LIGHTNING ARRESTERS WITH POLYMERIC HOUSING : NATURAL AGEING

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SUMMARY

Since development of lightning arresters or insulators which use insulated housings from synthetic materials began, one of the greatest difficulties has been to define a correlation between accelerated ageing in the laboratory and natural ageing when part of the network. With this as the aim, the purpose of this study is, from one point, to present a study on the natural ageing of lightning arresters with silicone housings, taken from examples of FERRAZ lightning arresters installed within the medium voltage French distribution network since 1992, and from another point, by comparing natural damage with damage produced by different types of accelerated ageing tests.

PRESENTATION OF THE LIGHTNING ARRESTER WITH A SYNTHETIC HOUSING

The FERRAZ lightning arrester with a synthetic housing, as shown in Figure 1 consists principally of a stack of zinc oxide based ceramic plates and an RTV type silicone housing moulded directly onto them.

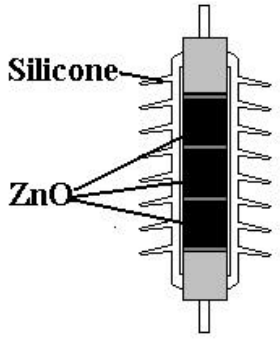


Figure N°1

The main parameters, related to the varied constraints of ageing which will feature in the following chapters, are:

- for withstand against pollution: the gradient of the service voltage expressed in kV/cm which is the ratio of the constant service voltage of the lightning arrester, by the creepage distance of the housing. In the case of those lightning arresters studied, this ratio is 0.167 kV/cm.
- for the hydrophobic characteristics of the housing, important for the dielectric withstand to rain or pollution: the contact angle expressed in degrees which, for the silicone studied, was between 105◦ and 110◦.

STUDY OF NATURAL AGEING

This study is in three parts:

- the first represents the results of the measure of the superficial leakage current and the duration of hydrophobic transitions from tests carried out on naturally ageing lightning arresters.

- the second groups together the measured results of mechanical characteristics of test-piece housing material taken from naturally ageing lightning arresters and test-piece material taken from artificially ageing lightning arresters.

- the third shows analysis results of test-piece material taken from naturally ageing lightning arresters and from artificially ageing lightning arresters.

Measure of superficial leakage current and of durations of hydrophobic transitions

The loss of characteristics provoked by natural ageing are principally due to the action of Ultraviolet rays on the molecules which make up the surface of the housing material and to the action of pollution.

As far as the UV action is concerned : it breaks down the SiO chemical liaison and thus provokes a surface oxidisation of the material. The material thereby loses its insulation properties. The direct consequence of this damage is a lesser withstand to a saline atmosphere and to pollution, which results in an increase of superficial leakage current which passes to the surface of the housing resulting in service voltage.

The other important effect is that of pollution, either saline, industrial or organic (algae, fungus, ...).The deposit of a layer of pollutant on the housing modifies the surface properties of its material, in particular its hydrophobic character. In this case the consequence is the same as with the effect of UV rays, that is, the increase of superficial current. The duration corresponding to this increase is the duration of hydrophobic transition. To define this last characteristic more precisely : A new silicone type of material, completely clean is totally hydrophobic, water on its surface forms completely separate droplets, surface current passes badly between disjointed humid areas, it is therefore of weak value. Conversely if the material has lost its hydrophobic character the water spreads over its surface and the current wastage flows more easily, it increases. Thus in the case of prolonged foggy pollutant conditions the surface of the material passes from a hydrophobic condition to an absorbent condition thus establishing a duration of transition. This duration may be longer or shorter depending on the material and its condition of ageing.

We have seen that one of the important parameters in judging the ageing of a material is the variation of the surface current when the lightning arrester is subjected to voltage. However this damage of the surface is only evident under certain humidity and pollution conditions, it cannot be detected on a housing which is completely dry and without pollutants present.

It is for this reason that we have used the "Tracking Wheel Test" as a criteria for the comparison of ageing, or otherwise known in the Canadian Standard LWIWG-01 as "Dead-end/suspension Composite Insulator for Distribution Lines".
According to this test procedure the lightning arrester can be seen in four different situations during each cycle :

- In position 1 the lightning arrester remains under voltage for a period of 60 seconds in such a way that superficial discharges are created.
- In position 2 the lightning arrester cools down.
- In position 3 the lightning arrester is immersed in a saline solution in order to create a pollutant layer.
- In position 4 the lightning arrester is drained.

