

AN INVESTIGATION INTO THE QUALITIES OF NEW AND FIELD AGED
CYCLOALIPHATIC (CE) INSULATION

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SUMMARY

Outdoor Cycloaliphatic Epoxide insulation is sometimes used as a replacement for ceramic insulation. Non-ceramic insulation is subject to environmentally driven aging mechanisms, resulting in performance decline over time. This paper compares ceramic to Cycloaliphatic Epoxide insulation under simulated marine pollution conditions and discusses the effects of aging on electrical performance.

INTRODUCTION

Until the 1980's, porcelain and glass insulators enjoyed widespread application within high voltage electrical networks. The last 25 years (since 1976) have been characterized by the influx of new materials into the high voltage insulator market. The use of Cycloaliphatic Epoxide (CE) resin insulators has therefore increased in reticulation networks throughout the western world.

It is generally accepted that approximately 7.5 million CE insulators have been employed in the world to date [1]. The production of CE insulators in the Republic of South Africa (RSA) is in the vicinity of 3.8 million individual units (Figure 1), providing a sufficient sample space and thus facilitating a representative and reliable evaluation of the product.

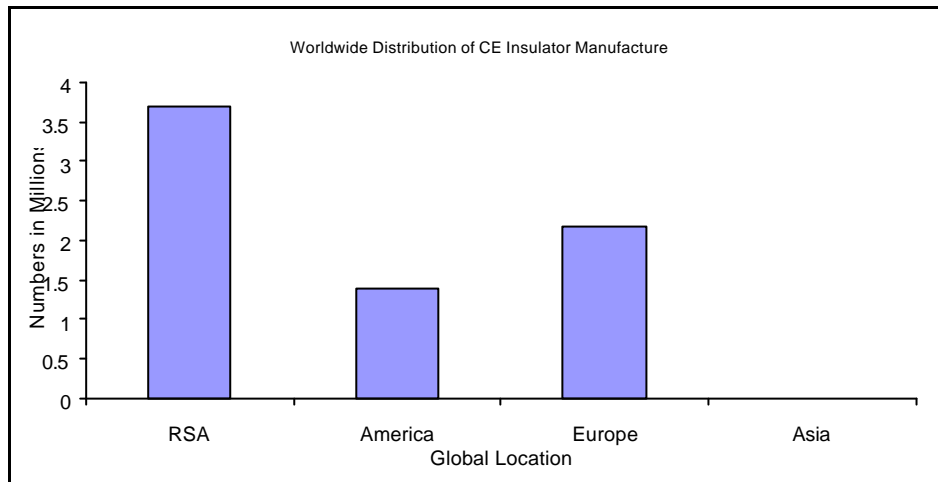


Figure 1: Worldwide Distribution of CE Insulation Manufacture (Approximated)

For many years there has been a considerable amount of controversy as to the suitability and stability of CE products for use as outdoor insulation – specifically in areas typified by high levels of natural solar radiation (UV) – and lately in marine and tropical climates. This paper compares CE insulators to Porcelain and Glass Disc insulators, under IEC 507 salt fog conditions. Additionally, the mould release layer is evaluated (a layer of silicone based grease used in the CE de-moulding process) – and a comparison between field-aged and new CE insulators is made.

EVALUATION TECHNIQUES

Salt Fog Tests to compare CE, Porcelain and Glass Cap and Pin Insulation

The test method adopted for the salt fog evaluation of 22 kV CE insulators is the IEC 507 method. IEC 507 does not make provision for the testing of polymeric insulators, or insulators retaining mould release layers on their surfaces, so a test to compare porcelain to CE insulation was devised.

The test parameters were:

- A porcelain and CE insulator of identical dimensions and profile were selected for the test.
- The CE insulator was cleaned with methanol (low impact) in order to remove the mould release layer.
- The CE and porcelain insulator were exposed to a series of salt fog tests of increasing salinities, simultaneously.

