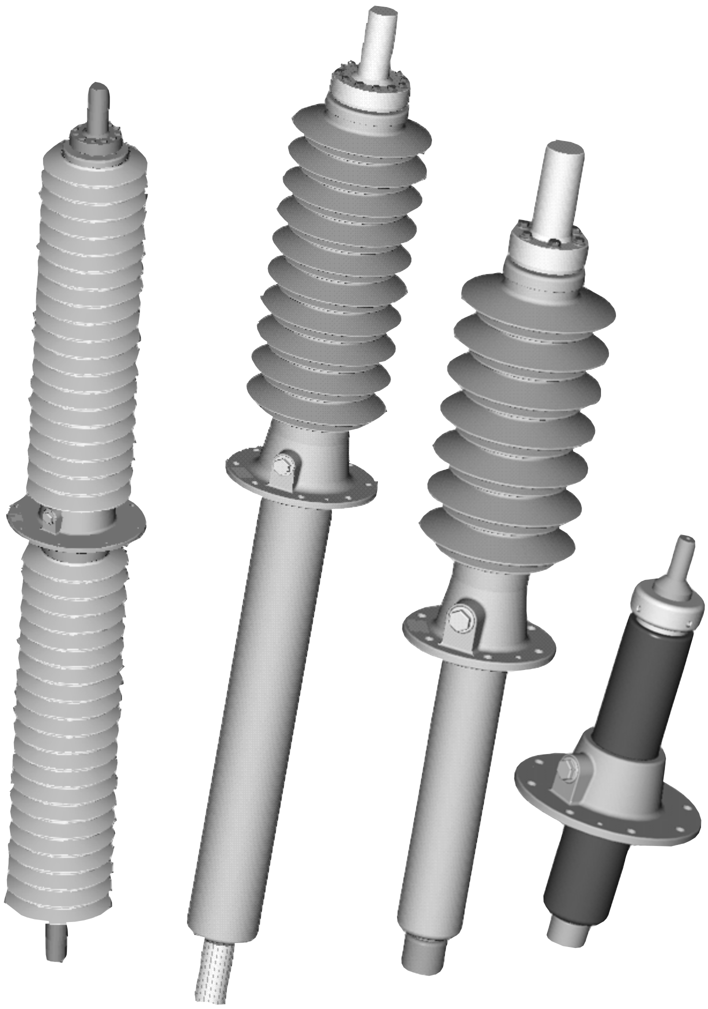
Resin impregnated paper bushings

Product information



Contents

1 Contents

This product information provides features and properties of bushings manufactured with Resin Impregnated Paper as the main inner electrical insulation. Corresponding information regarding outer silicone rubber insulation of bushings and the interface between the resin impregnated paper body and the silicone rubber outer insulation are presented in a separate product information, 2750 515-131.

2 Features

Features and benefits of GSA type solid RIP (Resin Impregnated Paper) bushings:

Solid
With a solid RIP bushing the risk for fire is significantly reduced. In addition, the bushing can be installed in any mounting angle, oil leakage from the bushing together with monitoring of pressure and oil level are eliminated. Furthermore, the bushing is rated at a higher temperature class.

Seals the transformer
The sealing of the transformer becomes more simple with fewer interfaces to seal. With the reduced risk for oil leakage from the transformer the risk for fire is reduced as well.

Non-brittle materials
The design with non-brittle materials increases the protection of people and equipment. The bushing withstands punch and impact to a much greater extent than oil impregnated bushings with porcelain insulators. The earthquake withstand is also increased.

Light weight, compact
The GSA bushings with its RIP body weigh less than than comparable oil impregnated bushings and have a more compact design, thus the GSA bushings are easy to transport and handle during installation and maintanance of the transformer and require less space inside the transformer. The low weight as well significantly increases the earthquake withstand. The materials are chosen to provide the lowest possible life cycle environmental impact.

Compared to Oil Impregnated Paper bushings, GSA bushings with Resin Impregnated Paper have the same excellent partial discharge free performance, but the advantage that there is no need for oil expansion chambers, especially valuable during horizontal mounting.

Several hundred thousand OIP bushings are in service today since the middle of the 1950’s, and they are by far the most common solution for high and extra high voltages. RIP bushings are installed in numbers of several tens of thousands since 1960. Variants of RIP bushings regarding length on the oil-side can easily be designed and manufactured. The delivery time of such variants is usually shorter than that of their OIP counterparts.