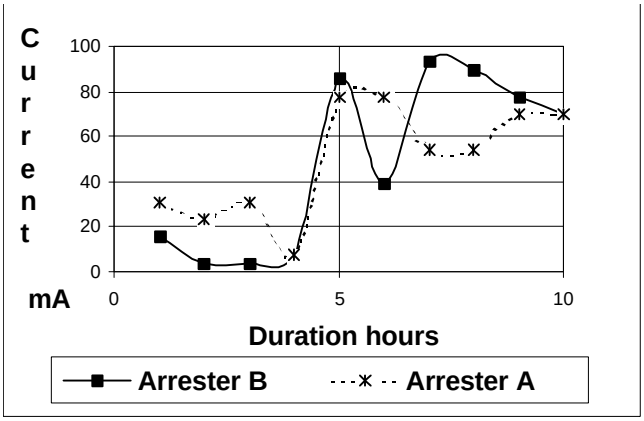
The parameters of the test are : :

- Gradient of voltage of the material : 0.276 kV/cm.
- Conductivity of the saline solution : 1000 microsiemens
- Duration of the test : 150 hours minimum

The sample of lightning arresters used in the study were taken from French network after 5 years service in a seaside area.
Lightning arrester A : 5 years service in a seaside area.

Lightning arrester B : lightning arrester from the same standard batch of manufacture as those above

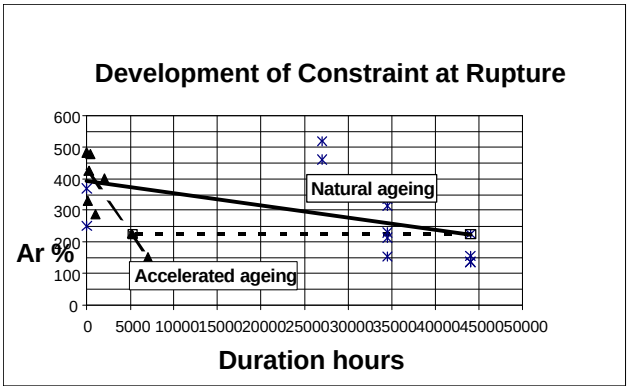
The following network of curves represents the superficial leakage current of each lightning arrester in relation to the duration of the test.



The study of these curves clearly shows that there is no difference in the behaviour/condition between the non exposed lightning arresters and the lightning arresters taken from the network .
The duration of the hydrophobic transitions are equivalent, approximately 5 hours, and also the values of the leakage current, in the order of 100 mA.
As far as the insulation characteristics are concerned, there is no premature ageing after 5 years of service in an exposed area.

Measure of Mechanical Characteristics on Test-Pieces of Housing Material

The two characteristics chosen as parameters of measure are the elongation at rupture Ar expressed as a % and the constraint at rupture Cr expressed as mPa. The test-pieces of housing material were taken from lightning arresters subjected to the following conditions:
3 Lightning arresters : 5 years service in an area in the South of France
5 Lightning arresters B : 4 years service in a seaside area
3 Lightning arresters C : 3 years service in an industrial area
1 Lightning arresters D : Standard lightning arrester having undergone a climatic ageing Xénotest as per NFT 460-042 standard with a duration of 5000 hours..



From the diagram above, which obviously shows the appearance of more rapid ageing during the accelerated test, we are able to make the following observations:

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- The length of time in service is the predominant factor rather than the site of the installation
- We are able to establish a correlation between this type of test and natural ageing and define an acceleration factor from the test by comparing the kinetics of the development of characteristic studied.

For the elongation at rupture the coefficient was:

$K_{Ar} = 44000/5200 = 8.5$

By extrapolating this factor, a real ageing of 20 years could be simulated by a climatic test duration of 2 years.

Analysis of Test-Pieces of Housing Material

These surge arrester housings are made out of a fluid Liquid Silicone Rubber (LSR). The main characteristics of the LSR are given below ; basically this silicone elastomer belongs to the class of reinforced polydimethylsiloxane derivatives.

Viscosity (A+B) mPA.s	Hardness ShA	Tensile strength Mpa	Tensile strength kN/m	Elongation at break %
90 000	57	6	12	200

Diagnostic methods

Most of the surface characterisations have been performed on a surge arrester specimen which have been on the field for 5 years.

- SEM and Profilometry methods for the characterisation of the superficial morphology. The Profilometer was a Mutituyo Surftest 301 : the roughness is measured with a 5 µm diamond sensor on a 2.5 x 2.5 mm area. The maximum depth Ry and the arithmetic means Ra of the observed profiles have been determined. These observations have been run on ethanol washed surfaces in order to characterise the silicone surface without any pollutant.The surface of the selected samples were observed with an Hitachi Z800 scanning electron microscope after gold metallization.
- Single Reflection Diamond ATR spectroscopy in order to make evidence of any visible modification of the chemical composition. A Perkin Elmer-1760 FTIR spectrometer equipped with a Golden Gate single reflection diamond ATR apparatus has been used. Superficial layers of 0.6 mm x 2 mm x 2 µm can be observed with this single reflection method.
- The hydrophobicity of the materials have been characterised by static contact angle measurements. This measurement have been performed with water . The drop profile is optically analysed with a telescopic video microscope : Olympus DMS 300. Moreover, in order to estimate the remaining potential of hydrophobicity recovery after 5 years of outdoor exposure, the amounts and the physicochemical characteristics of free silicone oils have been determinate by solvent extraction IR spectroscopy and GPC.

