Coating Glass Insulators for Service in Severe Environments

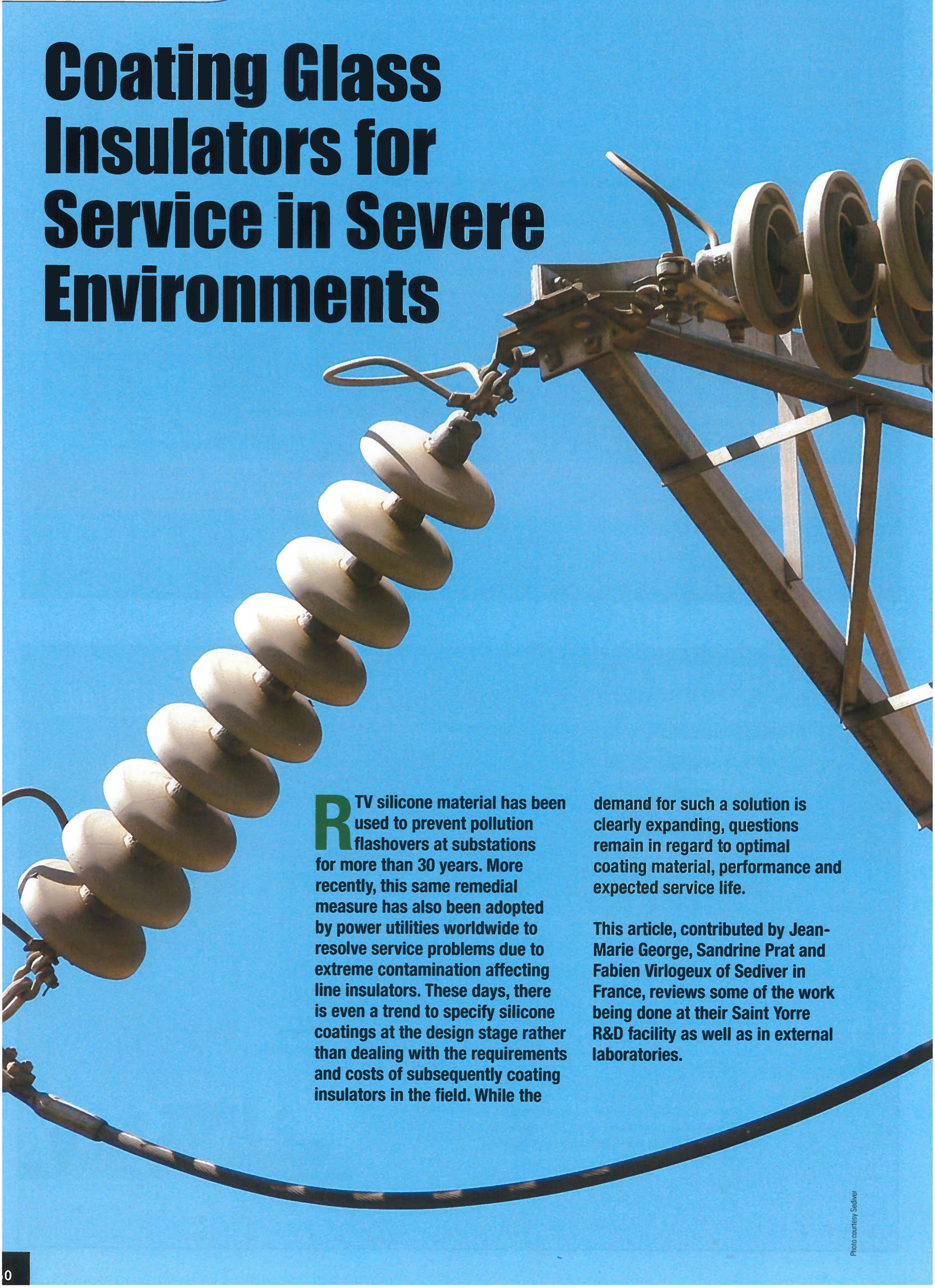


Photo courtesy Sediver

RTV silicone material has been used to prevent pollution flashovers at substations for more than 30 years. More recently, this same remedial measure has also been adopted by power utilities worldwide to resolve service problems due to extreme contamination affecting line insulators. These days, there is even a trend to specify silicone coatings at the design stage rather than dealing with the requirements and costs of subsequently coating insulators in the field. While the demand for such a solution is clearly expanding, questions remain in regard to optimal coating material, performance and expected service life.