Figure 2 illustrates the peak leakage current flowing over the surface of CE and porcelain insulators of identical dimensions (25 mm/kV), with glass cap and pin insulators included as reference to a known insulation type (UB120: 24 mm/kV).

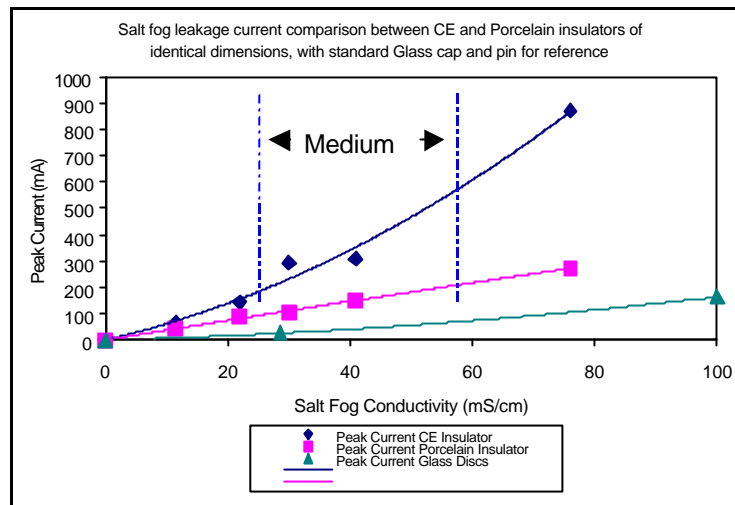


Figure 2: A comparison between CE and porcelain insulators

Mould Release Resiliency Tests

CE insulators are cast objects and are formed by the injection of the polymer resin system into a mould. Mould release agents are applied to the moulds to facilitate the removal of the cast object after cure or gellation. The mould release is a silicone based grease or oil which possesses good hydrophobic (water repelling) qualities and acts as a filter to solar UV radiation [2].

The mould release resiliency tests were devised to evaluate:

- The effect of the mould release layer on the validity of the IEC 507 salt fog test method test results.
- The resiliency of the mould release layer – under adverse environmental and high voltage conditions.

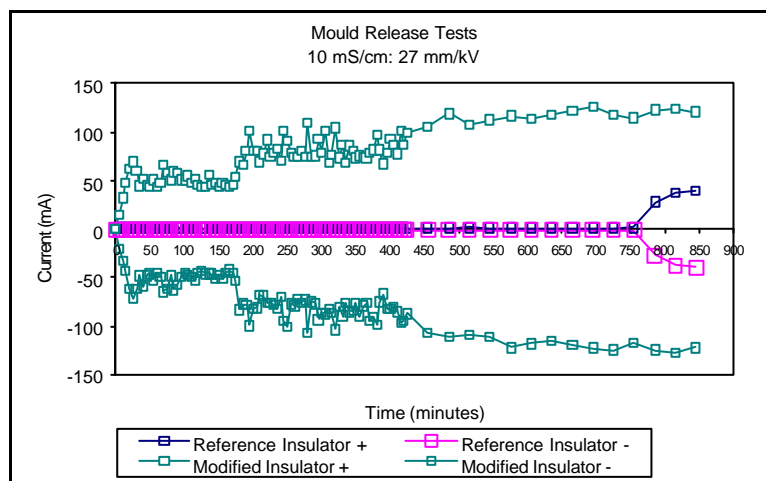


Figure 3: Mould Release Resiliency Test Results

Two CE insulators (27 mm/kV) of identical profile and dimensions were selected for the mould release tests, and exposed to a salt fog severity of 10 mS/cm (class: very light). The mould release layer was removed from the one insulator (Modified Insulator), while the other insulator remained representative (Reference Insulator) of a typical insulator as received from a manufacturer. Both insulators were exposed to IEC 507 salt fog conditions, simultaneously. The leakage current data was recorded over a continuous 16-hour test interval. The peak values for each 10 minute interval are shown in Figure 3.

