Application of silicone Rubber and testing for polymer surge arresters

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Introduction

- Insulator contamination has been a problem since the birth of electrical power distribution.
- While numerous attempts with other protective methods have had their limitations, there is an Composite insulator one of the solution that utility maintenance engineers can depend on.
- Lightweight polymeric insulators considered necessary for 1,000 kV lines

- 1959: GE develops first polymeric insulator ,but experiences problems with tracking & erosion of epoxy sheds
- 1960s: Europeans introduce first generation of modern Polymers fiber glass rod covered with various types of polymer sheds & hardware

Video courtesy ABB

Advantages of Composite insulator

- Mechanical strength
  - Fiber-glass reinforced epoxy tube
  - Metal end flanges
- Withstanding heat developed during current interruption
- Withstanding decomposed SF6gas

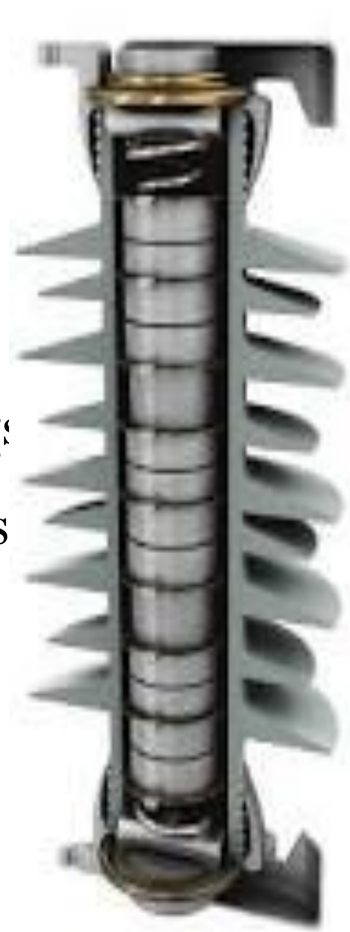
Liner of epoxy, reinforced with polyester fibers

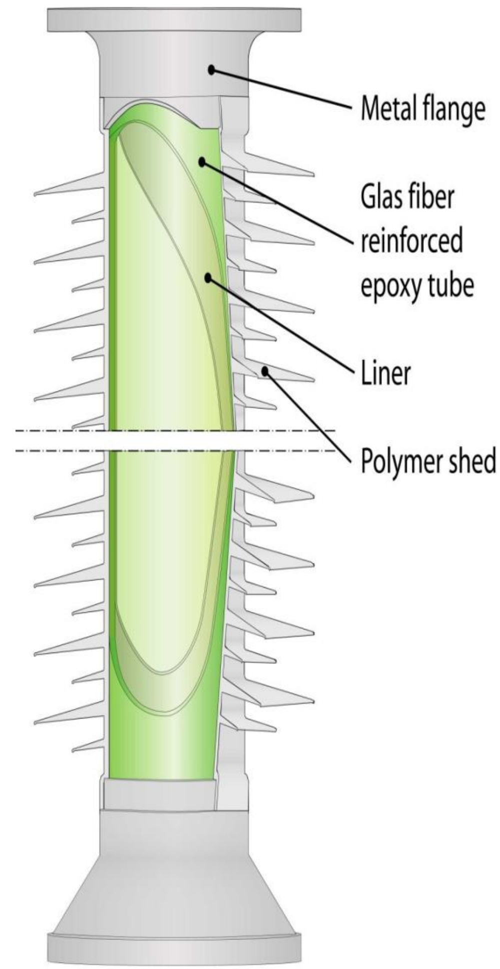
- Flash-over resistant due to hydrophobic surface

- 90% weight reduction
- Reduced breakage
- Lower installation costs
- Aesthetically more pleasing
- Improved resistance to vandalism
- Improved handling of shock loads
- Improved power frequency insulation
- Improved contamination performance

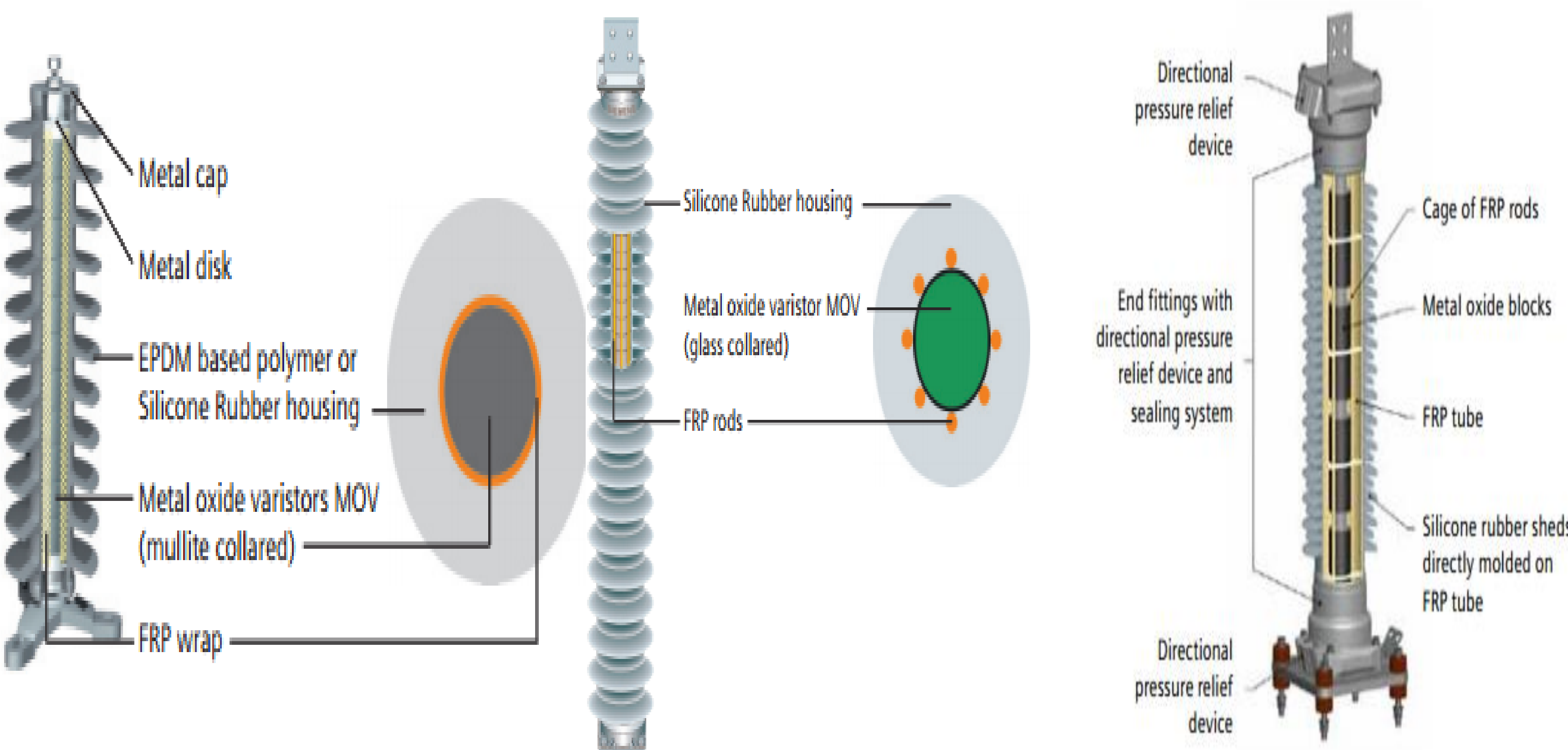
Components of Modern polymer housed arrester

- Fiberglass Rod
- Shed
- Sheath
- Metal end fitting
- Zinc oxide blocks





Design of composite arrestor



wrap design

cage design

Core design

Different types of Housing materials

The only material used for high voltage apparatuses with composite polymer insulation is silicone rubber.

- The silicone rubber (SR) is divided into three main categories (all have the same base polymer, Polydimethylsiloxane(PDMS))
  - High Temperature Vulcanising rubber (HTV)
  - Liquid Silicone Rubber (LSR)
  - Room Temperature Vulcanising rubber (RTV)

Selection Of Housing Material

Choice of housing material, formulation depends on:

- Insulator design.
- Manufacturing process and constraints.
- Cost
- And properties deemed important by the supplier and user.

Functions of Housing/Weathershed

- Seal fiberglass core from natural elements.
- Provide electrical strength under wet and contaminated conditions: **no flash over.**
- Wet fiberglass core will fail quickly.

Materials for Housings

- Silicone rubbers: HTV's, RTV's, RTV2's, LSRs.
- Ethylene, propylene rubbers: EPDM, EPM, EP- silicon alloys.
- Epoxies: cycloaliphatic epoxies.
- Polyolefins: ethylene vinly acetates (heat shrinkable materials)

NOTE: these are generic names.

Typical Ingredients

- Base polymer (differences in specific type)
- Reinforcing filler.
- UV stabilizing filler.
- Tracking and erosion stabilizing filler.
- Processing aids.
- Colorants.
- Base polymer fraction =10-90% of net weight.

Wide variation in performance among ‘same name’ materials. DO NOT generalize.

Stresses and Aging

Mechanical, Electrical, Environmental (UV, moisture, contamination, mold/fungus, etc.)

These Stresses Cause Aging: Reduction of insulation strength

Acceptable Aging : minor superficial changes, can be handled by product design.

Unacceptable Aging : major local or global changes, can cause premature failure.