This article, contributed by Jean-Marie George, Sandrine Prat and Fabien Virlogeux of Sediver in France, reviews some of the work being done at their Saint Yorre R&D facility as well as in external laboratories.

Among the initial motivations behind the development of RTV silicone coatings on glass were requests by utility maintenance staff seeking to maintain the benefits of glass on their overhead lines but also looking to avoid any requirement for periodic washing under challenging contaminated service conditions. For example, one of the benefits of glass insulators is the ease with which inexpensive yet reliable diagnostics can be carried out using unaided visual observation alone. This is in contrast to the more complex demands linked to inspecting other types of insulators and is especially valuable when it comes to ensuring safe live line working.

Selection of Coating Material

RTV silicone coatings are available in a range of different chemical compositions and therefore the impact of environmental and electrical stresses must be evaluated on each alternative material. In general, the addition of these types of coatings will result in a substantial difference in pollution withstand capability of an insulator, due to the hydrophobic nature of silicone. Still, coating longevity, performance and ageing ultimately depend on the ideal chemistry as well as on method and quality of application.

Screening of available silicone coatings was based not only on extensive company experience over years of testing different polymeric housing materials but also considered important performance factors such as hydrophobic properties and resistance to erosion and tracking. While the applicability of tests such as the inclined plane is still being debated for silicone rubber, there are a number of alternative methodologies to evaluate and rank silicone coatings. Among these, the long-term multi-stress program implemented by Terna, the grid operator in Italy, has also been performed at the laboratory in Saint Yorre. Tests such as this have conclusively demonstrated that erosion resistance can vary greatly among different coatings and favor those protected by means of added alumina tri-hydrate (ATH) filler.

Ageing & Longevity of Coating

When dealing with polymeric insulating materials, ageing is always a central issue and composite insulators have been used long enough to give some basic indications based on field experience. According to engineers at Sediver, utility maintenance crews sometimes have to replace composite insulators after about 15 to 20 years of service (and in certain situations even less depending on product or environment). The principal area of weakness in the case of certain designs comes from possible erosion of the rubber housing and seals which are essential to prevent exposure of the core to moisture ingress.

Coating applied to a toughened glass insulator is fundamentally different from the basic design of composite insulators. While clearly looking for a material that offers the best erosion resistance, even should a coating become eroded or damaged, the integrity of the insulator is never at risk, i.e. whatever may happen to the coating does not compromise the inherent properties of toughened glass, which still performs no different from a non-coated insulator. R&D work in this field by Sediver has therefore been focused on three aspects of coatings:

- Erosion resistance
- Hydrophobicity evolution under various stress conditions
- Performance under pollution

Several ageing tests have been established or are being developed to better understand the behavior of coatings under diverse environmental conditions. For example, long term AC and DC tests in chambers containing clean or salt fog at various stress levels and different regimes have been running continuously at the Saint Yorre R&D ageing laboratory. Particular