Salt Fog Comparison between New and Field-aged CE Insulators

Post-type CE insulators conforming to criteria as set out in table 1 were removed from their service positions in the field.

Table 1: IEC 815 Dimensioning of New and Field-aged CE Insulators

Criteria	Test Insulator
Average Diameter	< 300 mm
Specific Creepage 'd'	19 mm/kV
Pollution Level	Pollution Level I
I _{max}	1.538A

The insulators were serving in a semi-arid climatic area characterised by very light pollution levels. The predominant aging factor was their exposure to high levels of solar ultraviolet radiation and nocturnal dew formation. The nocturnal dew formation could result in the hydrolysis of the CE insulator surfaces.

The insulators were visually inspected and were found to have the characteristic chalking, roughening and total lack of hydrophobicity typical of UV aged CE. This could be due to the exposure of the SiO₂ (silica) filler material as a result of the insulator surface aging mechanisms.

The insulators were subjected to salt fog testing (Table 2) and the leakage current data was recorded.

Table 2: Leakage Current Data for Field-aged CE Insulators

Serial	Age Years	8 mS/cm Peak current mA	20 mS/cm Peak current mA	28 mS/cm Peak current mA
B19H-1	13	265.7	558.5	<u>656.3</u>
B19H-2	13	282.7	594.4	<u>679.3</u>
B19H-3	13	251.1	521.7	<u>769.7</u>
B19H-4	13	254.5	426.2	<u>841.3</u>
B19H-5	13	316.1	347.6	<u>836.9</u>
Modified	-	140.0	256.7	410.7
Reference	-	0.0	0.0	0.0

* Underlined values indicate unacceptably high leakage current activity

DISCUSSION

Comparison between CE and Porcelain Insulators

CE performs poorly under salt fog conditions when compared to porcelain and glass-cap-and-pin insulators. The porcelain and CE insulators can be utilised in the medium severity pollution class environment. The following can be deduced from Figure 2, within the limits of the medium severity pollution class:

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- at 22 mS/cm salt fog severity: the peak leakage current magnitude is 144 mA and 87 mA for CE and porcelain, respectively.
- at 56 mS/cm salt fog severity: the peak leakage current magnitude is 550 mA and 208 mA for CE and porcelain, respectively.

The power loss over the CE insulator surface is high, until the formation of dry bands limits the continuous conduction of leakage current (Figure 4). The power loss for the porcelain insulator remains relatively constant during the test.

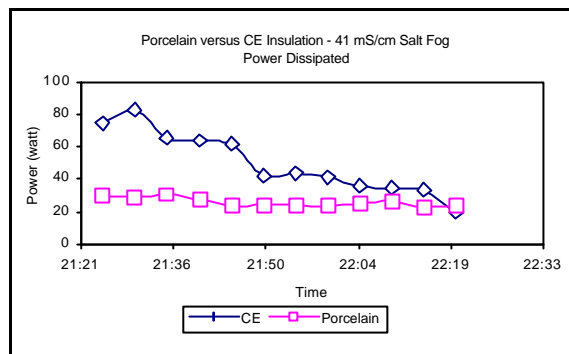


Figure 4: Power Loss over Insulator Surfaces

Leakage current and dry band activity are the most active aging entities on polymeric insulator surfaces [3]. Evidence of aging, due to the salt fog testing, is manifest in increasing peak leakage current levels at constant salt fog conductivities.

When conducting a second set of salt fog tests, it was found that the CE insulator, at 20 mS/cm, conducts similar peak leakage currents as for the previous 40 mS/cm salt fog test. This aging-related phenomenon is also found when performing the mould release resiliency tests on the modified and reference CE insulators.

Mould release tests

The mould release layer was evaluated under salt fog conditions by using two identical insulators – one with and one without the mould release agent on the external surfaces. The Modified Insulator begins to conduct leakage current over its CE surface the moment that the salt fog test is in progress, while the Reference Insulator required 750 minutes of salt fog testing to deplete the hydrophobic properties of the layer.