Silicone Rubbers

- 3 varieties: HTV, RTV and LSR.
- Insulators use HTV (high temperature vulcanizing)
- RTV(room temp vulcanizing) is used for protective coatings, RTV and LSR types are used for apparatus housings.
- HTV is superior to RTV and LSR in terms of tear strength and handling.
- All varities can be formulated to give the desired electrical performance

Simplistic Representation Of Base Polymer.

Poly Di Methyl Siloxane (PDMS)

CH_3 CH_3

I I

- 0 – Si - 0 - Si – 0 –

I I

CH_3 CH_3

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CH_3 CH_3

Minimum requirement for silicone rubber

Test	Reference Specification	Specified Value
Resistance to tracking and Erosion @ 4.5kV, 6Hrs	IEC: 60587/ASTM :D 2303	No tracking and erosion should be observed
Volume resistivity (Ω-cm)	IEC: 60093	2×10^13
Tear Strength(KN/m)	ASTM D 624-B	Min.12
Resistance to weathering and UV	ASTM G53-96 ASTM G154/155	No crack to be observed during test duration of 96 Hrs
Resistance to flammability	IEC: 60707	Burning behavior to be checked
Arc Resistance	ASTM 495-1973	>200 sec
Specific Gravity	DIN 52479/D 792	1.52-1.58
Dielectric Strength in kV/mm	ASTM D 149/IEC 60243	17.5
Hardness(shore A)	ASTM D 2204	68± 7
Ultimate Elongation(%)	ASTM D 412	Min 100
[illegible]sile Strength	ASTM D 412	Min 40 kg/sq mm

Ethylene Propylene Rubbers

- Used in several forms
  - EPM: copolymer of Ethylene and Propylene Monomers.
  - EPDM: Terpolymer of Ethylene Diene Monomer.
  - Alloy: Mixture of EP rubber and silicone polymer(EP fraction dominates)
- EPDM is the largest used variety.

Simplistic Representation of an EPDM Rubber

Ethylene Propylene Hexadiene Monomer

CH_3

I

- (CH_2 – CH_2) - (CH– CH_2) - CH -CH_2-

I

CH_2

I

CH = CH-CH_3

Ethylene Propylene HD

Epoxies

- Two types used
  - Biphenyl epoxy
  - Cycloaliphatic epoxy
- Cycloaliphatic epoxies have better tracking resistance.

Material Tests

- **Electrical Properties**

- Dielectric strength (ASTM D 149)
- Dissipation Factor (ASTM D 150)
- Arc Resistance (ASTM D 495)
- Tracking and erosion resistance (ASTM D 2303)
- Water resistance (100 h boiling water test)

- **Mechanical Properties**

-Compression (ASTM D 575)

-Tension(ASTM D 412)

-Flexure strength(ASTM D 790)

-Shear (ASTM D 732)

-Hardness (ASTM 2240)

-Impact Resistance (ASTM D 256)

Material Test (Cont..)

- **Mechanical Properties**

  - Fatigue (ASTM D 623)

  - Creep (ASTM D 2290)

  - Tear (ASTM D 624)

- **Physical Properties**

  - Water absorption (ASTM D 570)

  - Thermal resistance (ASTM D 756)

  - Thermal expansion (ASTM D 696)

  - Flammability (ASTM D 229)

- **Chemical and Environmental**

  - Chemical resistance (ASTM D 471)

  - Ozone resistance (ASTM D 1149)

  - Natural aging (ASTM D 573)

  - Weathering and Sunlight (ASTM D 518)

  - Corona resistance (ASTM D 2275)

  - Fungi resistance (ASTM G 21)

UV in Sunlight

- At 300 nm, sunlight UV energy= 398 KJ/mole
- Polymers contain chains that can be broken with this energy. **<u>So all polymers affected by UV.</u>**
- Backbone of silicones more UV resistant than other polymers

Polymers are stabilized for UV, formulations are screened by long term UV tests with moisture

UV produced Changes

- Chalking: Depolymerization of top polymer layers leaving filter behind
- Crazing: surface microcracks<0.1mm deep
- Cracking: surface cracks>0.1 mm deep
- The above changes were observed in many first generation EP and epoxy insulators
- Today's EP and epoxy materials can be suitably formulated to eliminate crazing and cracking. Mild chalking and/or discoloration can be still noticed
- Silicones have generally not exhibited these changes

Effect of UV Produced Changes on ELECTRICAL Performance

- *Silicone rubbers – practically no effect*
- *In many EP rubbers, chalking is only cosmetic, no effect on electrical performance in most locations*
- *However there have been some undesirable consequences*

  -higher power dissipation when wet
- *Excessive chalking and cracking can lead to sustained discharges, material degradation and flash over*
- *Negative effects are more important for transmission insulators than distribution due to higher mm/kv of distribution insulators*

hydrophobicity

- Ability of surface to prevent water filming
  - Water drops beading
- Often misunderstood property
  - Hydrophobicity loss does not mean failure.
- Does not always guarantee good NCI
  - Localized degradation possible
- Flashover Performance of hydrophobic NCI is better than a wettable NCI

Methods for evaluating Hydrophobicity

- Contact angle – **Advantages-**

  simple, inexpensive, quick,

  field employable

  Limitations- un reliable, affected by

  weather

WETTABILTY

MORE HYDROPHOBIC

LESS HYDROPHOBIC

CRITICAL SURFACE TESTING(dynes/cm)

FLOURINES

SILICONES

EPS

EPOXY

Hydrophobicity

- All polymers are initially hydrophobic
- Hydrophobicity is reduced during during service
  - Dirt, UV corona, discharges, chemicals(water)
- For EPs, epoxy, the above will eliminate hydrophobicity
- For silicones, only excessive corona and strong discharges can destroy hydrophobicity locally

Hydrophobicity Recovery

- Desirable as high surface resistance restored
- Mainly due to Diffusion of LMW polymer chains from bulk to surface
- Recovery ability different for polymers,

  silicones=highest, and

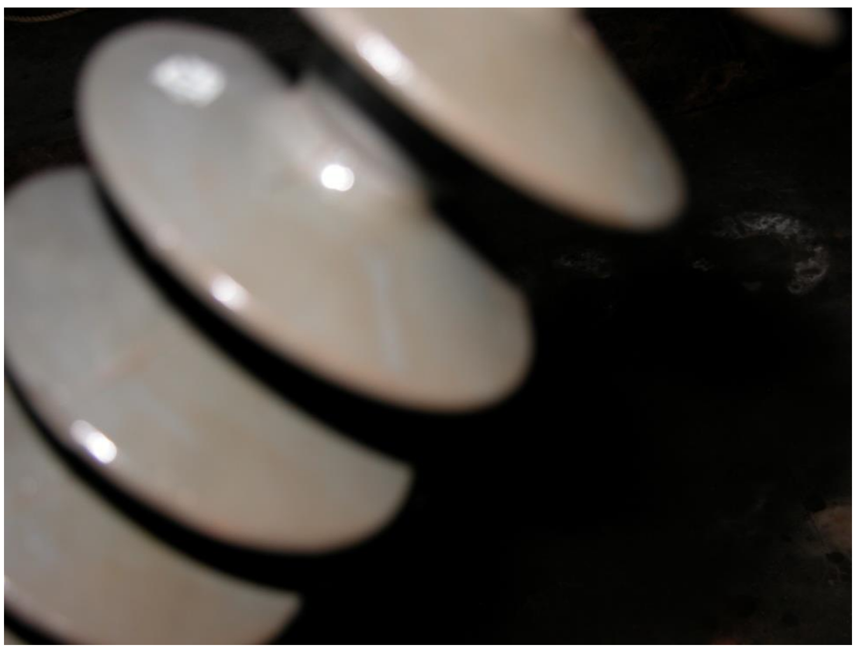
  - high surface resistance obtained even before

    visible recovery (beading) occurs
- Recovery ability lost for EP, epoxy when dirty

Hydrophobicity Recovery

- Silicones exhibit recovery even when contaminated
- Is dependent on
  - Formulation
  - Temperature
  - Contamination(thickness and type)
  - aging

Hydrophobicity recovery

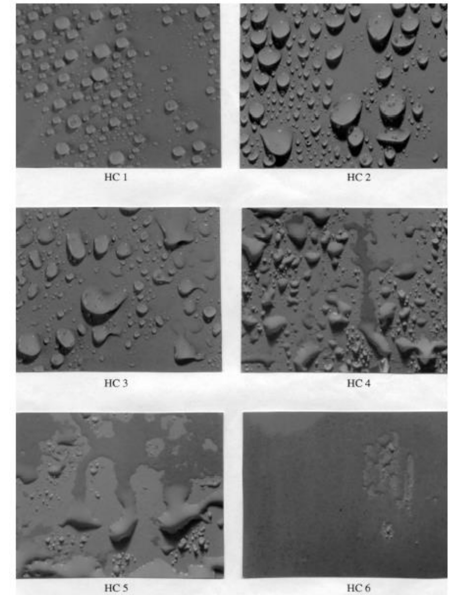


ydrophobicity before energization

Hydrophobicity after energization

Hydrophobicity transfer

Methods for Evaluating Hydrophobicity



- Contact angle
  - Advantages :simple, inexpensive, quick ,non-destructive ,
  - field employable
  - Limitations: unreliable, affected by weather, roughness,
  - gravity
- STRI classification
  - Adv.: simple, more reliable than contact angle, field employable
  - Limitations: EPs are wettable yet perform well, false warnings
- Surface diagnostics(ESCA, FTIR, SEM,etc)
  - Adv.: reliable, repeatable, useful for ranking various formulations
  - Limitations : destructive, time consuming, not field employable
- Surface resistance
  - Adv.: non-destructive, includes interaction effect of water/surface/stress
  - Limitations: time consuming, not standardized