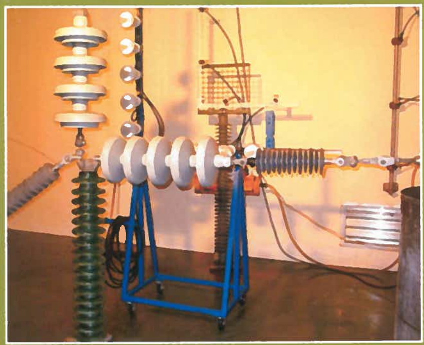
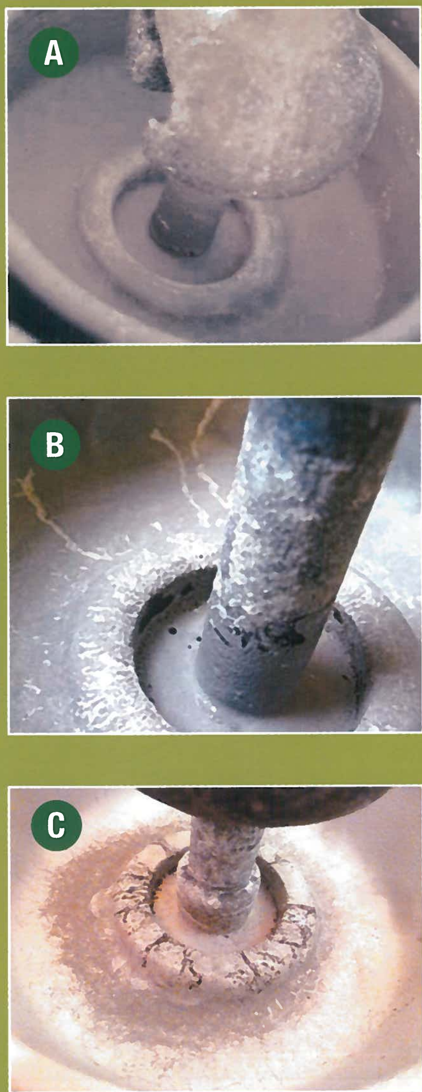


Photo courtesy Sediver

Multi-stress laboratory testing on coated insulators.



Photos courtesy Sediver

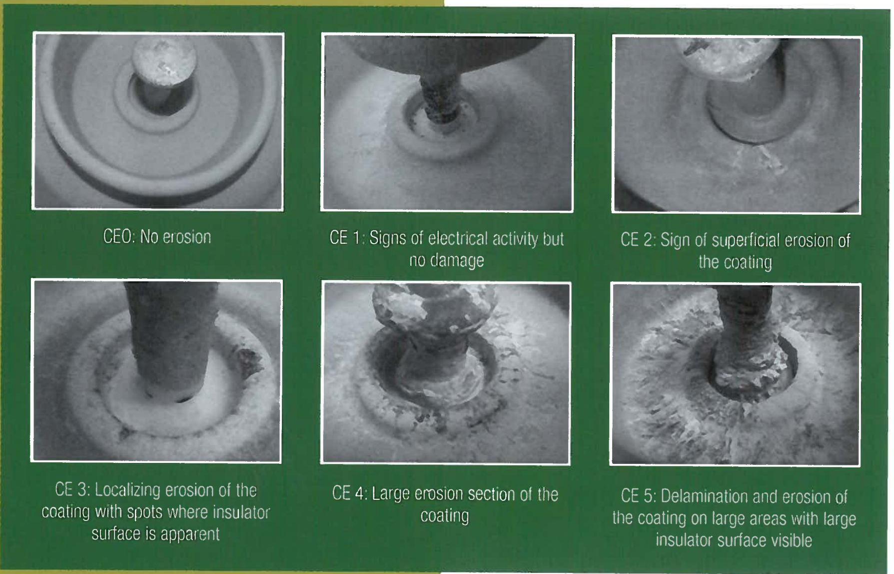
Different erosion levels related to selection of ATH filler.

Coating longevity, performance and ageing ultimately depend on optimum chemistry as well as method and quality of application.

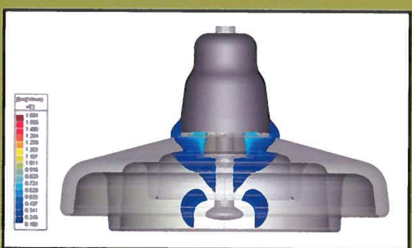
Whatever may happen to the coating does not compromise the inherent dielectric properties of the glass disc, which still performs no different from a non-coated insulator.