3 Basics

3.1 History

Epoxy Resin Impregnated Paper, RIP or ERIP, is an insulating material that has been used in high voltage bushings and other equipment since 1960.

3.2 Standards

ABB Components GSA-type Resin Impregnated Paper bushings are specified and tested according to IEC 137 and IEEE C57.19.00/01 in applicable parts.

3.3 Production

A web of crêped paper in strips or at full width is wound onto a mandrel or a conductor to form a condenser body. Conducting inserts, often aluminium foil, are placed at calculated positions to give a grading of the electric field. This core is heated and dried and then vacuum impregnated by a liquid plastic which is then heated and cured to form a void-free completely solid condenser body.

The impregnation medium is a mixture of epoxy resin, hardener and accelerator. The resin can be a mixture of different epoxy resins to give good processing and service performance. The hardener can be anhydride hardeners of different descriptions. The accelerators vary from application to application, and are usually added in small amounts to modify the curing process.

Mechanically, RIP is in normal service in an almost steel-elastic phase. Above the glass transition temperature, T_g, epoxy comes into a visco-elastic rubbery state. At temperatures above the glass transition temperature, the mechanical strength and the modulus of elasticity drops to a fraction of the normal values. T_g is in the order of 130 °C or higher for RIP to give adequate margin to the IEC 137 specified maximum temperature of 120 °C. Passing the T_g is a reversible process. Material decomposition will occur first at temperatures above 160 °C.

3.4 Electrical stresses

The long term electrical withstand is assured by using a high safety factor between breakdown voltage stress and service voltage stress. Every bushing is proven to be partial discharge free at the rated voltage ($\sqrt{3}$ times the normal in-service phase-to-earth voltage) before leaving ABB Components.

3.5 Mechanical stresses

In order to prevent the long term mechanical creepage of epoxy at elevated temperatures, the design is made with a certain safety factor to the break stress in tension and in bending. GSA bushings are designed to withstand the maximum allowed service stress continuously for at least 30 years.

3.6 Temperature

The working temperature range of RIP is -60 to +120 °C. The working temperature range of the complete bushing is limited to the values specified in the applicable Technical Guide. The long term stability of the material is proved by testing of samples under mechanical stress at elevated temperatures.

Thermal runaway is not encountered in GSA bushing if used according to the limitations in the applicable Technical Guide and IEC 137.

3.7 Failing modes

During external short circuit on the bushing surface, the bushing normally retains its structural integrity and seals the transformer even after the event. The bushing must be checked for damage before re-energizing. Vandalism by stone-throwing normally does not destroy the bushing. The bushing may survive vandalism by gun-fire if the active part of the condenser body is not hit, and the sealing system is not disturbed. A central gun-fire hit through the stressed region of the condenser core will probably cause an electrical breakdown through this channel.

3.8 Chemicals

The epoxy used in GSA bushings has an excellent chemical withstand towards hydrocarbon oils, water, bases and acids. The epoxy is slightly swelled by long term immersion in Acetone, Dichlorethylene, Ethylacetate and Butylacetate. Water is absorbed to an amount of 0,53% per weight at saturation at room temperature. The epoxy does not influence the transformer oil. The storage procedure and precautions are described in the applicable Installation and Maintenance Guide.

3.9 Replacement

Different conductor parts can easily be replaced e.g. if a higher current is required. The bushing itself is manufactured as one integrated part.

4 Material properties

RIP is a composite between paper, epoxy and aluminium foil. Since RIP consists of about 80 % epoxy, the mechanical/electrical/physical behaviour of this composite is dominated by the epoxy. Typical material properties for GSA Resin Impregnated Paper are listed in the table below.

Property	**Value**	**Standard**
Colour	Brown	
Specific gravity	1.27 g/cm^3	DIN 53479
Tensile strength	88 MPa	ISO 527
Elongation at break	2.5 %	ISO 527
Dielectric constant (50 Hz)	3.9	Bushing tests IEC 137
Dissipation factor (tan d 50 Hz)	< 0.005	Bushing tests IEC 137
Modulus of elasticity	4.8 GPa	ISO 527
Temperature expansion coefficient	$45 \cdot 10^{-6}$ K^{-1}	TMA
Thermal conductivity	0.26 W/m·K	ASTM C177-85
Glass transition temperature	139 °C	DSC

5 Testing

The GSA bushings and sub-systems including its different materials have been thoroughly tested according to the sub clauses below. Specific tests on silicone rubber and the interface to RIP are presented in the product information regarding silicone rubber, *2750 515-131*. The tests except 4.1. ”Tests on the epoxy system” are divided in the main functions of the GSA bushing.