Defense Mechanisms

There are 2 defense mechanisms

Leakage current suppression: primary mechanism

proper polymeric insulator design and material

superior for silicone polymers

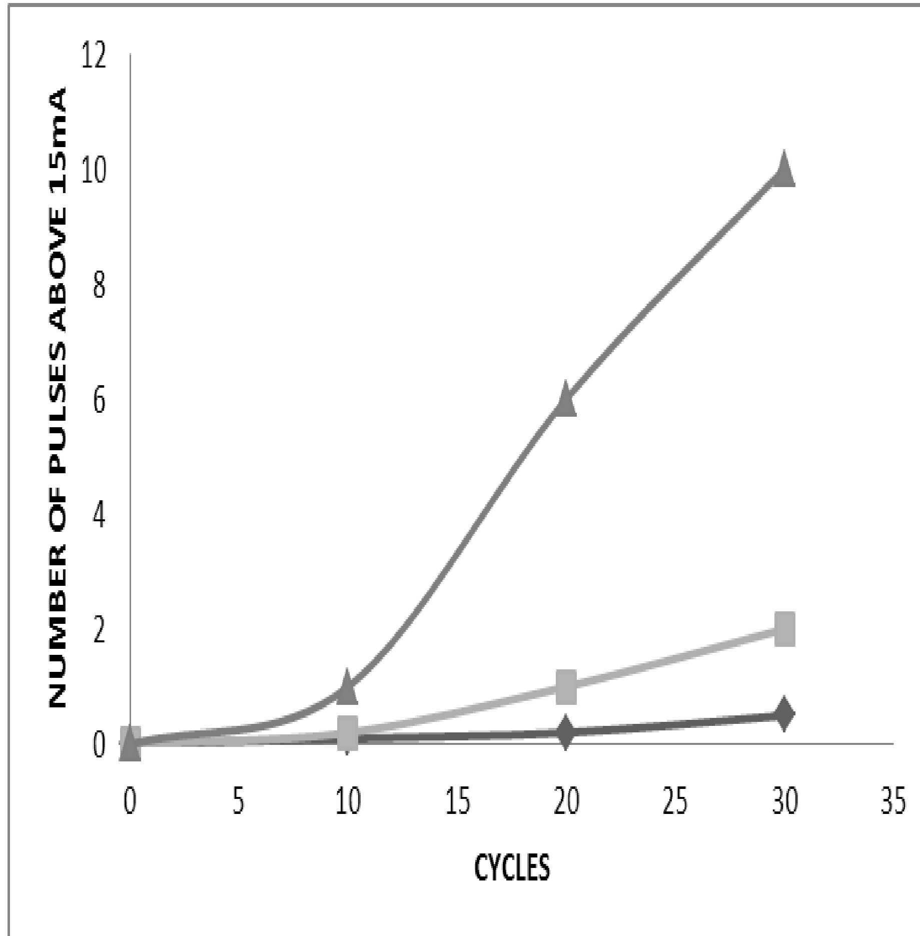
Tracking, erosion resistance: secondary mechanism

Tracking: carbon deposition

Erosion : Loss of material

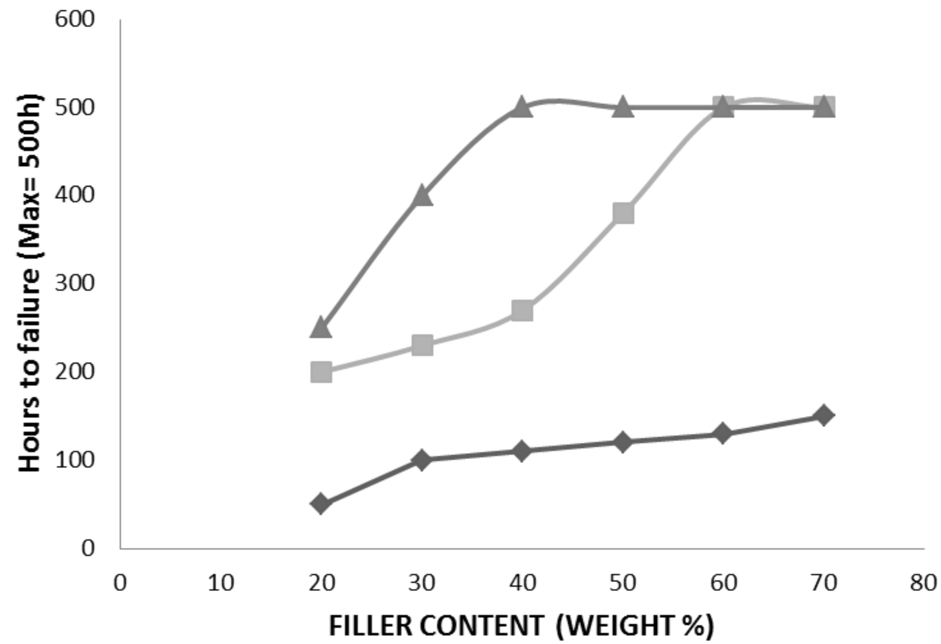
Leakage current suppression

- Superior for silicone polymers
- Impacts flashover performance under contaminated conditions



Tracking and Erosion Resistance

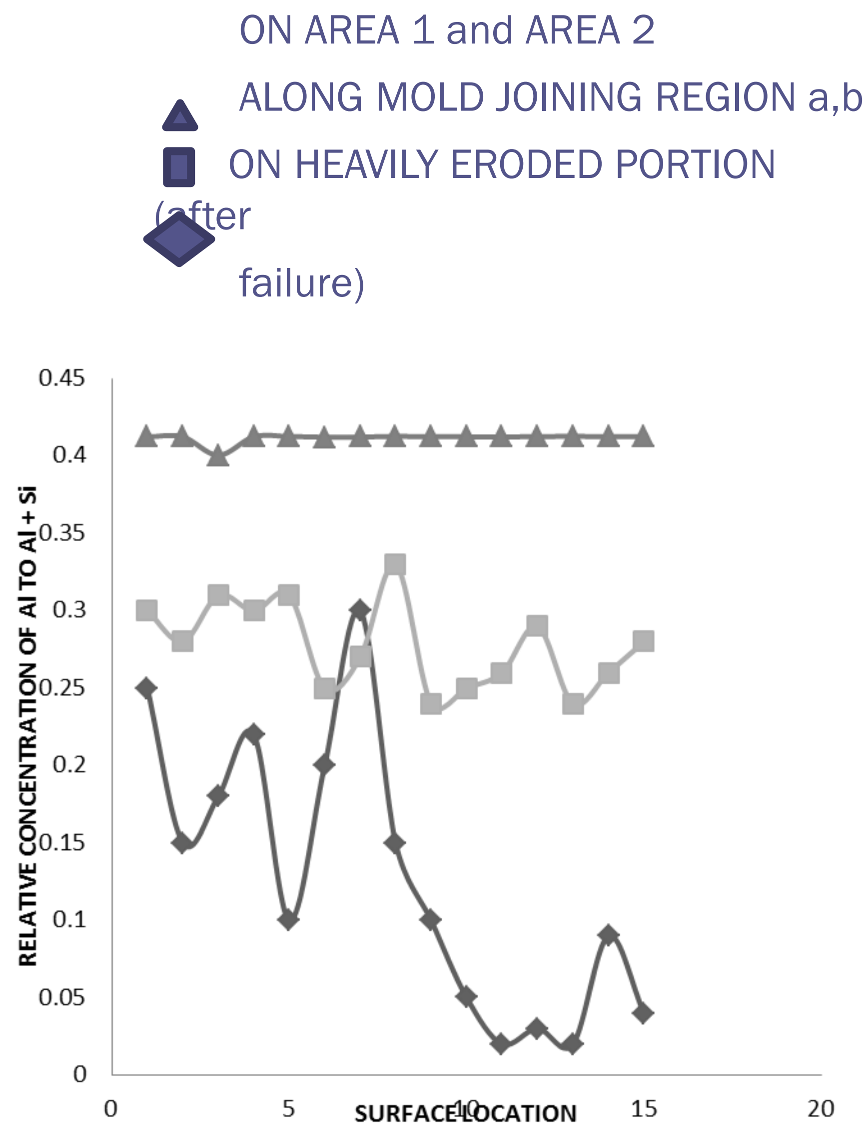
- Filler level is polymer and processing dependent.
  - Many silicones in service with little filler.
  - Eps, Epoxies need high filler levels (50%+)
- Higher filler concentration improves Tracking and Erosion resistance.
- Fillers improve some aspects, but degrade others.



<u>Specify device performance, not material details</u>

Role of Filler Dispersion

- Can cause premature and preferential degradation.
- Can be checked in a SEM with Energy Dispersive X-ray attachment.
- Mold parting line can be a problem due to poor filler dispersion.
- Poor filler dispersion can occur in regions other than mold line.



