

KOEBERG INSULATOR POLLUTION TEST STATION (KIPTS) –
AN IN HOUSE INSULATOR PRODUCT AGEING TEST STADARD

W L Vosloo, R Swinny and *JP Holtzhausen

SAHVEC, division of TSI, and ESKOM Enterprises, Insulator Centre,
PO Box 222, Brackenfell, 7561, SOUTH AFRICA

* Department of Electrical and Electronic Engineering, University of Stellenbosch,
Private bag X1, Stellenbosch, 7600, SOUTH AFRICA

SUMMARY

Currently, a wide variety of insulator products are being used on the Eskom Distribution system. These insulating products are exposed to diverse environmental conditions, which include high pollution levels (marine, industrial, sugar cane fires, etc.), frequent wetting cycles, ultra-violet radiation and variant wind conditions. The accelerated ageing test as per IEC 1109, Annex C was specified in the past to obtain an indication of the performance of insulator products under simulated environmental conditions. Research performed at Koeberg Insulator Pollution Test Station (KIPTS) indicated that IEC 601109, Annex C does not adequately simulate the diverse environmental conditions that exist in South Africa. The Distribution Group of Eskom has therefore embarked on a philosophy of natural ageing type testing to account for these factors in the evaluation of insulator products.

This paper presents the general procedure that will be used by Eskom Distribution for the pollution performance evaluation of 11, 22, 33, 66 and 132 kV outdoor insulation products. The procedure also stipulates the acceptance criteria used at the Koeberg Insulator Pollution Test Station (KIPTS) to determine which products are acceptable or not for use by Eskom under general (IEC 60815, light to medium pollution classification) and extreme (IEC 60815, heavy to very heavy pollution classification) environmental conditions.

INTRODUCTION

High Voltage insulators are exposed to a multitude of extreme mechanical, electrical and environmental stresses. The first insulator products used were made from glass and porcelain (ceramic materials), and these have dominated the insulator market for many years. The performance of this type of insulator has been the subject of many research projects, and application principles are well established.

Efforts to reduce costs and vandalism problems, supported by developments in material science technology, have led to new insulator designs using polymeric (non-ceramic) materials. These materials are often hydrophobic (water repellent) as opposed to hydrophilic (easily wettable) ceramic insulators. As a result of their low wettability, these insulators typically perform exceptionally well in extremely polluted environments. However, during prolonged exposure to pollution their hydrophobicity deteriorates, resulting in higher leakage currents and material degradation. Hydrophobic greases and coatings applied to ceramic insulators are also becoming more popular in South Africa. Surge arresters, line equipment, and station posts with polymeric housings have also entered the insulator market. International research on insulator testing and ageing has led to basic guidelines on the assessment and application of non-ceramic insulators. However, these guidelines are not necessarily applicable in South Africa, as they do not reflect local environmental conditions such as high humidity and extreme ultraviolet solar radiation.

In order to be in a position to evaluate new insulator designs, Eskom embarked on an extensive Research and Investigations program to study the performance of non-ceramic insulators under local conditions (encompassing insulator test stations, monitoring in-service insulators, and laboratory work). The existing artificial ageing methods (IEC 1109) have certain limitations. For South African environmental conditions it was found that IEC 1109 Annex C has limitations and does not represent local conditions. Natural ageing tests were found to be a better alternative. This is also supported by other researchers e.g. Hackam [1], who stated "Only tests in field stations and actual performance on power lines could yield realistic results on outdoor service performance"

KOEBERG NATURAL AGEING TEST STATION

Koeberg Insulator Pollution Test Station (KIPTS) is situated along the Cape West Coast, about 50 meters from the sea on property made available by Koeberg Nuclear Power Station. The test station consists of test bays for 11, 22, 33, 66 and 132kV complete with control room, environmental monitoring station, pollution monitors and leakage current logger systems. The climate at KIPTS is characterised by dry summers, high winds, mist banks, and heavy marine and industrial pollution. The rainfall occurs mainly in winter. The pollution index at KIPTS is in the order of 2000 $\mu\text{S}/\text{cm}$, which is extremely high and would be classified as 'very heavy'.