5.1 Tests on the epoxy system

The epoxy system and its components have passed full testing according to standards DIN 16 945 ”Reaktionsharze, Reaktionsmittel und Reaktionsharzmassen” and DIN 16 946 Teil 1 ”Giessharzformstoffe - Prüfverfahren” as well as additional internally specified material testing.

5.2 Carry current

Operating current, solid conductor

Test	Object	Standard/ Method
Temperature Rise Test	GSA52-OA/2000/0	IEC 137
Temperature Rise Test	GSA73-OA/2000/0.5	IEC 137
Temperature Rise Test	GSA123-OA/1600/0	IEC 137
Temperature Rise Test	GSA170-OA/1600/0.5	IEC 137
Temperature Rise Test	GSA73-AA/4000	IEC 137
Temperature Rise Test	GSA52-OA/1250/0	IEC 137
Temperature Rise Test	GSA145-OA/1250/0	IEC 137
Temperature Rise Test	GSA123-AA/2000	IEC 137

Operating current, draw lead

Test	Object	Standard/ Method
Temperature Rise Test, 740 mm^2	GSA170-OA/1600/0.5	IEC 137
Temperature Rise Test, 185 mm^2	GSA170-OA/1600/0.5	IEC 137

Short-circuit current

Test	Object	Standard/ Method
Dynamic current + thermal short time curr.	GSA170-OA/1600/0.5	IEC 137
Calculation of short-circuit forces	Whole assortment	IEC 137
Calculation of thermal short time curr.	Each conductor type	IEC 137

5.3 Insulate

Operating voltage, long time

Test	Object	Standard/ Method
1000 h salt fog test, 10 g/m^3	GSA52-OA/1250/0, 2 pc.	IEC 1109
1000 h salt fog test, 1 g/m^3	GSA52-OA/1250/0, 2 pc.	IEC 1109
5000 h environmental test, 14 kV AC	GSA24-OA/1250/0	IEC 1109
5000 h environmental test, 14 kV DC	GSA24-OA/1250/0	IEC 1109
2 years test operation at DITS[1)], 84 kV	GSA123-OA/1250/0	-
2 years test operation at DITS, 84 kV	GSA145-OA/1250/0	-
Test of performance with thawing ice layer	GSA170-OA/1600/0.5	[2)]
Determination of tan δ=f(t), C1=f(t)[3)]	GSA52-OA/2000/0	[4)]

1 Dungeness Insulation Test Station, operated by NGC at the English channel coast.
2 Coating insulator with 10 mm ice and measuring of tan δ and leakage current along insulator during thawing.
3 Tan δ and C1 as a function of temperature.
4 Measuring of tan δ and C1 during temperature cycling in the interval -60..+120 °C

Over voltages

Test	Object	Standard/ Method
Dielectric withstand test	GSA52-OA/2000/0	IEC 137/ IEEE C57.19.00/01-1991
Dielectric withstand test	GSA73-OA/2000/0.5	IEC 137/ IEEE C57.19.00/01-1991
Dielectric withstand test	GSA123-OA/1600/0	IEC 137/ IEEE C57.19.00/01-1991
Dielectric withstand test	GSA170-OA/1600/0.5	IEC 137/ IEEE C57.19.00/01-1991
Dielectric withstand test	GSA73-AA/4000	IEC 137/ IEEE C57.19.00/01-1991
Dielectric withstand test	GSA123-AA/2000	IEC 137/ IEEE C57.19.00/01-1991
Dielectric limit test	GSA52-OA/1250/0	[5]
Dielectric limit test	GSA145-OA/1250/0	[5]

Potential connection

Test	Object	Standard/ Method
Temp. cycling + measuring contact resistance	Conductive glue joints	10 cycles +20..-60..+120..+20 °C

5.4 Seal and fixate the RIP body to the flange

Sealing

Test	Object	Standard/ Method
Temperature cycling, flange sealing	Test specimens	10 cycles +20..-55 °C
Ageing test, flange sealing	Test specimens	1000 h at +120 °C + cycl. as above
Determination of lower temp. limit	Test specimens	Cooling to < -40 °C until leakage