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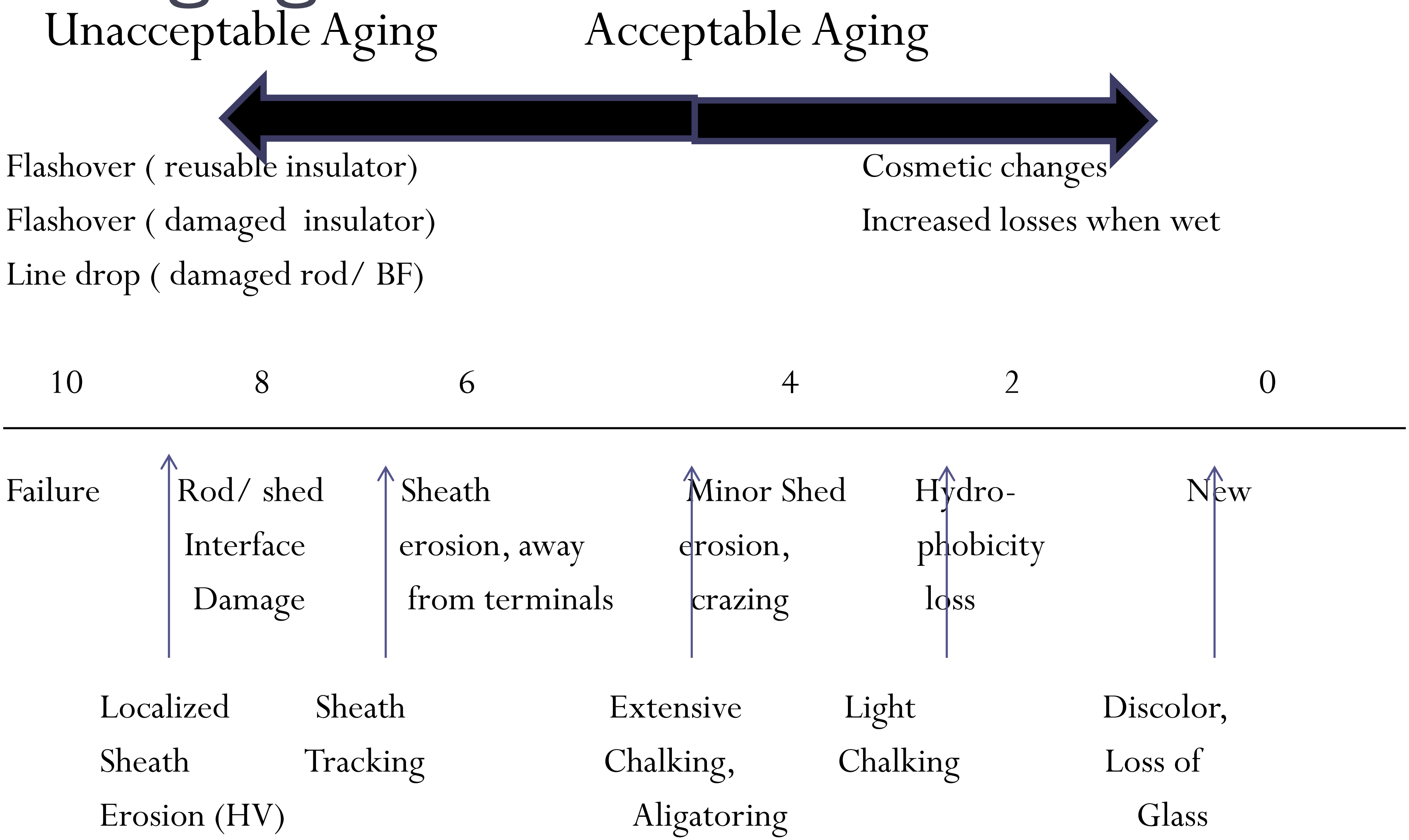
Fungi Resistance

- Importance for NCIs in hot and humid regions.
- Bacteria and mold should not be allowed to grow on NCI as it uses material as culture medium, slowly deteriorates insulation.
- Some silicone rubbers in hot and humid regions have experienced mold growth.
- So far no problems, except loss of hydrophobicity in moldy areas.
- No mold growth in places with high temperature but low humidity (Phoenix) or high humidity but low temperature.

Aging Chart



Unacceptable Aging
Acceptable Aging
Flashover (reusable insulator)
Flashover (damaged insulator)
Line drop (damaged rod/ BF)
Cosmetic changes
Increased losses when wet
10
8
6
4
2
0
Failure
Rod/ shed Interface Damage
Sheath erosion, away from terminals
Minor Shed erosion, crazing
Hydro-phobicity loss
New
Localized Sheath Erosion (HV)
Sheath Tracking
Extensive Chalking, Aligatoring
Light Chalking
Discolor, Loss of Glass

The main difference between materials are

- Fillers (HTV is highly filled with Alumina Tri Hydrate(ATH))
- Catalyst system

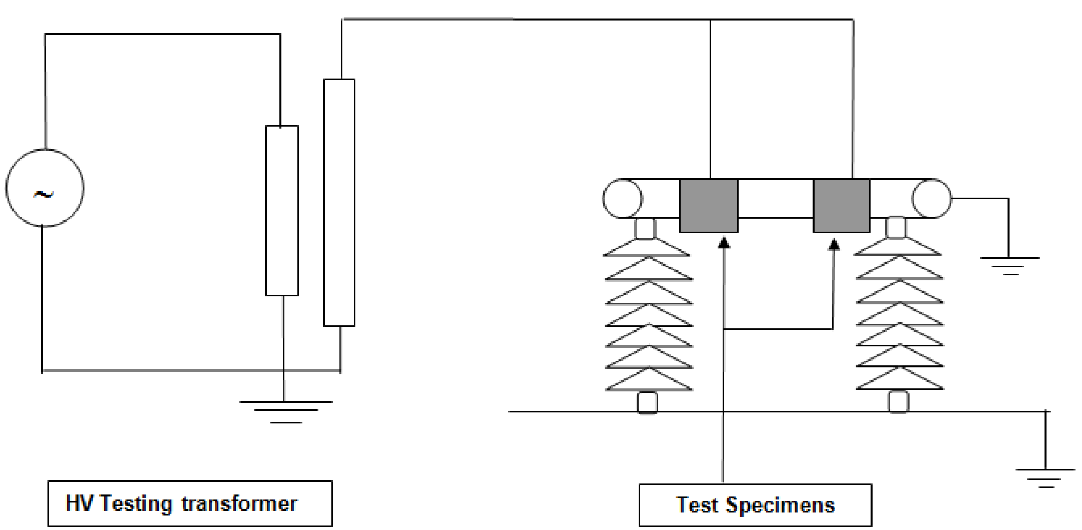
Advantage of Silicon Rubber:

Flashover resistant, Ageing withstand, UV stability, Mechanical strength

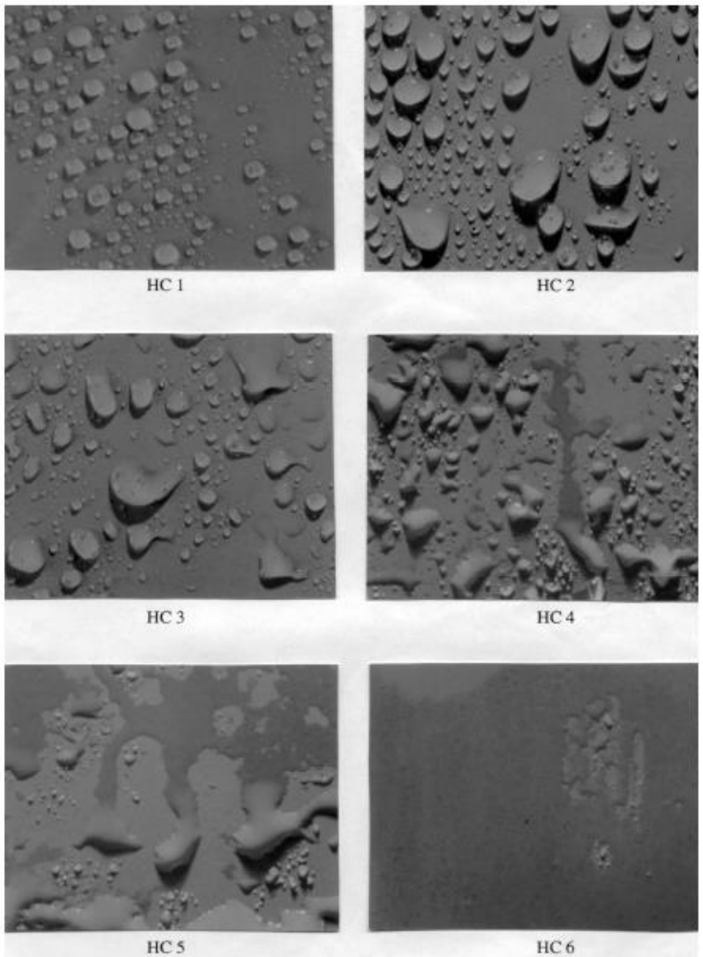
- Ethylene propylene monomer(EPM), ethylene propylene diene monomer (EPDM) , Cycloaliphatic epoxy resin, Ethyl vinyl acetate are the other polymer

Hydrophobicity Recovery test

- Sheds cut from the insulator were subjected to Hydrophobicity recovery test. Mechanical stress was given by bending the samples on earth electrode. Corona was generated by applying 12kV to needle type electrode placed 1mm above the test samples.