In every cases, the characteristics of the exposed materials have been compared with sample of unexposed silicone elastomer which have been taken from a new surge arrester or from a moulded film of the same material.

Results

The general aspect of one of the two surge arrester can be seen in Figure 2a. There is no apparent sign of erosion or tracking on the sheds. Presence of pollutant in the form of small particles of few microns can be seen on the entire surface with some domains contaminated by micro-organisms.

- Superficial physicochemical characteristics.

Figure 2b and 2c give typical illustrations of the surface materials of an exposed and unexposed surge arrester, respectively. There are no visible cracks or traces of erosion at this scale either ; this observation is consistent with other published data [1]. On the other hand, small particles are present at the surface of the exposed specimen. These particles can be washed off by ethanol ; according to the IR spectra they are silicates.

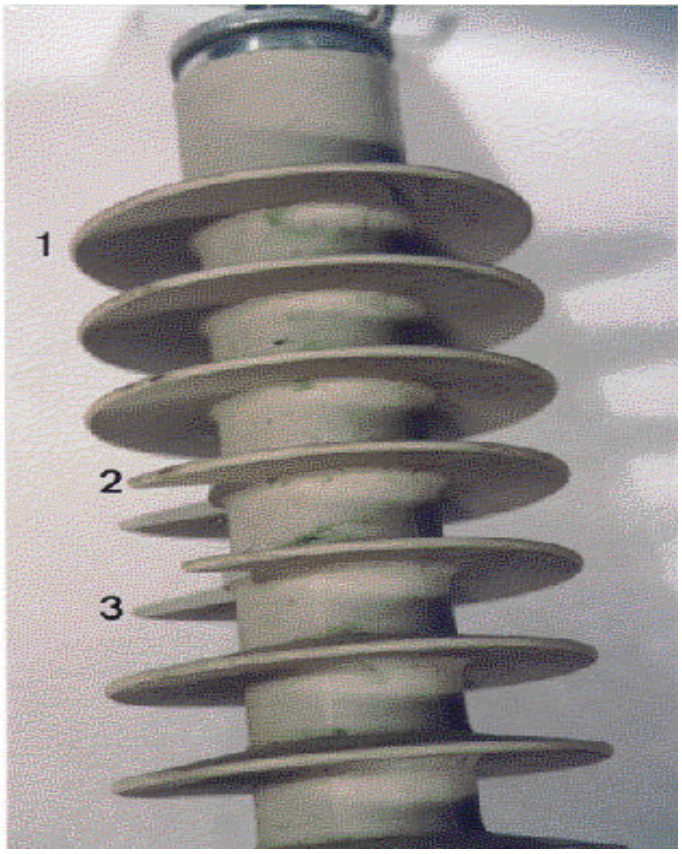

Figure 2a
General view of the upper part of the specimen

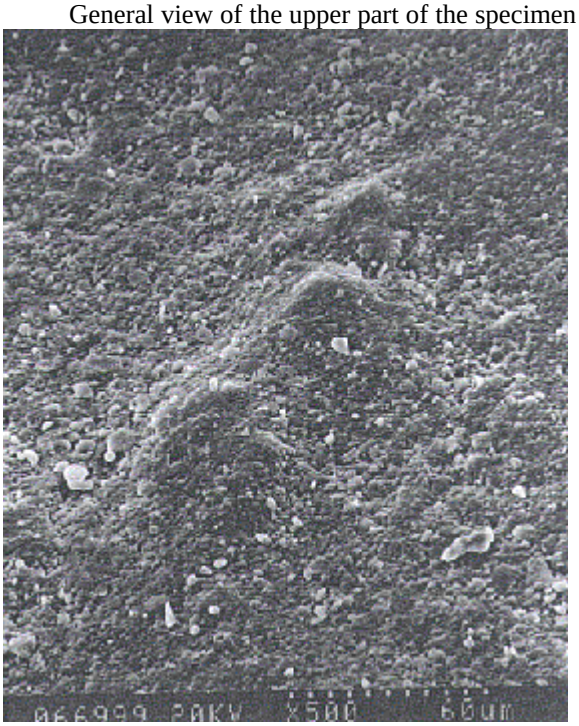

Figure 2b
SEM picture sample 2 (upper surface)

