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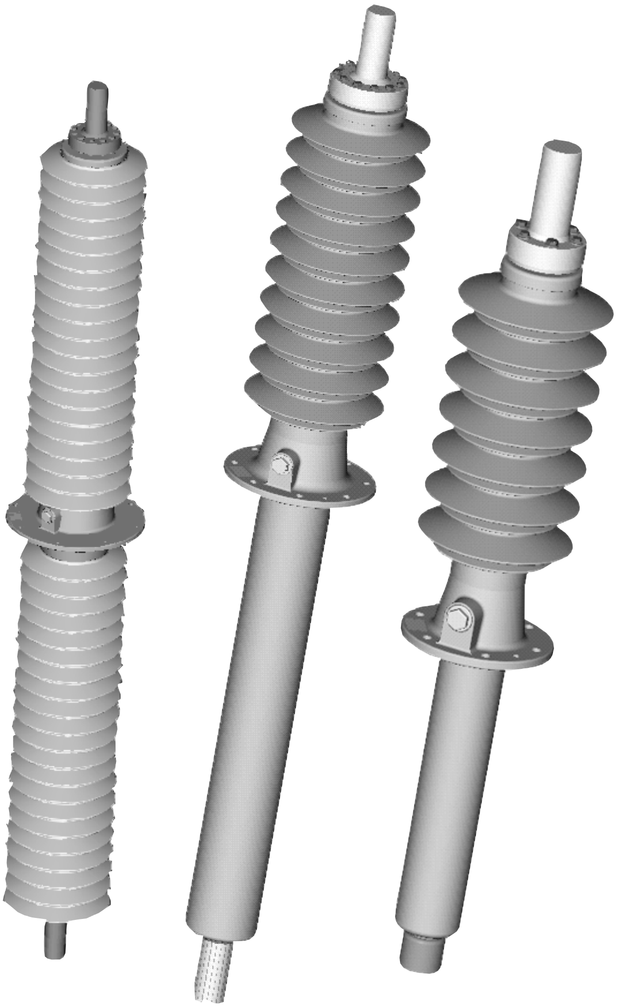
Silicone rubber

Product information



Contents

1 Contents

This product information provides features and properties of the ABB silicone rubber outer insulation of bushings. Corresponding information regarding Resin Impregnated Paper (RIP) as the main inner electrical insulation of bushings are presented in a separate product information, *2750 515-130*.

2 Basics

Silicone rubber is a generic term used for a group of materials with the common feature that the backbone of the basic polymer is a silicon/oxygen chain. This chain is often poly-dimethyl-siloxane, PDMS. Silicone rubber is an elastomere, meaning that it can be deformed within very wide limits with comparatively low forces, and then return to its original shape when the force is released. The material is elastic, but incompressible.

2.1 Formulation

There are many different silicone polymers commercially available, but relatively few are suitable for high voltage equipment. Silicone rubber (SR, or sometimes SIR or SiR) for high voltage outdoor insulation purposes is always a mixture of different materials. The proportions and the quality of the components are chosen to optimise the performance in service as well as during production.

- Basic polymer
- Filler, normally AluminiumTriHydrate, ATH
- Catalyst
- Other additives, for instance mould release agent

2.2 Processing

Different formulations of SiR requires different processing when producing high voltage insulators.

Low pressure moulding (up to 10 bar) with relatively low curing temperatures (50 - 80 °C) is used with low-viscosity RTV (Room Temperature Vulcanised) or LSR (Liquid Silicone Rubber) rubber.

High pressure injection moulding (up to 250 bar) with high curing temperatures (130 - 180 °C) is used with HTV (High Temperature Vulcanising) rubber.

Helical winding of an extruded profile to give an insulator with a ”thread” shaped shed is used with HTV when a high degree of production flexibility is desired.

2.3 GSA

Powersil 311 is used as high voltage outdoor insulation and is a HTV silicone rubber.

2.4 Other bushings

ABB bushing types GOF-SR, GGA, GGFL and GGF are fitted with hollow core composite insulators with cast aluminium flanges and a fibre reinforced epoxy tube as backbone. The insulator housing is applied with low pressure moulding or helical winding, depending on the application.