Hydrophobicity Recovery test evaluation



STRI classification

Virgin sample

100 hours corona aged sample

Recovery of hydrophobicity of sample after 48 hours

Tests on shed and housing material

Hardness test:

- Two specimens of the housing material of a size, shape and thickness appropriate for the hardness measurement method given in ISO 868 shall be taken from the housing of two insulators.
- If the shed shape or thickness is inappropriate, then samples may be made separately using the same manufacturing process and parameters.

- Measure and record the ambient temperature and the hardness of the two samples in accordance with ISO 868 with a Shore A or D durometer, as appropriate.

Flammability test

- This test is intended to check the housing material for ignition and self-extinguishing properties.
- Sample thickness shall be 3 mm.

Acceptance criteria:

Application	IEC 60695-11-10 Categories		
	V0	V1	HB40-25mm
Overhead line insulators for U_m ≤ 72,5 kV			X
Overhead line insulators for U_m >72,5 kV	X		
Other insulators for U_m ≤ 145 kV			X
Other insulators for U_m >145 kV		X	

FIBRE GLASS REINFORCED ROD

Sl No	Test	Reference Specification	Specified Value
1	Verification of dimensions	As per approved drawing	As per drawing
2	Bending Tests	As per enclosed specification	210 Kgfm (min)
3	Dye Penetration	IEC:61109 (Cl. 5.4.1)	No dye penetration for 15 minutes (min)
4	Flammability	IEC:60707	Burning behavior to be checked
5	Percentage of glass content	ASTM D 2584	70% (min)
6	Hardness test (Barcol)	ASTM D 2583	50 min
7	Flexural strength	ASTM D 790 M…..	9900 kgf/cm^2 (min)
8	Water absorption	IEC:61109, ASTM D 570	0.1% max
9	Brittle fracture resistance test		Should withstand
10	Specific gravity	ASTM D 792	1.9 to 2.1 gm/cc

Porosity Test (Dye penetration test)

- The specimens were placed on a layer of steel balls of 2mm diameter in a tray. A solution of 1% of Astrazon BR200 in methanol is poured into a vessel, its level being 2mm to 3mm higher than the level of the balls. The specimens were observed for 15 minutes

Acceptance criteria:

- No Rise of Dye by capillary action within 15 minutes.

Porosity Test (Dye penetration test)

Samples Starting of the Test

Samples after 15 minutes of the Test

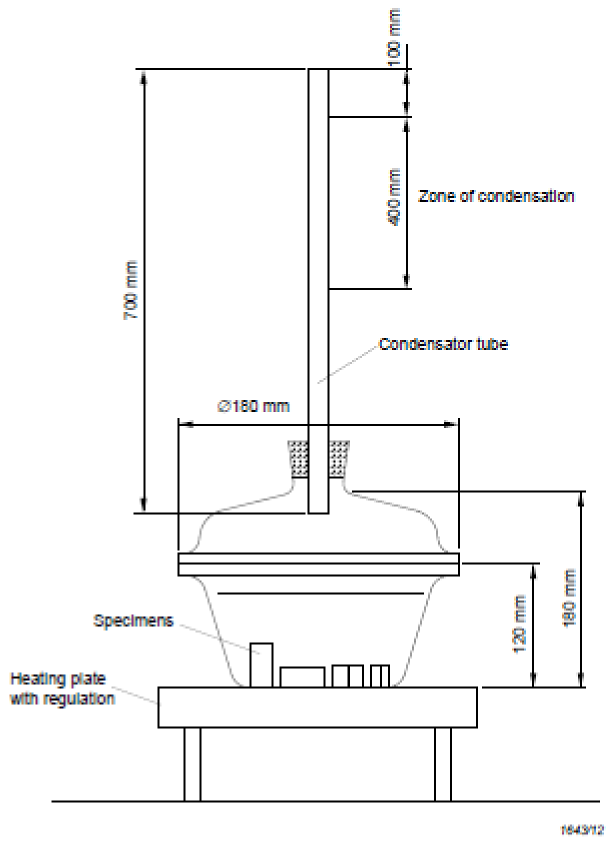
Water Diffusion test:

- The surfaces of the 6 specimens were cleaned with isopropyl-alcohol and filter-paper immediately before boiling. The specimens were boiled in a container for 100 hours ± 0.5 hours in de ionized water with 0.1% by weight of NaCl.
- After boiling, the specimens were removed from the boiling container and placed in another container filled with tap water at ambient temperature for at least 15 min. the voltage test was carried out within 2 hours after the removal of specimen from boiling container.

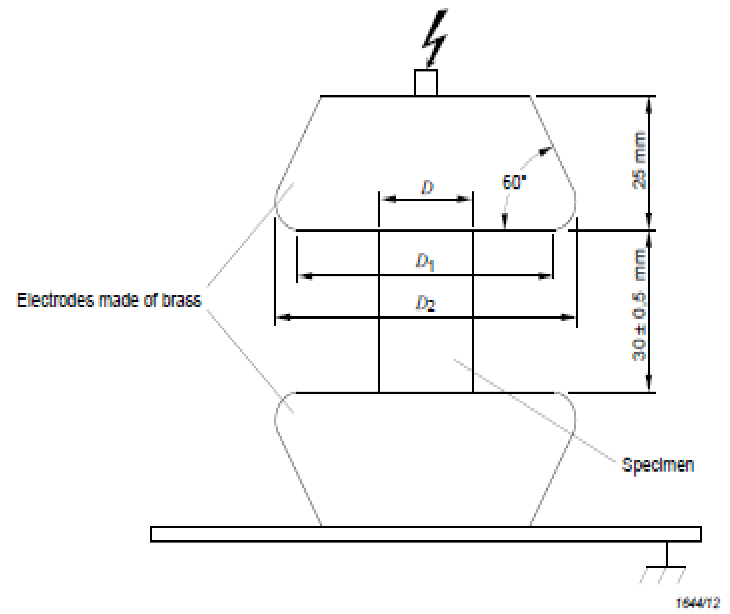
Water Diffusion test:

- Immediately before the voltage test, the specimens were removed from the container and their surface dried with filter paper.
- Each specimen was placed between the electrodes. The test voltage was increased at approximately 1 kV per second up to 12 kV. The voltage was kept constant at 12 kV for 1 minute and then decreased to zero. Leakage current measured are given below.

Tests on Core Material



boiling container for the water diffusion test



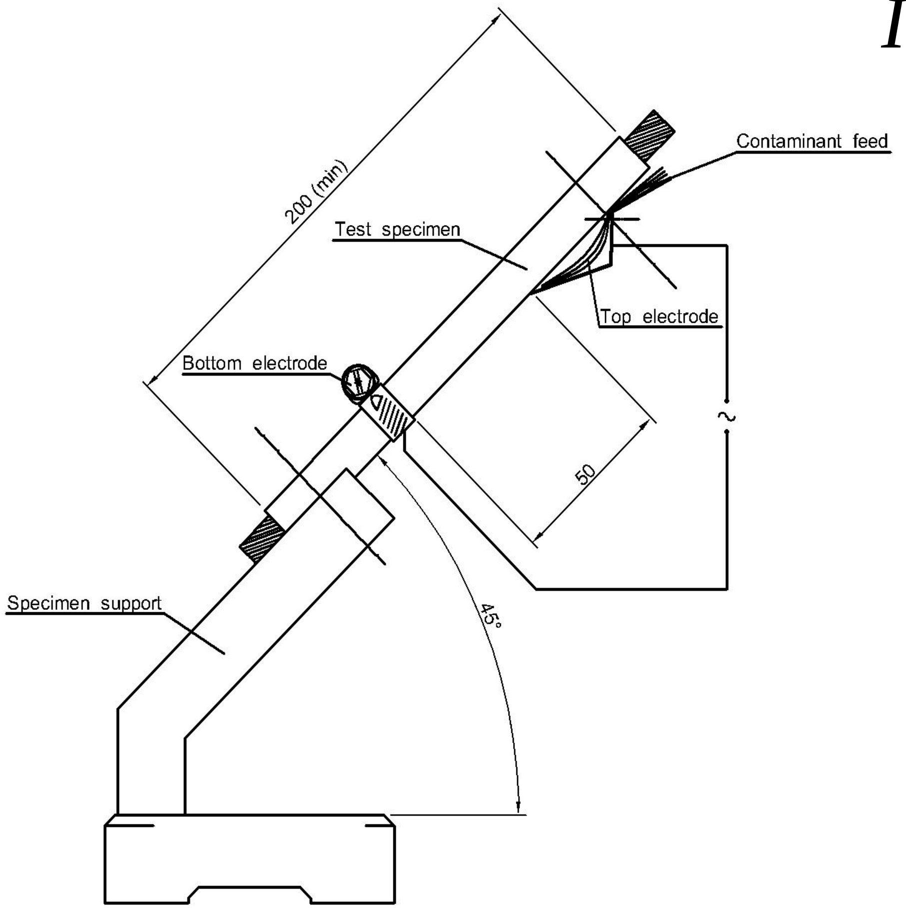
Electrodes for the voltage test

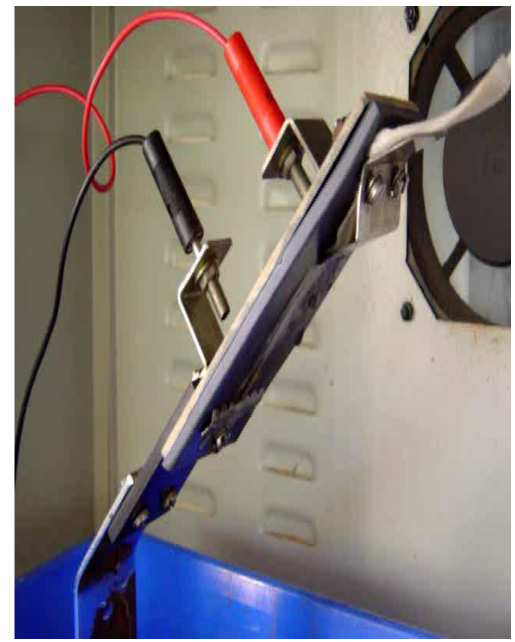
Tracking and Erosion test - Materials

- A more advanced measure of a materials resistance to arcing is tested using ASTM D 2303.
- It is used frequently for evaluating high voltage silicone elastomeric composite housing materials; flat samples are mounted on a 45-degree incline.
- A 400 ohm-cm solution flows from the top to bottom of the sample on the underside.
- A prescribed voltage is applied between electrodes at 2 inches apart.

