and bushings. These factors can cause catastrophic failure of the equipment due to internal flashover or by a failure to extinguish internal arcing. The rupture of a typical EHV circuit breaker usually releases far more SF<sub>6</sub> to the atmosphere than a small leak. Further, asset failure usually damages surrounding equipment and can cause power interruption to customers and unfavorable news headlines.

This paper describes a method and device which easily and efficiently removes moisture from SF<sub>6</sub> in substation assets. In so doing, it reduces the chance of failure due to internal flashover, and by restoring the dielectric strength of gas already in-use, keeps it from the waste stream.

Water can enter equipment in a few ways. If an asset leaks SF<sub>6</sub>, then it must be refilled occasionally to keep it in service. Unless personnel are trained and extreme care is used in storage and use, the filling equipment itself can be covered with moisture and the moisture will ride into the asset with the SF<sub>6</sub>. Laying the equipment on the ground on a humid day is not considered “best practice” for SF<sub>6</sub> equipment handling.



Another pathway is for the moisture to enter the asset through the leak site. Though counter-intuitive, even though SF6 is leaking out, water can enter through the same hole due to the difference in molecule size as described by Graham's Law of Effusion. Here is a still picture of a gas leak from an SF6 pressure switch bellow, taken with an infrared camera.



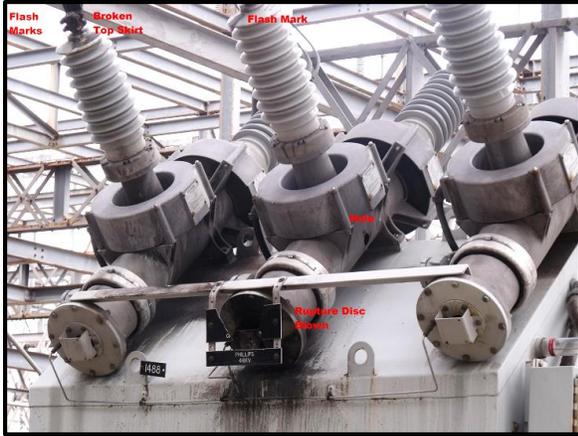
Still another way is mistakenly filling a circuit breaker with wet SF6 that has been removed from some other asset. Marking the cylinders is very important so technicians know.



If a circuit breaker has never leaked gas and never been refilled, chances are good that moisture is not a problem if the original filling was with dry gas. In the normal operation of a circuit breaker to interrupt fault currents, the arcing dissociates SF<sub>6</sub> into other molecules. SF<sub>6</sub> readily heals and recombines but some does not and is the white, foul-smelling sulfurous powder seen in circuit breakers when they are dis-assembled. This powder, when combined with water, creates corrosive sulfuric acids which attack the metals and other materials of the circuit breaker. As the water builds up inside, the internal desiccant bag that is installed during manufacture is exhausted and can hold no more water. At this point, water build up within the breaker is more rapid and can simply puddle at the bottom of the interrupter. Water as frost is not such a great problem. Frost has a much higher dielectric strength than the liquid phase. Water in the liquid phase contaminates the surfaces of internal stand-offs and insulation, encouraging a flashover to ground, particularly for GIL and GIS systems where there are many standoffs. Damage caused by SF<sub>6</sub> contamination for GIL internal standoff insulators is show here:



Below is shown a case where the breaker required many fills over its 35-year life. The leak site admitted enough water over the years to cause the center phase to flash-over; and internal phase to ground fault.



The center phase ruptured, all the SF<sub>6</sub> was released to atmosphere. The force of the blast shattered porcelain and damaged nearby equipment. This failure cost the utility over \$250,000. Disassembly of the other two poles revealed standing water puddled at the base of the interrupter.

Low SF<sub>6</sub> density and moisture build-up were the cause of this failure to interrupt the arc, which continued to burn until the interrupter melted.



The moisture content of SF<sub>6</sub> in HV equipment can be easily measured using portable test equipment. A decision needs to be made after the results are reviewed whether the asset is returned to service. In some cases, the moisture content is marginal and does not warrant a full-scale process of vacuum, rinsing with dry nitrogen, and refill.

A vacuum retro-fill as the process is called, is time-consuming, requires crew from different departments, and requires a lot of expensive equipment.

Any disassembly increases the risk of early-failure from assembly error or fatigued parts. It is better to never take a circuit breaker apart, if possible.