The ageing at Koeberg has been correlated to the "IEC 601109, 5000h ageing test" and a factor of 2:1 was found [2]. KIPTS therefore constitutes the ideal marine and industrial pollution condition in which to evaluate insulator products.

Figure 1(a) shows an insulator that was subjected to accelerated ageing according to IEC 1109 Annex C. The unit passed the test, and qualified as one of the best performers ever tested. An identical unit was energised at KIPTS and failed within the first 8 months. The question to be asked here is, "Does accelerated artificial ageing prove the integrity of an insulator that is to be used in severe marine environments".

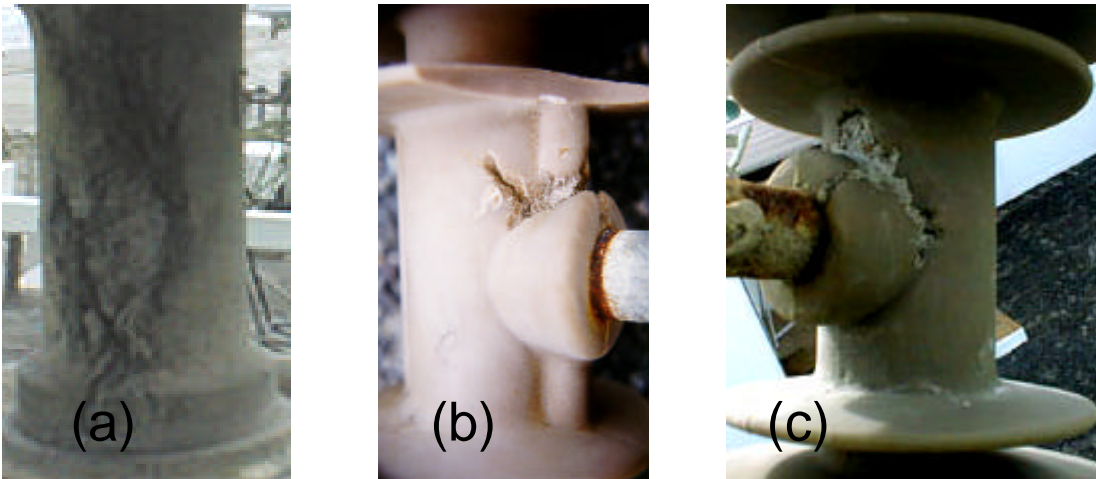


Figure 1: (a) Silicone rubber insulator after 8 months energised at KIPTS, (b) Field aged Cycloaliphatic cut-out fuse, (c) Cycloaliphatic cut-out fuse after natural ageing test at KIPTS.

Figure 1(b) shows a Cycloaliphatic cut-out fuse which developed severe erosion in the pin area after 5 years in service. An identical failure mode has been observed on a similar unit energised at KIPTS (shown in figure 1(c)). Many samples of other insulators have been retrieved from the field and they too show similar failure modes to that observed at KIPTS, thus proving that KIPTS is an ideal test facility to prevent inferior products from entering the South African market.

TEST PROCEDURE

The natural ageing test entails the installation of the insulator product at KIPTS and monitoring the performance of the insulator product over a period of either six and/or twelve months. Test results will be time independent, which means that test results from one year can be compared to results from any other year, should the necessary environmental data be available.

The complete test procedure [3] for polymeric insulator products can be seen in Figure 2 which includes among others, the following:

- The physical design details of the insulator products shall be verified in relation to the detailed design drawing to verify that products conform to Eskom specifications.
- The insulator product shall be X-rayed to check for internal defects
- A material sample shall be stored for future reference in a sealed container. Prior to this, material analysis will be performed in order to determine a new material's "fingerprint"
- An artificial ageing test shall be performed. This shall be followed by a material analysis to determine an artificially aged "fingerprint"
- A natural ageing test shall be performed. This shall be followed by a material analysis to determine a naturally aged "fingerprint"
- Upon completion of the above test procedure the insulator product shall be rated acceptable or unacceptable based on the acceptance criteria

All ceramic insulator products require a certificate of approval from KIPTS. The test procedure entails that the physical design details of the insulator products shall be verified in relation to the detailed design drawing. Acceptance will be based on compliance with the creepage and profile characteristic requirements.

The following measurements and observations shall be performed during the test period to determine a general and extreme environmental ageing condition.