Once the hydrophobic properties of the mould release layer have been depleted, a continuous and conducting pollution layer is established over the surface of the CE insulator, thus allowing leakage current conduction, the formation of dry bands and the aging of the CE surface shown in figure 5.

The aging of the insulator surface is evident in the gradually increasing magnitude of peak leakage current during the test period (Figure 3), and the formation of dry bands (Figure 4). Once the mould release layer has deteriorated on the Reference Insulator to such an extent that leakage current is measured, the magnitude of the leakage current rapidly increases until it assumes a similar value as for the Modified Insulator. The mould release layer exhibits no recovery mechanism and once depleted, remains so.



Figure 5: Effects of 9 Hour Mould Release Resiliency Test (Leakage Current) on CE insulator Surface.

Comparison between New and Field-aged CE Insulators

Defining the qualities of a New CE insulator is a controversial issue – when using existing IEC standards for context. Wetting agents or surface modification is often prescribed when performing artificial pollution tests on hydrophobic insulators – in order for the artificial pollution to adhere and contaminate the surface in a uniform and effective manner.

For the purposes of this paper, a New CE insulator is identical to a Reference Insulator – and hence, does not conduct leakage current over its surface during the standard 1 hour IEC 507 salt fog test.

The Modified insulator conducts significant magnitudes of peak leakage current over its surface (Table 2), however it is clear that the effects of natural field aging have affected the peak leakage current performance of the Field-aged CE insulators to a greater extent, since their peak leakage current magnitudes are higher for similar salt fog severities. This can be attributed to:

- The surface roughening on the field-aged insulator ‘trapping’ a larger volume of conductive salt fog pollution.
- The fact that the Field-aged insulators rapidly establish unstable dry band conditions.

An unstable dry band on an insulator can in many cases be an unavoidable condition. Most insulator designs encourage the use of stable dry band zones to limit the leakage current over the insulator surface (thus limiting aging and reducing the probability of flashover), as a dry band is in fact a high impedance current limiting entity.

An unstable dry band is possible if the following criteria are satisfied:

- The volt-drop across the dry band is sufficient to ‘fire’ the dry band into a conducting condition.
- Foreign matter enters into the dry band zone and establishes a short-circuit of the dry band – for instance, a droplet of conductive condensation due to the effect of gravity runs into the dry band zone, or airborne biological material achieves a similar effect.

The significance of the dry band is that it allows the unaffected zones on the insulator to wet-out and achieve a low impedance condition. When the dry band ‘fires’ the insulator presents a low

impedance surface condition that allows for high peak leakage current conditions to exist. When the wetted zones dry and increase their impedance the leakage current is limited. On the other hand, if the leakage current magnitude is sufficient, the insulator will flash over.

The Field-aged insulators, after initially high peak leakage current magnitudes, rapidly form unstable dry band zones. It is this phenomenon that causes the field-aged CE insulators to register high peak leakage currents when compared to the Modified and Reference insulators (as described in the previous paragraph).

The Modified CE insulators form unstable dry band zones too, but the surfaces of the insulators do not permit as much pollution to adhere to them as do the Field-aged insulators (smoother surfaces) – thus, when the unstable dry band is in the ‘fired’ condition the unaffected wetted zones present a sufficiently high impedance that inhibits the peak leakage current magnitudes from reaching similar magnitudes as the Field-aged insulators.

CONCLUSIONS

- The Porcelain versus CE Insulation comparison (identical profile and dimensions) clearly indicates that CE insulation is not a replacement material for Ceramic insulators, with regards to electrical performance under salt fog conditions (simulated marine environment).
- The mould release agent has a significant and beneficial impact on the early performance of field-deployed CE insulation, resulting in optimistic performance rankings during the initial period of application.
- Aged CE insulators permit higher peak leakage current conditions as a result of the superior wetting (due to the damaged insulator surfaces) of the zones external to the dry bands.
- The probability of flashover is higher for aged than for new CE insulators, for a given pollution level.

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