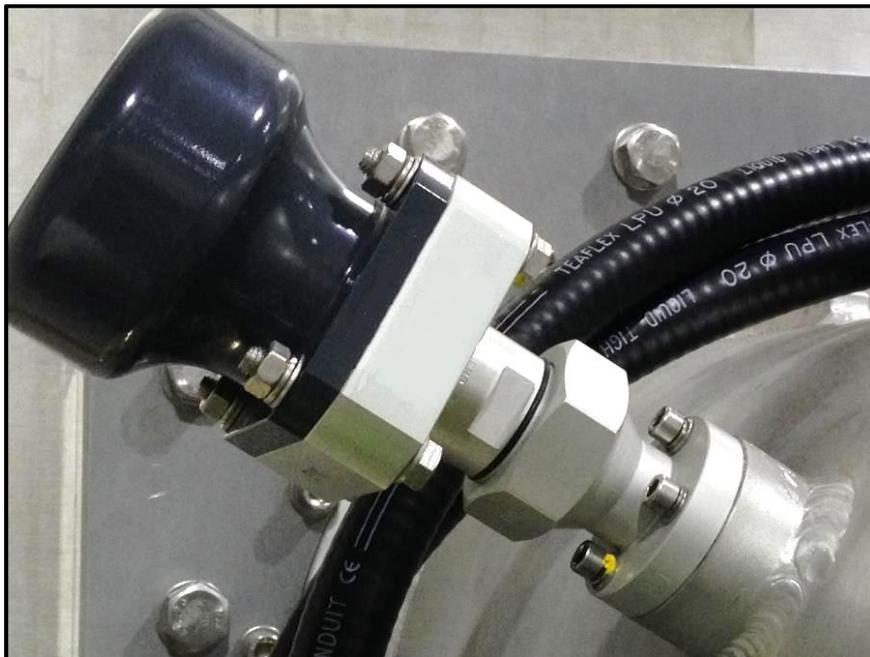
Removing moisture passively from outside the circuit breaker offers many advantages.

The proposed method is very easy to apply, installed on the filling port of the circuit breaker, GIS, or GIL. The device has extremely active desiccating material and is also pre-charged to 1 bar of virgin SF6.

The high build quality and self-sealing connector makes it possible for application even on energized equipment, remaining attached in a semi-permanent manner.

When saturated, the device may be re-built with fresh material and the spent desiccant is not considered hazardous, simplifying disposal. The device will remove up to 40 ml of water.

The concept is well proven on EHV bushings destined for 1100 KV DC converter stations. The large amount of polymer and other process materials includes some small amount of water; it is impossible to avoid. Three such devices are used on this particular bushing to absorb moisture that is released by internal materials. This bushing is half oil insulated and half SF6 insulated. The right hand side holds 600 pounds of SF6. Three absorbing units are used on the right hand side at the mounting flange.



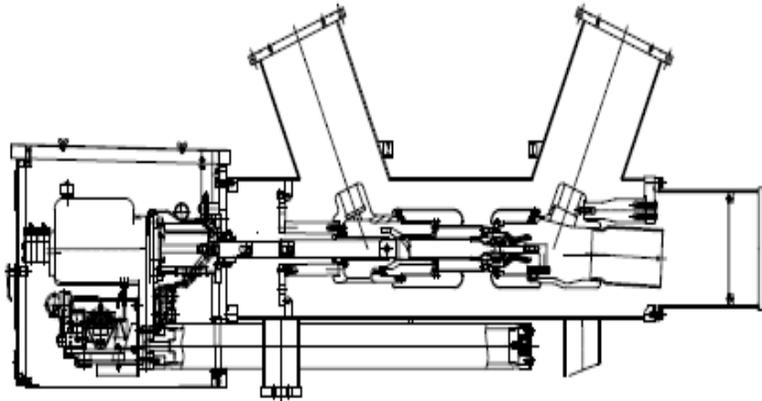
Factory tests were performed at HITACHI HVB factory in Atlanta, GA.

A single pole of a 362Kv Dead-Tank IPO circuit breaker was used in the test. First, a vacuum was applied to the interrupter tank to 1 inch of Mercury.

Then, at the opposite end of the tank, 30 ml of water was injected using a syringe. After that, dry virgin SF<sub>6</sub> with a frost point of -41C was introduced and a pressure of 5.2 bar was maintained.