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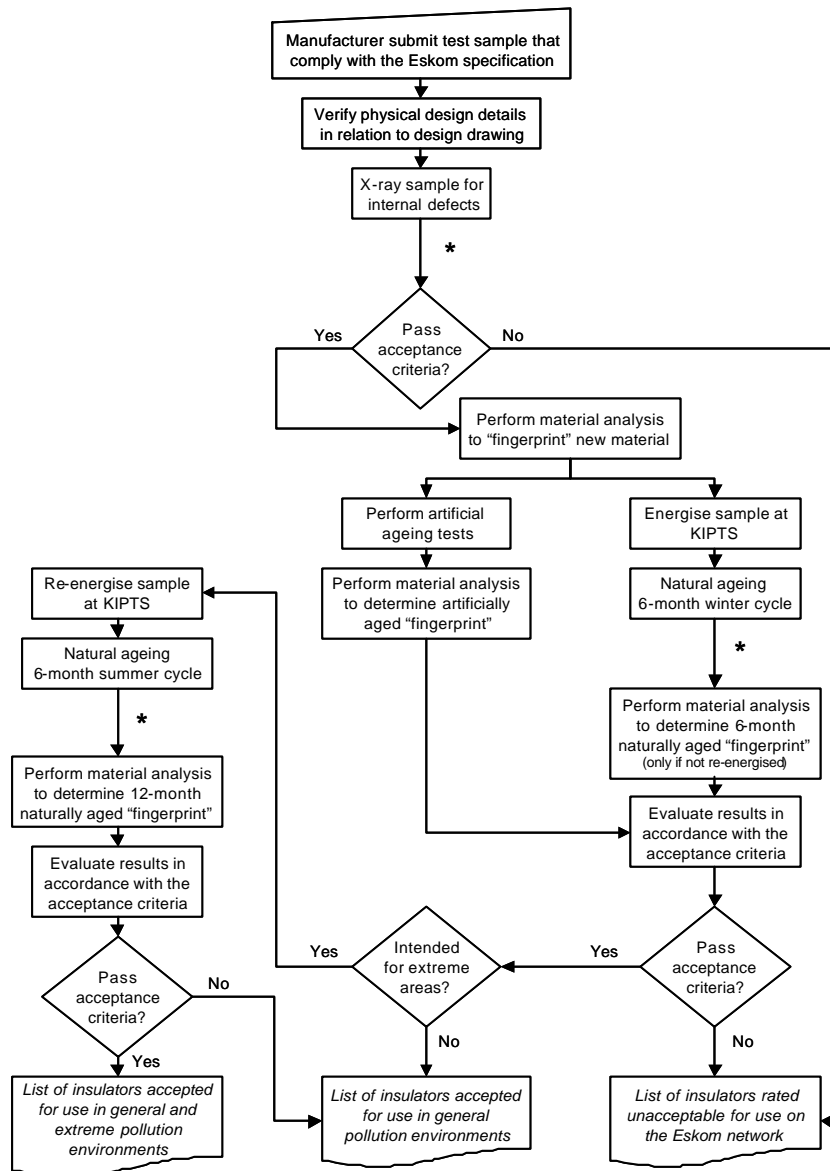


Figure 2: Flowchart of the test procedure for insulator products at KIPTS.

Leakage Current Parameters Monitored

The electrical current (leakage current) flowing over the surface of an insulator under test is recognised worldwide as one of the main parameters needed to monitor the performance of insulators. Small leakage currents in the order of mA's can cause severe damage to non-ceramic insulating materials (due to sparking). Therefore, monitoring the leakage current is of utmost importance at KIPTS. The following leakage current parameters are measured or calculated from the measured values (0.5 % accuracy), sampled at 2 kHz continuously, ignoring values below 0.5 mA, and stored every 10 minutes.