2.5 Temperature

Silicone rubber in general has a very high chemical and thermal stability. The bonds of the silicone chains are stronger than the bonds of other polymers like EP rubber or epoxy. This property gives silicone rubber its stability against heat and UV radiation. The temperature interval of the GSA silicone rubber is -45 to +180 °C. Below -50 °C the rubber elastic mechanical properties of the material changes and the material becomes more brittle. This change is due to crystallisation of polymer in the filler and is therefore reversible. During the brittle phase the material still works as an insulator, but it becomes sensitive to mechanical shocks. Other factors limit the allowable temperature interval of the bushing to those prescribed in IEC 60137, temperature class 2.

2.6 Chemicals and UV

Silicone rubber withstands ozone and UV light very well. The natural UV radiation mainly consists of wavelengths over 300 nm because shorter wavelengths are filtered out in the atmosphere. Silicone has its maximum UV absorption at 290 nm which means that that wavelengths over 300 nm do not brake down the material.

The rubber swells to some extent in hydrocarbon oils and greases, to approximately the same extent as Chloroprene Rubber, CR. It is not dissolved in oil and has no adverse effect on the electrical performance of transformer oil.

SiR swells when subjected to the following: unpolar liquids like esthers, ethers, aromatic and chlorinated hydrocarbons, concentrated acids and bases, hot steam. The process is reversible.

SiR withstands water, silicone grease, salt, dust.

2.7 Sandstorm and electric erosion

Sandblasting can make the insulator hydrophilic but the hydrophobicity will be recovered.

The material must withstand discharge activity on the surface without being destroyed. The SiR used as outer insulation for ABB high voltage equipment shows excellent properties with respect to erosion resistance. However, this SiR as well as any other commercial rubber shows some discharge activity during severe pollution, though it is less than for non-hydrophobic materials like porcelain and EP rubbers. Polymer materials that have poor erosion resistance will not survive in polluted environments even if the material is hydrophobic under normal conditions due to the fact that discharge activity during the temporarily hydrophilic (wetting) periods sooner or later will eat up the material by erosion. The silicone for ABB high voltage equipment is additionally protected by added aluminium trihydrate (ATH) which has a proven arc and fire resistance capability. ATH contains bound crystal water which has an extinguishing effect on the surface discharges.

2.8 Interfaces

The interface between the silicone rubber, the flanges and the epoxy tube or RIP condenser body beneath is tight and allows no ingress of moisture or contamination. The bond is stronger than the intrinsic mechanical strength of the rubber.

2.9 Hydrophobicity

Hydrophobicity is the property of a surface to break up water films and create separate droplets. The word hydrophobic stems from Greek and means ”fears water”. The opposite is hydrophilic, ”likes water”. The hydrophobicity of silicone rubber is attributed to the low surface energy caused by non-polar groups, such as methylgroups ($-CH_3$). The hydrophobicity of a surface can be measured by spraying water on it and observing the ability to form droplets, and the shape of the water droplet layer (product information *2750 515-142, "Bushing diagnostics and conditioning*). A hydrophobic insulator has a higher voltage withstand during wet tests and pollution tests than a hydrophilic. Tests dominated by pollution layer conductance, like DC pollution tests, will show the highest improvement from porcelain to silicone rubber. Tests dominated by air gap breakdown, like dry lightning impulse testing will show virtually no improvement.

2.10 Loss and recovery of hydrophobicity

Silicone rubber may lose its hydrophobic property temporarily during periods of constant wetting, arcing and darkness. The time for loss of hydrophobicity during the extreme conditions of a 1000 h salt fog tracking and erosion test according to IEC 1109 is in the order of 200 - 500 h. The insulators recover within a few days if allowed to dry, faster if exposed to UV light, heat and mechanical rubbing.

A silicone rubber insulator with lost hydrophobicity is equally good as a porcelain insulator with the same design.

3 Features

Silicone rubber is self-extinguishing.

The elasticity and strength of the material reduces the risk of transport damages.