The absorber device was plumbed to a filling port, as shown.

Daily moisture readings were taken and logged. The temperature of the tank was maintained between 20 and 25 degrees C on the shop floor.

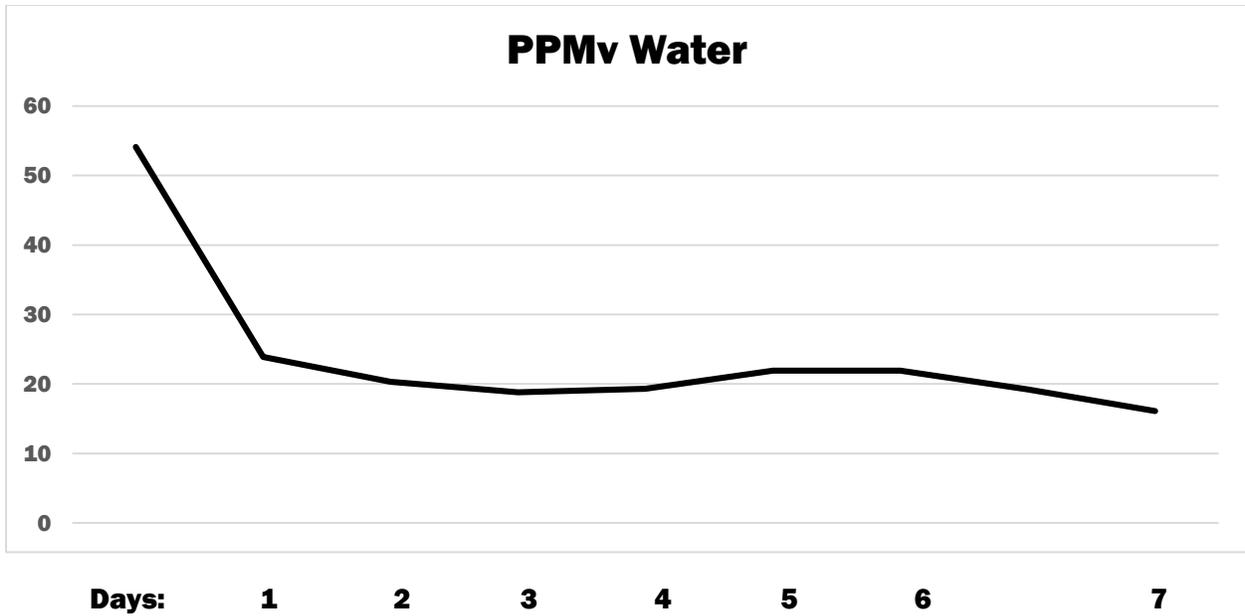


Length of interrupter tank 2.92m; diameter of tank 0.59m; diameter of bushing wells 0.44m

The test data clearly shows rapid moisture content decrease.

Days 5 and 6 were weekend days when the air conditioning was set to a warmer temperature, affecting the partial pressures slightly, shown as a small increase in moisture on those days

<b>Date</b>	<b>Time</b>	<b>Frost Point °C</b>	<b>PPMv Water</b>
8/24/15	6:30	-31.3	54.1
8/25/15	6:30	-38.8	23.9
8/26/15	9:30	-40.2	20.3
8/27/15	6:20	-40.9	18.8
8/28/15	6:10	-40.7	19.3
8/29/15	8:20	-39.5	21.9
8/31/15	6:10	-40.7	19.2
9/1/15	6:20	-42.2	16.1



It was surprising how a passive device at the end of a pipe would become intimate enough with the SF6 to remove moisture very quickly. We were very surprised by how effective it was. Actually, the small pipe may serve to increase gas velocity in normal convective movement. Installation and removal was easily understood; any technician can do it.

The device is in production. It is supplied in a vacuum-sealed bag to keep it clean until needed for use. The absorber is filled with dry SF6 to 1 bar. The standard fitting is 20 mm DN-20 which is self-sealing, so the SF6 is sealed in until use and desiccating material stays dry. There is little risk of introducing contaminants into the asset during assembly.



All standard SF6 fittings are available. Although the Malmkvist (abb) fitting is not self-sealing on the male end, we have designed a modified Malmkvist which does self-seal and is compatible with any standard Malmquist fitting.

The device is named NOMO. It stands for “No Moisture”

Thank you. Please send inquiries to [info@incon.com](mailto:info@incon.com).