- Highest positive and negative leakage current peaks (mA)
- Positive and negative leakage current pulse counters
- Positive and negative average leakage current (mA)

- RMS leakage current (mA)
- Positive and negative integrated charge (Coulomb)
- Integrated leakage current squared (Coulomb-Ampere)
- True power dissipation (Watt)
- Energy (Joule)
- Maximum leakage current waveform (16 cycles) and associated voltage waveform per day

Pollution Monitoring

Weather patterns and pollution drastically affect the performance of non-ceramic insulators. Environmental monitoring at KIPTS utilises the "Round robin pollution monitor study test protocol" [4] as prescribed by the Cigre Task Force 33.04.03. Pollution monitors such as Directional Dust Deposit Gauges (DDD), Equivalent Salt Deposit Density (ESDD) and Non Soluble Deposit Density (NSDD) are utilised to obtain monthly pollution levels.

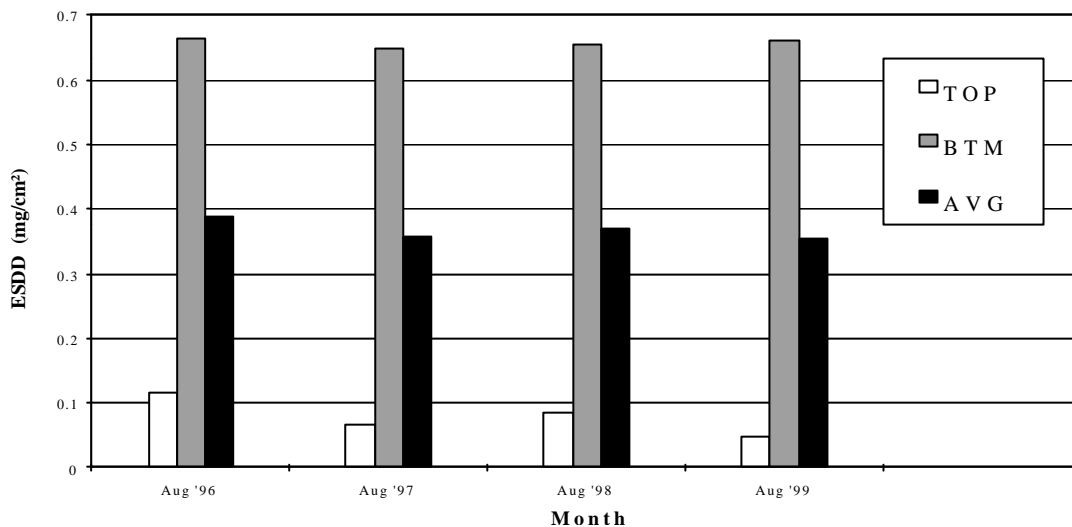


Figure 3: Annual ESDD measurements on U120BS glass cap and pin disk insulator.

Pollution measurements performed at KIPTS since 1996 show the pollution levels to be constant from year to year, as shown in figure 3 above.

Weather Monitoring Station

A weather station is installed at 3 m. The data captured is correlated to that of the Koeberg Nuclear Power Plant's weather station with sensors installed at 10, 50, 85 and 120 m. The following climatic parameters are monitored or calculated (1 % accuracy), sampled at 1 Hz continuously, and stored every 10 minutes:

- Wind speed (m/s) and direction (deg)
- Relative humidity (%)
- Temperature (°C)
- Dew point temperature (°C)
- Vapour pressure (hPa)
- Precipitation (mm)
- UVB (280 - 315 nm) solar radiation ($\mu\text{W}/\text{cm}^2$)

Visual Observations

Visual observations are made at KIPTS at three-monthly intervals, with emphasis on the following:

- Hydrophobicity in accordance with the STRI [5] method

- Material degradation (crazing/crocodile skinning, discoloration, chalking, peeling and flaking)
- Erosion (surface roughening, sheath/shed material loss, cracking/core exposure)
- Tracking
- Puncturing

Ultra-Violet Recordings

Ultra-violet (UV) video recordings are performed at KIPTS using the Corocam Mark II image intensified camera on a three monthly basis. A video will be compiled, to indicate the increase in electrical activity over a period of time (The vendor can request a copy at an extra cost as it is not included the standard test price). The UV recordings highlight the occurrence of corona activity, dry band arcing and surface discharges. An infra red (IR) camera will also be employed, should it be suspected that localised heating is occurring.