Tracking and Erosion test- Materials

Inclined plane method





ASTM D2303

Tracking and Erosion test `

- Voltage -4.5 kV
- Duration -6 hours
- Contaminant- 0.1% ammonium chloride (NH_4 Cl) and 0.02% of non-ionic wetting agent .

<u>Acceptance criteria:</u>

- No tracking & Erosion observed.

Standards---Composite/Polymer

IEC 62217 "Polymeric insulators for indoor and outdoor use with a nominal voltage > 1 000V - General definitions, test methods and acceptance criteria

- *IEC 61462*
- *IEC 61109*
- *IEC 62231*
- *IEC 60099-4*
- *IEC 62770*

ANSI/IEC Tests for products

Classification of Test:

- **Design tests-** Verify suitability of proto type tests design, material and method of manufacture
- **Type tests -**Verify those characteristics of insulators which depend on the size and shape
- **Routine tests -**Eliminate insulators with manufacturing defects
- **Acceptance test-** Test made on arresters or representative sample after agreement between manufacturer and user

Type Test-

- Insulator withstand test on the arrestor housing
    - Lightning impulse voltage
    - Switching impulse
    - Power-frequency voltage
- Residual voltage Test
    - Steep current
    - Lightning impulse
    - Switching impulse
- Test to verify long term stability under continuous operating voltage
- Repetitive charge transfer withstand
- Heat Dissipation behavior verification of test sample

Type Test

- Operating duty test
- Power-frequency voltage versus time
- Arrestor disconnector/fault indicator
- Short-circuit test
- Bending moment
- Seal leak rate
- RIV
- Test to verify the dielectric withstand of the internal components of arrester
- Test of internal grading components
- Weather ageing test—Salt fog method, UV light.

Type Test

- Hardness test
- Flammability test
- Dye penetration
- Water diffusion test

Routine Test

- Measurement of reference voltage
- Residual voltage test
- Internal partial discharge test
- Power-frequency voltage
- seal leak rate
- current distribution test
- Measurement of resistance / capacitance

Acceptance Test

- Measurement of power-frequency voltage
- Lightning impulse residual voltage
- Internal partial discharge test
- bending moment and tensile load tests shall be performed.
- thermal stability test

Insulator withstand test

- Lightning impulse test
  - 15 +ve and 15 –ve impulse
  - Test voltage will be 1.3 times the max residual voltage of the arrestor at nominal discharge current.
- Switching impulse test
  - 15 +ve and 15 –ve impulse
  - Test voltage will be at least the maximum switching impulse residual voltage of the arresters multiplied by $1,1 \times e^{m \times 1\,000/8}\,150$
- Power-frequency voltage test
  - Voltage with a peak value equal to the lightning impulse protection level multiplied by 0.88 for the duration of 1 min.

Insulator withstand test

Measuring system

Impulse generator 3MV,150 kJ

Cascade High voltage Transformer 1800 kV

Residual voltage Test

- <u>Residual voltage test</u>
  - The purpose of the measurement of residual voltages is to obtain the maximum residual voltages for a given design for all specified currents and wave shapes.
  - It is calculated from the residual voltage of sections tested during type tests multiplied by a specific scale factor.
- <u>Steep current impulse residual voltage test</u>
  - One steep current impulse with a peak value equal to the nominal discharge current of the arrester ±5 % shall be applied to each of the three samples.

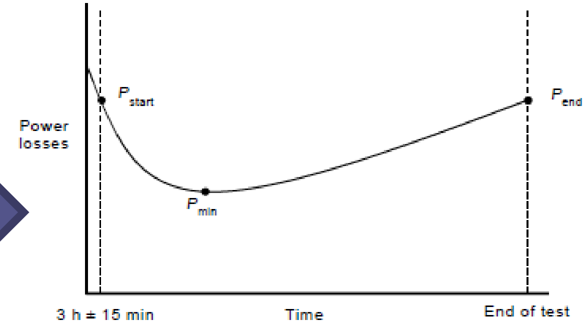
Residual voltage Test

- <u>Lightning impulse residual voltage test</u>
  - One lightning current impulse shall be applied to each of the three samples for each of the following three peak values of approximately 0,5, 1 and 2 times the nominal discharge current of the arrester.
  - Front time shall be with in 7 t0 9 us and tail time may have any tolerances(not critical).
- <u>Switching impulse residual voltage test</u>
  - One switching current impulse shall be applied to each of the three samples with peak values with a tolerance of ±5 %.

Test to verify long term stability under continuous operating voltage

- Typically, under normal operation, a surge arrester is stressed at a voltage below its reference voltage.
- Test to verify long term stability for the cases
  - MO resistor elements stressed below Uref
  - MO resistor elements stressed above Uref
- However, for certain arrester designs the normal operating voltage may be at or even above Uref, in which case it may not be possible to perform a test in the same manner.

Power loss vs. time during long term stability test



Repetitive charge transfer withstand

- The purpose of this test is to verify the repetitive charge transfer rating, *Qrs, of an arrester.*
- Initial tests
  - Residual voltage test at nominal discharge current
  - Reference voltage test at specified reference current
- Application of 1.1 times Qrs
  - 1st sequence:, 20 impulses per sample (10 samples)
  - if not more than one sample failure during 1st sequence: test passed
- Test evaluation: no mechanical damage at visual inspection & change of reference voltage within ±5%& change of residual voltage at nominal discharge current within ±5%

Heat dissipation behavior of test sample

- The behavior of the test sample is to a great extent dependent on the ability of the sample to dissipate heat, i.e. to cool down after being stressed by a discharge.
- Consequently, the test samples shall have a transient and a steady-state heat dissipation capability and heat capacity equivalent to the complete arrester if correct information is to be obtained from the test. For the same ambient conditions the MO resistors in the sample and in the complete arrester should in principle reach the same temperature when subjected to the same voltage stress.

Operating Duty test:

- The purpose of this test is to verify the arrester's ability to thermally recover after injection of the rated thermal energy, W_{th}, *or transfer of the rated thermal charge, Qth, respectively, under* applied temporary overvoltage and following continuous operating voltage conditions. The test shall be performed on three samples.
- *Thermal charge transfer rating* ***Definition***
  - maximum specified charge that may be transferred through an arrester or arrester section within 3 minutes in a thermal recovery test without causing a thermal runaway

Power frequency voltage-versus-time test:

- The purpose of this test is to demonstrate the TOV (temporary overvoltage) withstand capability of the arrester. In this test, the TOV is strictly a power-frequency overvoltage for time periods from 0,1 s to 3600 s

Test evaluation

- Thermal recovery
- No physical damage
- Change of residual voltage at nominal discharge current within ±5%