The low density and the slim shed profiles and the possibility of integrated design gives the insulators and bushings lower weight and reduced size. The GSA bushings weigh typically 30-50 % of their porcelain counterparts with the same mechanical and electrical strength. The mounting can in many cases be made manually, instead of with cranes. Transportation and handling are easier.

The ratio between strength and weight is high, making the products ideal for earthquake zones and mobile substations.

The non-brittle failure mode of the hollow core composite insulator greatly reduces the risk for personnel and equipment in the event of failures and in addition the risk of damage due to vandalism is reduced.

The high surface resistance limits leakage currents and gives high pollution withstand. The need for cleaning is eliminated or greatly reduced and the need for coating is eliminated. The amount of pollution withstood by a silicone rubber insulator during clean fog testing is in the order of 5 times that of porcelain.

4 Application areas

Silicone rubber can be used generally as outer insulation medium within the specifications of the applicable ABB Technical Guide. The best performance is obtained in areas with daily UV exposure. The worst areas, where it is recommended to use the same creepage distance as porcelain, is constant wetting or constant exposure to salt spray during dark or low UV conditions.

Generally, salt, dust, sand, acid rains, bird droppings and many other pollutants are handled very well by silicone rubber.

Short circuiting of short insulators by fresh bird droppings is not avoided by using silicone rubber. In areas where this is a problem, other counter-measures should be taken to discourage the birds from roosting on the bushings. Normally, the high hardness of HTV rubber chosen for GSA is enough to avoid gnawing by birds. Rats and other hard gnawing animals have to be stopped from attacking the insulators during storage and service. If deemed necessary and suitable, it is possible to do a field repair of small damages to the silicone rubber.

Cleaning may be necessary in areas where an in water non-soluble conducting layer of metal, soot, fungus or algae is formed on insulator surfaces. In such cases de-energised manual cleaning with cloths, water and if necessary soft detergent is recommended.

For applications with demands beyond the specifications in the Technical Guides for the specific product, please consult ABB.

5 Material properties

Typical material properties for GSA silicone rubber are listed below:

Colour	Light Grey RAL 7035	
Specific gravity	1.53 g/cm^3	DIN 53479
Hardness	67 Shore A	DIN 53505
Tensile strength	4.5 N/mm^2	DIN 53504
Elongation at break	200 %	DIN 53504
Tear resistance	13 N/mm	ASTM-D 624 B
Dielectric strength (1 mm sheet)	18 kV/mm	DIN VDE 0303
Volume resistivity	10^{15} Wm	DIN VDE 0303
Surface resistivity	10^{13} W	DIN VDE 0303
Dielectric constant (50 Hz)	4.0	DIN VDE 0303
Dissipation factor (tan δ 50 Hz)	< 0.02	DIN VDE 0303
Tracking resistance	3.5 kV	DIN VDE 0441
Arc resistance	300 s	DIN VDE 0441
Oxygen index (LOI)	40 %	ASTM-D 2863
Thermal conductivity	0.6 W/m °C	ASTM-C 177
Flammability	FV-0 (V-0)	IEC 707 (UL94)

6 Testing

The GSA bushings and sub-systems including its different materials have been thoroughly tested. Below some tests on the silicone insulator are listed, tests on resin impregnated paper are presented in the product information 2750 515-130.