Material Analysis

The main purpose of the material analysis is to “fingerprint” the material when new for future reference and to determine the condition of the material at the end of the natural ageing and artificial ageing cycles. The material analysis consists of the following:

- **Hydrophobicity** determination by means of the water droplet method and subsequent measurement of the contact angle of the water to the substrate.
- **Energy dispersive analysis of X-rays (EDAX)** for elemental analysis of the surface.
- **Surface evaluation by means of optical microscopy.** This indicates how the surface has aged (roughened, cracks) and the distribution of pollution deposits.
- **Photo-acoustic Fourier transform infrared (FTIR)** for surface chemistry evaluation relative to the core of the sample. This can be used to determine the type of material under test and to what extent polymeric change has occurred (loss of filler, hydrophobicity loss etc).
- **Thermal gravimetric analysis (TGA)** of the surface as well as the bulk of the material to compare polymer degradation of the surface.

Artificial Ageing Test

The main purpose of the artificial ageing is to determine the expected performance of the material under extreme UV, acid and humidity conditions that may not be adequately simulated during the natural ageing test. The artificial ageing will be performed under laboratory conditions and consists of the following:

- **Accelerated QUV-ageing** - Samples are exposed to UV in a weatherometer chamber that is equipped with ultraviolet light bulbs having a maximum spectral energy at 313 nm. The test cycle lasts for 2000 h and the specimen examined every 500 h during the exposure period for chalking and cracking under X10 magnification.
- **Acid resistance test** - Samples are exposed to dilute (1N) nitric and sulphuric acid at room temperature for a period of five weeks. Any chemical and physical breakdown is monitored.
- **Hydrolysis test** - Hydrolysis is measured by exposing samples of the material to boiling water for a period of five weeks and the surface of the material is monitored by infrared to measure the chemical breakdown as well as under X10 magnification to monitor physical breakdown such as cracks.
- **Ozone resistance test** - Samples are placed in a sealed vessel connected to an ozone generator. The ozone generator is run for 30 min per day to obtain a concentration of ozone that would not diminish during the ensuing 24 h period. The samples are exposed to this cycle that is run for five out of seven days for a period of three weeks. Sample breakdown for chemical and physical decomposition are monitored on a weekly basis.

ACCEPTANCE CRITERIA

The acceptance criteria used at KIPTS is similar to those used for the IEC [6] and ANSI [7] tests and are summarised as follows:

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- No more than three overcurrent trip-outs (Mace fuses blown)
 - No signs of material degradation
 - No signs of material erosion that could lead to core exposure
 - No signs of tracking in the material
 - No sheds are punctured
 - No signs of metalwork corrosion that could lead base metal exposure or failure of other hardware
 - The product insulation material must pass the QUV, acid, hydrolysis and ozone resistant tests
- Upon completion of the six-month winter cycle the insulator product will be evaluated according to the acceptance criteria. If the insulator product passes the evaluation the product will be rated acceptable for use in general pollution environments. Upon completion of the one-year cycle the insulator product will be evaluated again according to the acceptance criteria. If the insulator product passes the evaluation the product will be rated acceptable for use in both general and extreme pollution environments.

CONCLUSION

A test procedure and specification for the acceptance and relative ranking of all High Voltage insulator products at Distribution levels has been developed and implemented. All new insulation designs will be subjected to the KIPTS test, and this will ultimately lead to the correct choice of insulator products for South Africa.

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REFERENCES

- [1] R Hackam, "Outdoor HV Composite Polymeric Insulators", IEEE Transactions on DEI, Vol 6, No 5, pp 557 – 585.
- [2] WL Vosloo, "Koeberg Insulator Pollution Test Station (KIPTS): Final report for 1997", TRR/E/97/EL189, October 1997.
- [3] SCSPVAC13, "KIPTS natural ageing test procedure for outdoor insulator products Section 0 – general requirement", December 2000.
- [4] CIGRE TASK FORCE 33.04.03, "Round Robin Pollution Monitor Study Test Protocol ", 33-93 (TF 04-03) 5 WD, July 1993.
- [5] STRI guide "Hydrophobicity classification guide" 92/1,1992.
- [6] IEC 1109, "Composite insulators for AC overhead lines with a nominal voltage greater than 1000 V - Definitions, test methods and acceptance criteria", 1992.
- [7] ANSI C29.11-1989, "American National Standard for composite suspension insulators for overhead transmission lines - tests", August 1989.