Photos courtesy Sediver

Tests being performed on coatings at Sediver ageing laboratory.



Sediver CE coating erosion classification chart



Photos courtesy Sediver

Hydrophobicity (WC 3) near pin Electric field modeling.
(pollution level E7 according to IEC 60815-1).

attention has been given to trying to ensure the best correlation between test results and actual field experience. In fact, one of the main findings from the different methodologies tested is how difficult it is to duplicate real conditions using short-term laboratory procedures. For this reason, several strings of coated glass insulators have been installed at outdoor test stations selected because of their challenging environmental conditions. The target here has been not only to develop more knowledge but also to verify the consistency of results obtained versus those from laboratory testing.

Establishing the proper balance between erosion resistance and hydrophobicity has been approached through a novel philosophy that aims to combine Hydrophobicity Classification from IEC TS62073 with an internally developed erosion class chart, designated Sediver's CE classification. While initially only used internally, this classification system is now starting to be adopted elsewhere since it provides a relatively accurate measure of the dynamics between these key performance parameters.

Hydrophobic properties of alternative coatings are evaluated both through test results and observations made in the field.

It should be noted that findings have to be viewed with some caution given the wide possible diversity among severe service environments, e.g. from the deserts of Peru to the coastlines of Sicily. Similarly, behavior under AC or DC has to be analyzed with regard to the specific implied stresses. Such information has been accumulated for almost 20 years and over the past decade a monitoring program covering over a million coated glass discs has been in force. This has included yearly evaluations of samples removed from lines.

This work has confirmed good overall preservation of hydrophobicity including in service areas where washing cycles once had to be performed each quarter. The stress level encountered in these applications translates into some reduction of hydrophobicity around the pin area, which is expected given the electric field distribution prevailing in that region. For example, the hydrophobicity status of insulators after 7 years of service in a polluted coastal environment equivalent to level E7 (as described in the IEC 60815-1) can be explained by modeling electric field that shows that the pin section typically suffers more than the rest of the insulator.

The overall hydrophobicity of these coated insulators, even at the live end, seems to be preserved and can be classified between WC1 and WC3. What is also clearly evident based on laboratory tests on short strings as well as on field observations is that the complete string never loses all its overall hydrophobicity performance. This in spite of some hydrophilic areas appearing on localized areas of individual units, mostly near the

Table 1: Results of Clean Fog Pollution Test with Solid Layer ESDD 0.1mg/cm², NSDD: 0.19 mg/cm² CUR: 0.7*

	Test 1	Test 2	Average
RTV-coated, SDD 0.3 mg/cm²	88 kV	80 kV	84 kV
RTV-coated, SDD 0.1 mg/cm²	128 kV	136 kV	132 kV
Non coated glass, SDD 0.1 mg/cm²	76 kV	76 kV	76 kV

* Tests conducted at STRI on short string of 5 insulators (unitary leakage distance 445 mm).

energized side. Similarly, when small sections of coating are removed, the same approach applies and salt fog tests have confirmed no difference in performance versus fully covered units.

In parallel to such visual and hydrophobicity comparisons, the level of desired low molecular weight species (silicone LMW) left in the RTV silicone coated surface after several years in the field or after thousands of hours in an accelerated ageing chamber has also been investigated. In this regard, a Soxhlet test has been utilized in order to allow a quantitative measure by extracting the LMW left in the silicone. While further such research will help to better understand the dynamics of hydrophobicity recovery processes, one major trend has already been confirmed through research. Although top and bottom surfaces are coated with the same material and surface thickness, there is a difference in the amount of LMW species remaining after a few years such that there is a noticeable decrease at the beginning of the life of the insulator (corresponding to the initial years in service). However, the trend indicates that a possible stability in residual LMW content of the silicone coating is achieved over time. One possible explanation – still being investigated – is that after an initial phase of settling, the level remains relatively stable, ensuring the necessary hydrophobicity as well as hydrophobicity recovery.