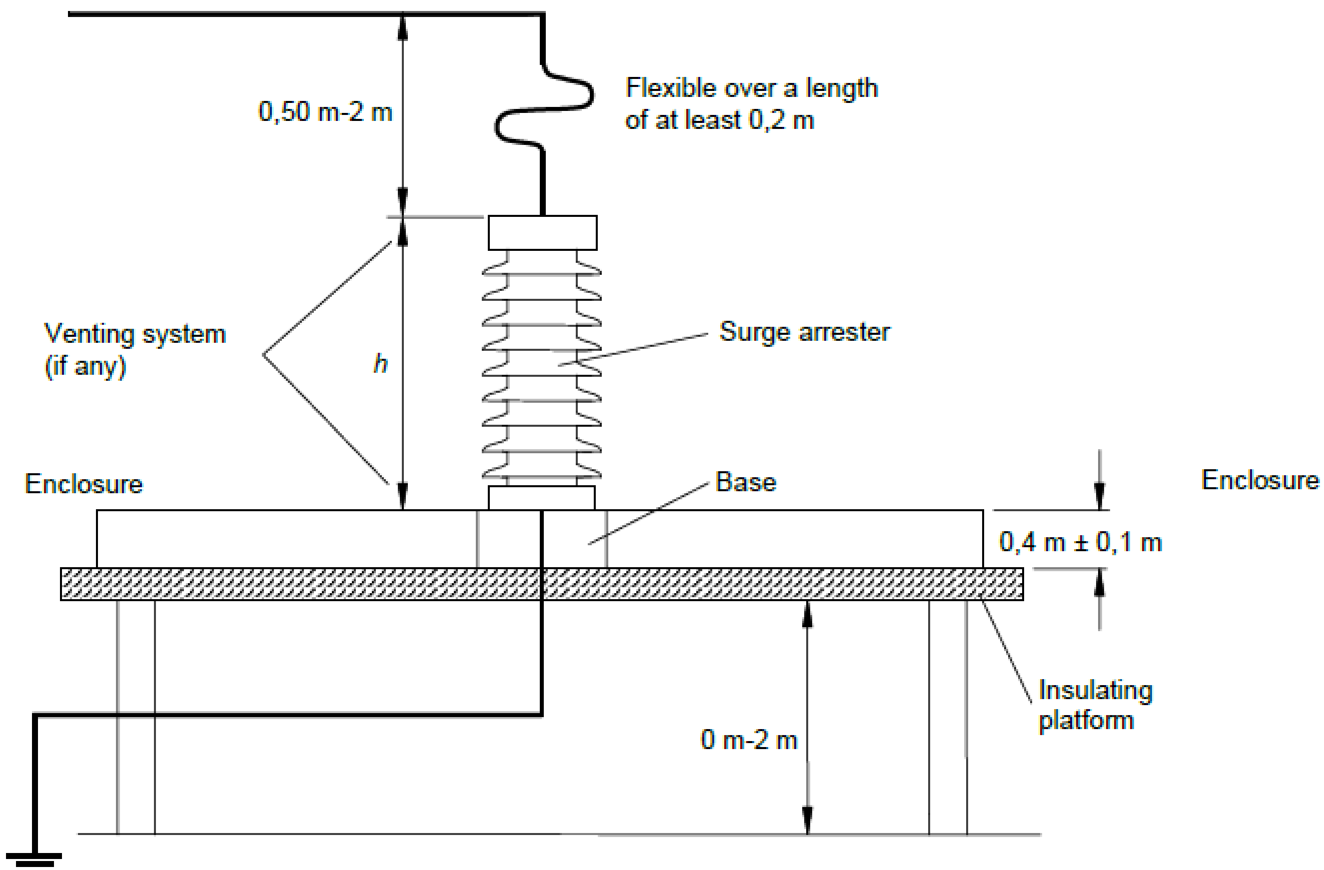
Arrester disconnector Test

- The purpose of the disconnector test is to verify that the disconnector of an arrester can withstand all stresses related to their application in arresters without operating.
- The test also demonstrates that the disconnector will perform according to the time-current characteristic published by the manufacturer.

Short circuit Test

- With respect to the short-circuit current performance, it is important to distinguish between two designs of surge arresters.
- Design A" arresters(polymer-housed arresters) have a design in which a gas channel runs along the entire length of the arrester unit and fills ≥50 % of the internal volume not occupied by the internal active parts.
- "Design B" arresters are of a solid design with no enclosed volume of gas or having an internal gas volume filling <50 % of the internal volume not occupied by the internal active parts.

Short circuit Test



Short circuit Test

- Depending on the type of arrester and test voltage, different requirements apply with regard to the number of test samples, initiation of short-circuit current and amplitude of the first short circuit current peak.
- For the high-current tests, the test samples shall be the longest arrester unit used for the design with the highest rated voltage of that unit used for each different arrester design.
- For the low-current test, the test sample shall be an arrester unit of any length with the highest rated voltage of that unit used for each different arrester design.
- The pre-failure can be achieved by either applying
  - a voltage source or a
  - current source to the samples

Pre failure test

Short circuit Test

Test requirements for polymer-housed arresters

	Required number of test samples	Initiation of short-circuit current	Ratio of first current peak value to r.m.s. value of required short-circuit current					
			Test voltage: 77 % to 107 % of U_r			Test voltage: < 77 % of U_r		
			Rated short-circuit current	Reduced short-circuit current	Low short-circuit current	Rated short-circuit current	Reduced short-circuit current	Low short-circuit current
"Design A"	4 or 5	Fuse wire along surface of MO resistors; within, or as close as possible to, the gas channel	Prospective: ≥2,5 Actual: no requirement	Prospective: ≥ √2 Actual: no requirement	Actual: ≥ √2	Actual: ≥ 2,5 *or:* Actual: ≥ √2 on longest unit and Actual: ≥ 2,5 on a unit with U_r ≥ 150 kV	Actual: ≥ √2	Actual: ≥ √2
"Design B"	4	Pre-failing by constant voltage or constant current source	Prospective: ≥ √2 Actual: no requirement	Prospective: ≥ √2 Actual: no requirement	Actual: ≥ √2	Actual: ≥ √2	Actual: ≥ √2	Actual: ≥ √2

Bending moment Test

- This test applies to polymer (except cast-resin) housed arresters (with and without enclosed gas volume) for *Us* > *52 kV. It also applies to polymer (except cast-resin) housed arresters for Us ≤ 52 kV for which the manufacturer claims cantilever strength.*
- The arrester shall be able to withstand the manufacturer's declared values for bending loads
- *The test shall be performed* on the arrester without insulating base or mounting bracket.

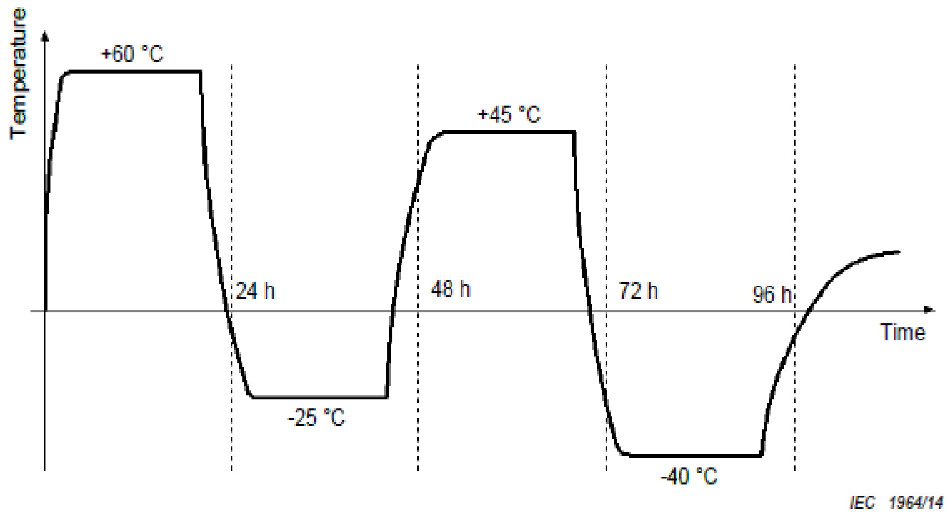
Bending moment Test- Test procedure

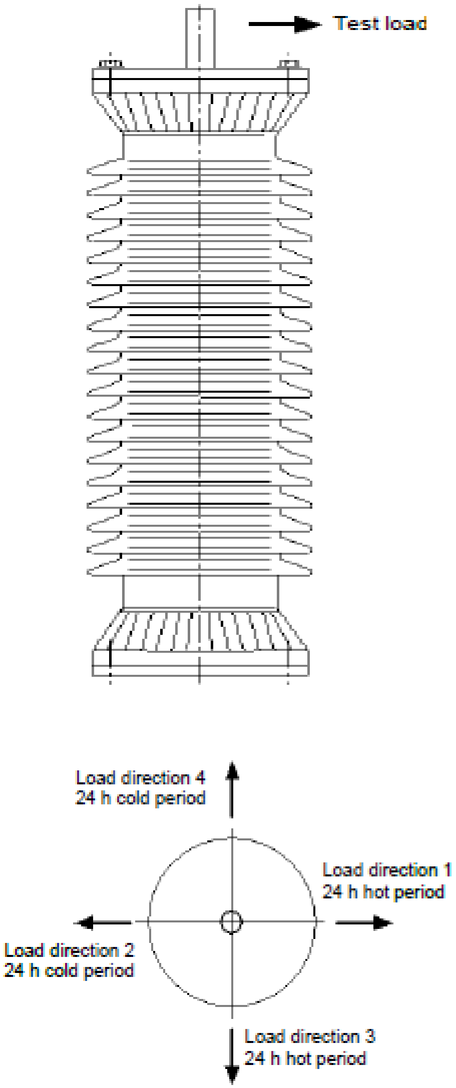
- Arrestor >52KV:Subject two samples to a bending moment test. The bending load shall be increased smoothly to specified short-term load (SSL) within 30 s to 90 s. When the test load is reached, it shall be maintained for 60 s to 90 s. During this time the deflection shall be measured. Then the load shall be released smoothly. The maximum deflection during the test and any residual deflection shall be recorded.
- The residual deflection shall be measured in the interval 1 min to 10 min after the release of the load.
- Subject a third sample to **mechanical/thermal preconditioning**
- Subject all three samples to the **water immersion test**