6.1 Environmental, screening and ageing tests

Test	**Object**	**Description**
1000 h tracking and erosion test at 84 kV according to IEC 1109.	GSA145-OA/1250/0	A fog with 10 kg/m^3 NaCl fill up the test chamber and there is no direct spraying on the test object.
5000 h ageing test at 14 kV AC according to IEC 1109 Annex C.	GSA24-OA/1250/0 2 x ABB Surge Arresters	The test comprises salt fog with a salinity of 7 kg/m^3, rain, humidity, simulated solar radiation and drying sequences (heat) in 24 h cycle. The test roughly corresponds to 10-15 years of service at the Mediterranean coast of France.
5000 h ageing test at -14 kV DC according to IEC 1109 Annex C.	GSA24-OA/1250/0 2 x ABB Surge Arresters	Test time 5210 h. Humidity, heat, rain, simulated solar radiation and salt fog as above. The same bushing was subjected to the AC 5000 h test.
1000 h tracking and erosion test, 30 kV according to IEC 1109.	2 x GSA52-OA/1250/0	A fog with 10 kg/m^3 NaCl fill up the test chamber and there is no direct spraying on the test object.
1000 h tracking and erosion test, 30 kV according to IEC 1109.	2 x GSA52-OA/1250/0 2 x ABB Surge Arresters	As above with reduced salinity of 1 kg/m^3 NaCl.
Test operation at DITS, 84 kV	GSA123-OA/1250/0	Test installation since January -96. Dungeness Insulation Test Station, operated by NGC at the English channel coast.
Test operation at DITS, 84 kV	GSA145-OA/1250/0	Same as above.
Test operation at Negev Test Station, 100 kV.	GSA145-OA/1250/0	Negev desert since June -97.
Test of performance with thawing ice layer, 100 kV.	GSA170-OA/1600/0.5	Coating insulator with 10 mm ice and measuring of tan d and leakage current along insulator during thawing.
Dielectric type tests according to IEC 60137 and IEEE C57.19.00/01-1991.	GSA52-OA/2000/0 GSA73-OA/2000/0.5 GSA123-OA/1600/0 GSA170-OA/1600/0.5 GSA73-AA/4000 GSA123-AA/2000	Wet power frequency voltage, lightning impulse voltage and chopped lightning impulse voltage.
Dielectric limit test.	GSA52-OA/1250/0 GSA145-OA/1250/0	Increasing and decreasing voltage several times in order to find mean value for sparkover, U_{50}, and scatter.
Determination of lower load temperature limit.	GSA123-OA/1600/0	Bending with mean value of cantilever test and service load during cooling down to -60 °C.
Effect of storage in water.	GSA52-OA/2000/0	Routine test after storage.
Vandalism. with subsequent routine test.	GSA52-OA/2000/0	Throwing brick, hitting with sledge hammer

6.2 Material tests

Test	Object	Description
1000 h tracking and erosion test, EdF HN 26-E-20 Juillet 1991 art.6.	3 samples 100 x 50 x 2.1 mm	Submitting test samples to salt fog during AC and climatic stress cycles without voltage.
Mechanical test after ageing. EdF HN 26-E-20 Juillet 1991 art.7.	6 samples	The purpose of the test is to check that the material mechanical characteristics remain compatible with the use of equipment.
Flammability test IEC 707 (eqvivalent to UL94).	6 samples	A vertically fixed test sample is heated for 10 s and when the flaming ceases the heating for 10 s is repeated.
Cigré low salinity cycle.	1 sample	1000 h cyclic salt fog with 8 hours of salt fog followed by 16 hours of rest. Salt solution with conductivity of 500 mS/cm.
Low temperature crystallisation.	4 samples	Differential Scanning Calorimetry.
Bonding test, SIR to RIP and flange.	3 samples	Tearing by hand and carving with knife.
Water absorption according to ASTM-D 471.	4 samples	Two samples in water with 0.1 wt.% NaCl and two samples in de-ionised water at 90 °C for 100 days. Measurement of weight and hydrophobicity.
Determination of UV radiation durability.	Test specimen	Cycles of radiation, temperature and humidity, measurement of hydrophobicity and mechanical strength.

7 References

The use of silicone rubber as high voltage outdoor insulating material dates back to 1967 when the first line insulators were installed. Since then several thousand hollow core insulators, more than a hundred thousand surge arresters, and more than a million line insulators, with silicone rubber, have been put in service.

The first GGFL bushing was delivered from ABB in 1992. The first GGA bushings were delivered 1993. The first GSA bushings were delivered 1995.

ABB Surge Arresters with the same silicone material have been sold as a commercial product since 1995.

An updated reference list for ABB products with silicone rubber can be obtained from ABB Components Sales Department.

8 Lifetime

The bushings from ABB are designed to withstand service for the life of the equipment it serves, normally at least 30 years.

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