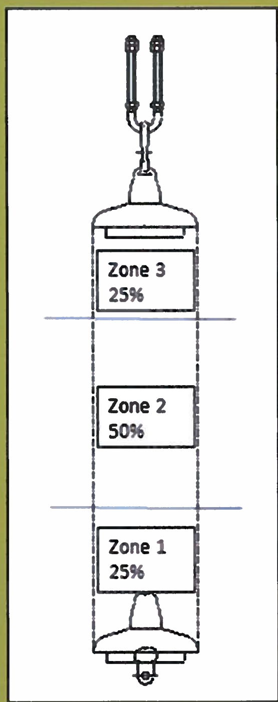
Field Monitoring

Various performance attributes have been monitored in the field including overall condition of the insulators, coating adherence, thickness, hydrophobicity and hydrophobicity recovery. There have also been measurements of pollution and its conductivity. Apart from the benefit of allowing laboratory test procedures to be calibrated against field findings, this has also allowed measuring the stress gradient on the coating along the string's length. Some units can be partially WC5, as discussed above, but overall the string remained hydrophobic in all the different service environments investigated.

To help monitor the evolution of coating performance along the string, a geometric approach was established whereby the string is divided into 3 sections of length: bottom 25%; top 25%; and middle 50%. Up to now, only light erosion (i.e. type CE2) has been observed in the bottom portion of strings. Similarly, in regard to hydrophobicity, only some areas in the same portion of string have been affected. This demonstrates a high hydrophobic buffer effect and resilience of the silicone coating applied to glass insulators.

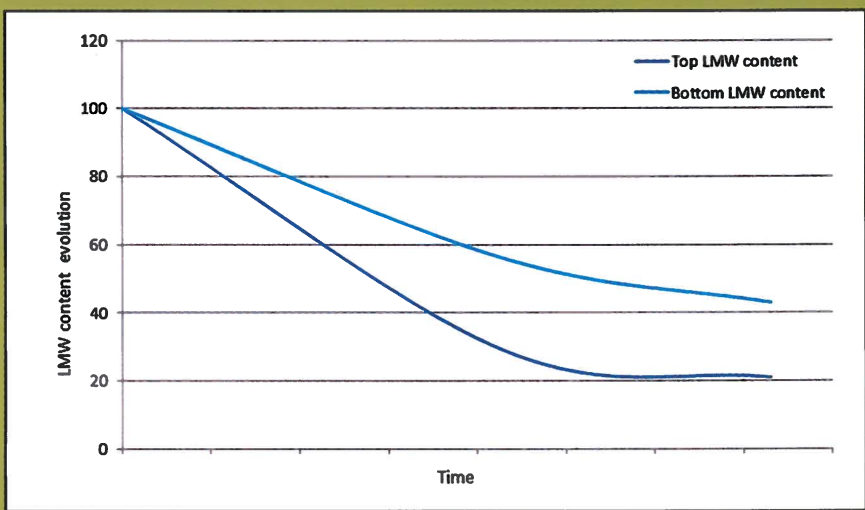
Pollution Performance

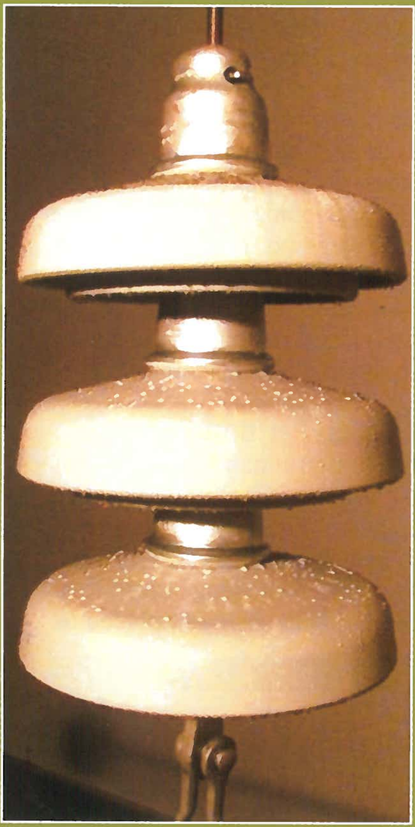
Service performance has confirmed that the risk of pollution flashover has been largely eliminated by the use of coatings in place of any periodic washing. Given this, special focus has been placed on