Axial strength of glue joint

Test	Object	Standard/ Method
Axial mechanical strength at room t.	Test specimens	-
Axial mechanical strength at -55 °C	Test specimens	-
Axial mechanical strength at 0 °C	Test specimens	-
Axial mechanical strength at 90 °C	Test specimens	-
Axial mechanical strength at 120 °C	Test specimens	-
Temperature cycling, flange fixation	Test specimens	[6]
Ageing test, flange fixation	Test specimens	[7]

Twist strength of glue joint

Test	Object	Standard/ Method
Twist strength at room temperature	Test specimens	-
Temperature, cycling flange fixation	Test specimens	[8]
Ageing test, flange fixation	Test specimens	[9]

5 Increasing and decreasing voltage several times in order to find mean value for sparkover, U_{50}, and scatter.
6 10 cycles +20..-55..+115..+20 °C and then measuring of axial strength at +20 °C
7 1000 h at +120 °C and then measuring of axial strength at +20 °C
8 10 cycles +20..-55..+115..+20 °C and then measuring of twist strength at +20 °C
9 1000 h at +120 °C and then measuring of twist strength at +20 °C

5.5 Mechanical loads on condenser body

Cyclic load

Test	Object	Standard/ Method
Cyclic bending 2 x 10 000 cycles	GSA52-OA/1250/0	[10]
Cyclic bending 2 x 10 000 cycles	GSA170-OA/1600/0	As above

Static load

Test	Object	Standard/ Method
Static bending test	GSA170-OA/1600/0.5	IEC 137
Static bending test	GSA73-OA/1600/0.5	IEC 137
Static bending test	GSA73-AA/4000	IEC 137
Acoustic emission during bending at 20 °C	GSA52-OA/1250/0	-
Acoustic emission during bending at 90 °C	GSA52-OA/1250/0	-
Acoustic emission during bending at -40 °C	GSA52-OA/1250/0	-
Bending limit test	GSA52-OA/1250/0, 3 pc.	-
Bending test with strain gauge	GSA170-OA/1600/—	IEC 1462 Ed. 1, March 1995
Bending test with strain gauge	GSA73-OA/2000/—	IEC 1462 Ed. 1, March 1995
Determination of pull strength	Test specimens RIP	ISO 527
Pull strength at different process parameters	Test specimens RIP	ISO 527

Earthquake

Test	Object	Standard/ Method
Full scale vibration test	GSA170-OA/1600/0.5	IEC 1463
Vibration response investigation	GSA170-OA/1600/0.5	IEC 1463
Vibration response investigation	GSA52-OA/2000/0	IEC 1463
Calculation of earthquake strength	Whole assortment	IEC 1463

10 Load equal to maximum service load of current bushing. Measuring of deflection at top and lower end of bushing.

5.6 Environmental loads

In order to ensure that the GSA bushings withstands any relevant environmental load affecting the bushing during its lifetime, tests are carried out both on SIR, RIP and sealing system. The table below shows tests carried out on RIP with respect to environmental loads. Environmental testing on silicone rubber and on the interface to RIP are presented in the silicone rubber product information.

Test	Object	Standard/ Method
Determination. of diffusion properties of RIP	Test specimen RIP	-
Effect of longtime storage in humid environm.	GSA52-OA/2000/0	Routine test after storage, IEC 137
Effect of storage in water	GSA52-OA/2000/0	Routine test after storage, IEC 137
Test of water absorption in RIP	Test specimen RIP	IEC 1462
Determination of lower temperature limit	GSA123-OA/1600/0	Bending during cooling to -60 °C
Determination of UV radiation durability, RIP	Test specimen RIP	Radiation + test of mechanical prop.
Determination of chemical durability, RIP	Test specimen RIP	Exposure + test of mechanical prop.
Hydrolysis of RIP	Test specimen RIP	VDE 0441 Teil 1

5.7 Special functional demands

Shall not cause fire

Test	Object	Standard/ Method
Test of flammability, RIP	Test specimen RIP	UL 94

Have a non-shattering failure mode

Test	Object	Standard/ Method
Vandalism	GSA52-OA/2000/0	Throw brick on bushing

Be maintenance-free

Test	Object	Standard/ Method
Summary of maint. and environm. demands	—	Calculation

Allow safe installation on site

Test	Object	Standard/ Method
Failure mode and effect analysis	Bushing design	Classic FMEA
Test assembly solid + pull through conductor	GSA bushing	-

Not cause hazardous environmental impact

Test	Object	Standard/ Method
Product life cycle analysis	Bushing design	Classic LCA analysis
Process LCA	Manufacturing process	Classic LCA analysis

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