Bending moment test

Chamber for thermal mechanical test

Bending moment





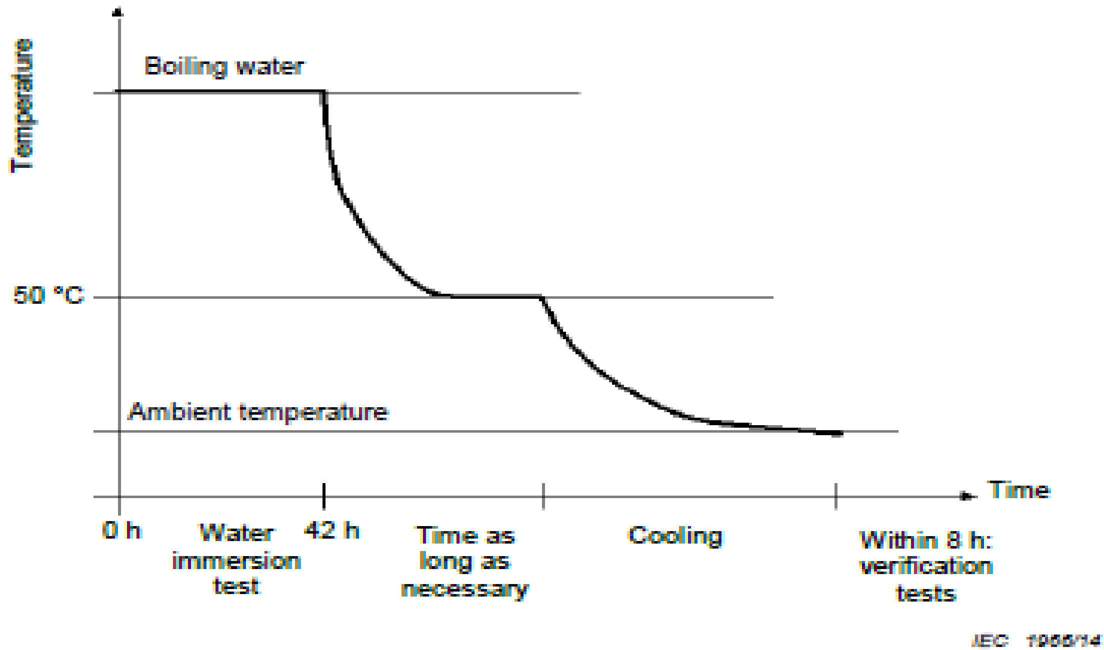
test-thermo mechanical test and direction of the cantilever load

Bending moment test

Water immersion test:

- The specimens shall be kept immersed in a vessel, in **boiling de-ionized water** with 1 kg/m^3 of NaCl, for 42 h.
- There is no visible damage;
- the slope of the force-deflection curve remains positive up to the SSL value except for dips not exceeding 5 % of SSL magnitude. The sampling rate of digital measuring equipment shall be at least 10 s–1. The cut-off frequency of the measuring equipment shall be not less than 5 Hz.

Bending moment



Water immersion Test

Bending moment test

Water immersion test:

within 8 h after- verification test

- the increase in watt losses, measured at *Uc and at an ambient temperature that* does not deviate by more than 3 K from the initial measurements, is not more than the greater of 20 mW/kV of *Uc (measured at Uc) or 20 %;*
- the internal partial discharge measured at 1,05 times *Uc does not exceed 10 pC;*

Seal leak rate Test

- The test demonstrates the gas/water tightness of the complete system. The test shall be performed on complete arrester units of any length.
- Enclosed gas volume/separate sealing system.
- If the arrester contains units with differences in their sealing system, the test shall be performed on one complete arrester unit. The internal parts may be omitted.
- If the arrester contains units with differences in their sealing system, the test shall be performed on one unit each, representing each different sealing system.
- The maximum seal leak rate (see G.4) shall be lower than 1×10^{-6} Pa·m^3/s.

Radio Interference voltage (RIV)Test

- These tests apply to open-air surge arresters intended for use on systems with $U_s \geq 72{,}5\ kV$.
- The test shall be performed on the longest arrester, with the highest rated voltage used for a particular arrester type. If other arrester types of lower ratings are equipped with exactly the same fittings (line and earth terminals, grading rings, etc.) they are qualified by the tests on the higher rated arrester and need not to be tested.
- This RIV test may be omitted if the same arrester has passed a partial discharge test.

Test to verify the dielectric withstand of internal components

- The purpose of this test is to verify the internal dielectric withstand capability of an arrester even under impulse currents of amplitudes higher than nominal discharge current.
- The test sample shall be heated in an oven for a time sufficient to obtain thermal equilibrium to at least 60 °C. The test shall be performed within 10 minutes after removing the sample from the oven. The test consists of one application of a high-current impulse with amplitude

Test of internal grading components

1. Test to verify long term stability under continuous operating voltage

- If internal grading components such as capacitors or (non-linear) resistors are used in the arrester they shall be tested in an accelerated test to verify long term stability under continuous operating voltage under the same test conditions as the MO resistors .The test samples may be individual components or a stack of such components.

2. Thermal cyclic test

- 3 samples subjected to thermal variations. five 48 hours cycles of heating and cooling to 60 deg and -40 deg. hot and cold periods shall be maintained for at least 16h. Impedance measured at 20deg before and after.
- No crack, PD will be less than 10 pC, Impedance not greater than ± 5 %

Weather ageing test

Test has two parts:

- First evaluates the effect of exposure of the arrester to salt fog.
- Second is the Evaluates the effect of exposure of the housing material to ultra-violet (UV) light.

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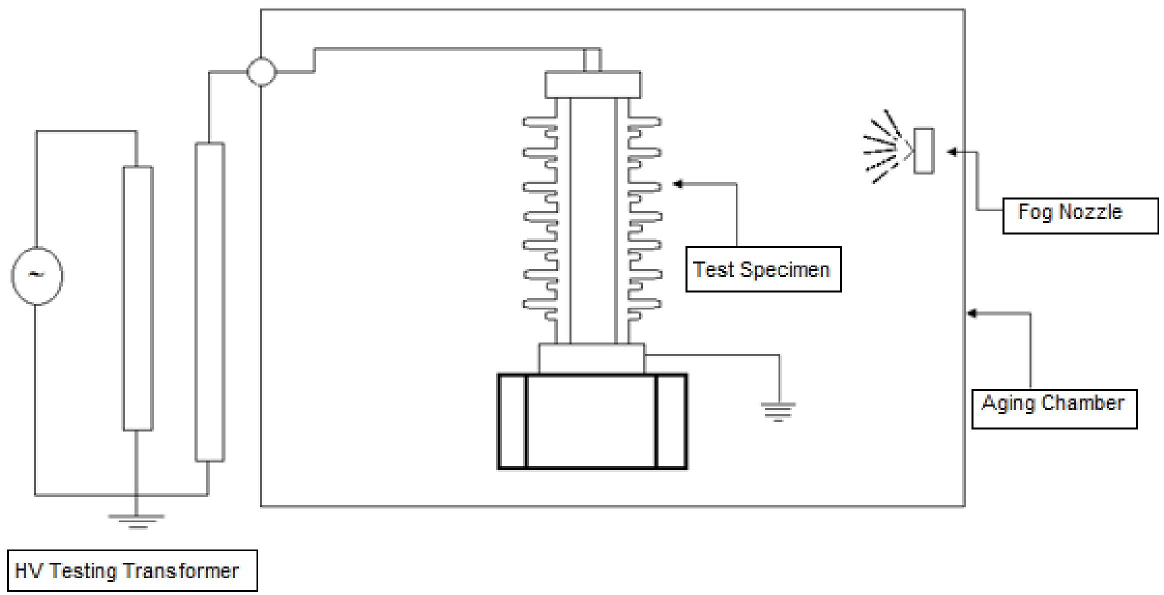
Weather ageing test

<u>Salt fog test</u>

- Duration of the test: 1 000 h
- Water flow rate 0.4 l/h/m3 ± 0. 1 l/h/m3
- Size of droplets 5 µm to 10 µm
- Temperature 20 °C ± 5 K
- NaCl content of water between 1 kg/m3 to 10 kg/m3
- The test voltage in kilovolts is adjusted to the actual creepage distance of the test specimens determined by dividing the creepage distance in millimetres by 34,6 (equal to a specific creepage distance of 20 mm/kV).

Weather ageing test



Schematic diagram-salt fog method

weather ageing test

Salt fog method Before and After ---168kV, 20kA and applied voltage is 133.5 kV rms.

Weather ageing test

<u>Acceptance criteria</u>

- No tracking occurs;
- if the reference voltage measured before and after the test at the same ambient temperature within ± 3 K has not decreased by more than 5 %, and if the partial discharge measurement performed before and after the test is satisfactory (**partial discharge level shall not exceed 10 pC)**
- For composite insulators: erosion depth is less than 3 mm and does not reach the core, if applicable;
- No shed, housing or interface is punctured.

Weather ageing test

Accelerated weathering test(UV):

- The insulator housing material shall be subjected to a 1 000 h UV light test using the following test method. Markings on the housing, if any, shall be directly exposed to UV light
- Xenon-arc methods: ISO 4892-1 and ISO 4892-2, using method A without dark periods, **standard spray cycle, black-standard/black panel temperatures of 65 °C, an irradiance of around 550 W/m2**
- Fluorescent UV method: ISO 4892-1 and ISO 4892-3, using type I fluorescent UV lamp, exposure method 1 or 2.
- After the test, markings on shed or housing material shall be legible; surface degradations such as cracks and raised areas are not permitted.

Conclusion

- Silicone, EP rubber and epoxy, when properly formulated provide satisfactory performance.
- Transmission NCIs use silicone or EP
- Variation in formulations of these materials exist
- For most outdoor locations, NCIs made from these materials (design OK) have performed satisfactorily.
- Silicone rubber provides better leakage current suppression than EP rubber stand epoxy = improved flashover performance.
- Failure in earlier NCIs due to manufacturing techniques, design, material, selection, misapplication.
- Significance improvements have been made, general performance "good".
- For 'properly manufactured ' NCIs, aging effects for most locations can be handled by design

Need to identify "defective/ deficient" NCI for EHV/UHV applications in severe locations.

Conclusion

- Composite arrestor is now preferred for all new power projects .
- The good news is that there are technology and products available today which will ensure increased reliability of the system .


Thank you for your attention