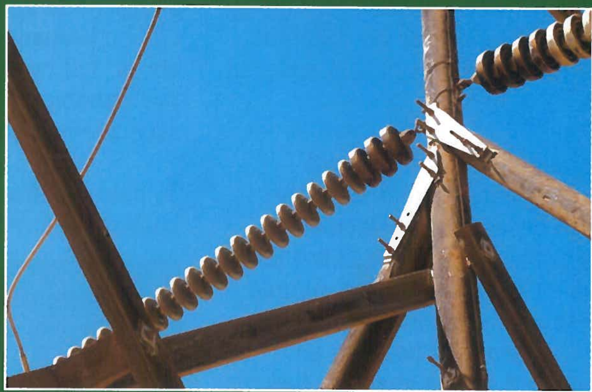


Top: Soxhlet testing
Chart shows evolution of LMW species content over years in service.

String sectioning for coating evaluation.







220 kV AC trial with insulators that are only undercoated.

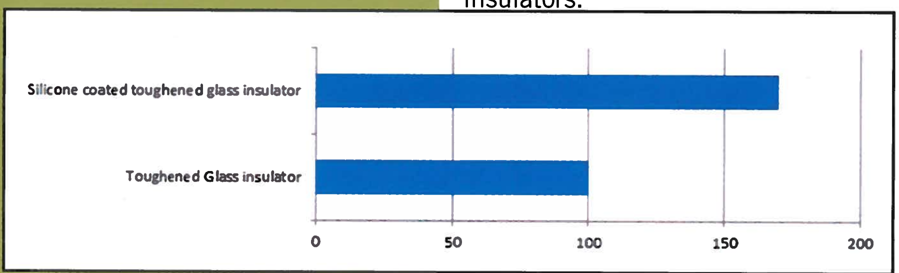
Photos courtesy Sediver

Photos courtesy Sediver

artificial pollution tests to verify this. For example, clean fog pollution tests with solid deposit layers were performed at STRI in Sweden and the findings were later confirmed at the HV laboratory in Bazet, France. One of the challenges in this regard relates to the preparation and deposition of the contamination on a hydrophobic surface prior to testing, with or without recovery. Results confirm a substantial increase in withstand voltage compared to a non-coated string with a performance similar or even superior to an equivalent composite insulator.

Additionally salt fog pollution tests (at 80g/l) in DC were performed on silicone coated glass insulators at the R&D laboratory in Saint Yorre. Once again, the coated insulators offered substantial improvement versus normal non-coated glass. This result is in line with findings from monitoring an actual DC line equipped with silicone coated glass insulators.

DC salt fog tests at Sediver laboratory. Average U_{50}% performance with base 100 for non-coated glass.



Future Developments

While R&D on RTV coatings is now concentrated on chemistry, ageing, performance and testing methodologies, there is also great value in continuing to monitor the condition of coated insulators in the field. Up to now there have been no reports of flashover, washing or replacement of any of these insulators. At the same time, the Sediver CE classification table and methodology discussed earlier is being ‘fine-tuned’ to better describe the real condition of insulators and this approach could one day form the basis for a standard method of evaluation.

Better understanding the performance of silicone-coated insulators is also providing new directions for development. For example, testing and monitoring of insulators where the coating was applied only to the bottom of the insulator began several years ago and there are already successful applications in Latin America with such ‘undercoated’ insulators. Similar trials are in progress in North America and Africa with equally good results. This development may provide further opportunities for technical publications on the topic. ☒