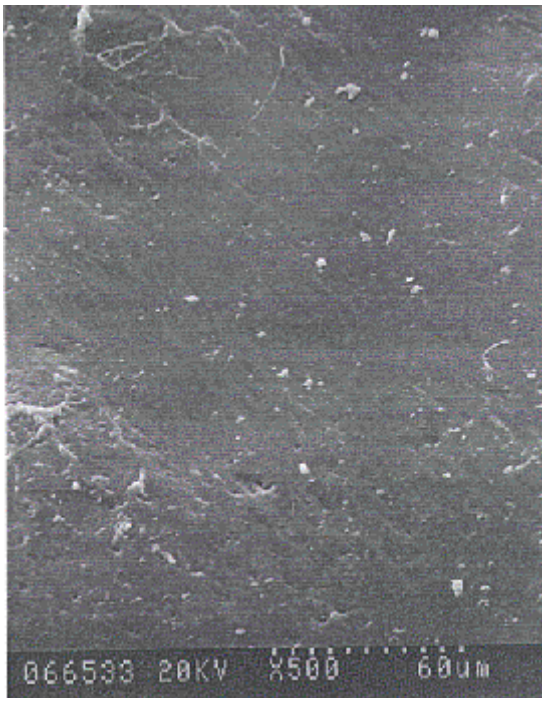

Figure 2c
SEM picture of the surface of an unexposed specimen

Moreover, the absence of degradation at this scale is con firmed by the results of the profilometry. According to the selected parameters Ra and Ry, the micro-roughness of the exposed specimen is very similar to the characteristics of a 2 mm thick film which has been prepared by casting :

Material	Ra µm	Ry µm
Film	0.62	4.5
Surge arrester (samples n°1)	0.74	5.3

If we compare the IR spectra of the upper surface of sample 2 of the specimen with the IR spectra of a similar sample taken from an unexposed surge arrester one can note the following comments :

The main visible absorption bands correspond to the structure of a reinforced polydimethylsiloxane silicone elastomer. For example the bands at 2962 cm $^{-1}$ and 1007 cm $^{-1}$ correspond respectively to CH3 and Si-O-Si groups. In the case of the exposed specimen spectra one can notice the presence of a band at 3696 cm $^{-1}$.

As already mentioned, this should correspond to a silicate pollutant. The presence of this silicate should be responsible as well for the slight deformation of the absorption band at 1007 cm $^{-1}$. No other significant differences are noticeable.

Hydrophobicity

The results hereunder of the measurements of the water contact angles show that the values which have been founded on the 5 years exposed specimen are higher than the usual values that are currently obtained on the polydimethylsiloxane materials. Because these measurements were done on the polluted surface, this should be the result of the presence of the silicate particles : they form micro-heterogeneities which decrease the apparent wettability. Moreover, this level of hydrophobicity suggests that the silicate particles have been covered with a layer of silicone oil. The deposition of kaolin powders on the surface of this kind of material decreases the water contact angle to values as low as 40°-50°.

Materials	Moulded film	Sample 2	Sample 3
Contact angles	107° 108°	115.4° 115.2°	115.7° 116°

The ability of silicone elastomers to recover their hydrophobicity is related to the presence of silicone oil [2, 3, 4] which are not integrated in the polymer network and which can migrate to the surface. Within the context of this hypothesis, the durability of the elastomer should be related to the amount of free silicone oils whatever their origin .

Pieces of sheds which have been taken from the exposed specimen and an unexposed one have been extracted with hexane. The two samples contain almost the same amounts of extractable oils : 2.8 % and 2.7 %, exposed and unexposed, respectively. Moreover, the IR and the

GPC analysis of the extracted material asses that they contain 85 % of a polydimethylsiloxane oil of the same molecular weight.

CONCLUSIONS

The results of these threes studies on arresters with 5 years service do not show any degradation of the electrical and physicochemical characteristics of the material . These data confirm the good withstand of silicone to climatic and electric attack. Moreover, the silicone elastomer does always content free silicone oils which can maintain the original hydrophobicity of the material.

[1] - SÖRQVIST T. and al., Surface ageing and its impact on the performance of polymeric insulator, 9th ISH, P. 3234-1, 1995

[2] - Prof. Dr-Ing KÄRNER H. and al., Hydrophobietransfer und Lebensdauer des Hydrophobieefekts, ETG-Facbericht, vol. 69, p.21, 1997.

[3] - RIQUEL G., Natural and artificial ageing of non-ceramic insulators : Evaluation of diagnostic techniques, 9th ISH, P. 3188-1, 1995.

[4] - HOMMA H and al., Diffusion of low molecular wright siloxane from bulk to surface, Conf record of the Int. Symp on electrical insulation, 1996.