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IEEE Guide for the Application, Maintenance, and Evaluation of Room Temperature Vulcanizing (RTV) Silicone Rubber Coatings for Outdoor Ceramic Insulators

IEEE Dielectrics and Electrical Insulation Society

Sponsored by the
Outdoor Service Environment Committee

IEEE

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Sponsor

Outdoor Service Environment Committee
of the
IEEE Dielectrics and Electrical Insulation Society

Approved 11 December 2002

IEEE-SA Standards Board

Abstract: Various important aspects that are needed for satisfactory long-term performance of High-Voltage Insulator Coatings (HVIC) are presented in this guide. Various possible application scenarios, maintenance issues on coated insulators, factors affecting long-term performance, the question of aging, laboratory accelerated tests, and functional outdoor evaluation are described.
Keywords: aging, evaluation, hydrophobicity, HVIC

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Introduction

[This introduction is not part of IEEE Std 1523-2002, IEEE Guide for the Application, Maintenance, and Evaluation of Room Temperature Vulcanizing (RTV) Silicone Rubber Coatings for Outdoor Ceramic Insulators.]

The problem of outdoor insulator flashover due to contamination has existed as long as outdoor insulation itself. Insulator flashovers result in power outages that are expensive and hence undesirable. It was understood that in order to prevent flashover, the leakage current must be minimized. Room temperature vulcan (RTV) coatings minimize leakage current by preventing water filming on the insulator surface.

The use of RTV coatings began on a trial basis since the 1970s. Large-scale application of the coatings began in the 1980s. User experience of RTV coatings has been highly successful. But it must be mentioned that for any specific application, judgment and experience are required to analyze and balance the many characteristics, which are discussed to obtain satisfactory performance and reliability.

The work toward this guide began in the early 1990s. Round robin tests were performed in several laboratories. Concurrently, input regarding user experience was solicited.

IEEE Std 957™-1995[a] deals with some aspects of RTV coatings. This guide aspires to provide more details and information on the subject of RTV coatings.

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IEEE Guide for the Application, Maintenance, and Evaluation of Room Temperature Vulcanizing (RTV) Silicone Rubber Coatings for Outdoor Ceramic Insulators

1. Overview

1.1 Scope

This guide is based on the knowledge and experience of manufacturers, users, and researchers of room temperature vulcanizing (RTV) silicone rubber coatings that are used to improve the contamination performance of outdoor high-voltage (HV) insulators. This guide discusses various important aspects that are needed for satisfactory long-term performance of high-voltage insulator coatings (HVIC)—namely, various possible application scenarios, maintenance issues on coated insulators, factors affecting long-term performance, the question of aging, laboratory accelerated tests, and functional outdoor evaluation. However, it must be mentioned that for any specific application, judgment, and experience are required to analyze and balance the many characteristics, which are discussed to obtain satisfactory performance and reliability.

1.2 Purpose

This guide is intended for the use of RTV coatings on ceramic and glass insulators.

1.3 Applications

This guide is specific enough to be applicable to porcelain and glass insulators in stations as well as transmission and distribution lines.

RTV coatings are also in use for mitigating animal-induced outages in stations. The coatings used, and the important aspects, may be different than those used for insulator contamination performance improvement. The manufacturer should be consulted prior to use of HV insulator coatings for animal protection.

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2. References

This guide should be used in conjunction with the following publications. When the following publications are superseded by an approved revision, the revision shall apply.

ASTM D 149-1997, Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies.[1]

ASTM D 150-1998, Standard Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation.

ASTM D 257-1999, Standard Test Method for DC Resistance or Conductance of Insulating Materials.

ASTM D 495-1999, Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation.

ASTM D 2132-1998, Standard Test Method for Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials.

ASTM D 2303-1997, Standard Test Methods for Liquid-Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials.

IEEE Std 957™-1995, Guide for Cleaning Insulators.[2,3]

3. Definitions

For the purposes of this guide, the following terms and definitions apply. IEEE 100™, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B2][4] should be referenced for terms not defined in this clause.

3.1 erosion: An irreversible and nonconducting degradation of the RTV coating that occurs by loss of material. This can be uniform or localized. Shallow surface traces can occur on coatings. (See IEC 611109-1992 [B1].)

3.2 hydrolysis: Depolymerization of the material due to the interaction of the ions of water.

3.3 room temperature vulcanizing silicone rubber: A silicone elastomer formed by vulcanization at room temperature of a liquid silicone polymer.

3.4 tracking: An irreversible degradation by formation of paths starting and developing on the surface of the RTV coating. These paths can be conductive even under dry conditions. Tracking can occur on surfaces in contact with air and on the interfaces between different insulating materials. (See IEC 611109-1992 [B1].)

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4. Background

The problem of outdoor insulator flashover due to contamination has existed as long as outdoor insulation. Insulator flashovers result in power outages that are expensive and hence undesirable. For example, a 250 ms outage can shut down a paper machine, resulting in hours of down time, possible equipment damage, and up to $50,000 in lost production. Although the preliminary theories of flashover caused by contamination did not emerge until the 1930s, it was realized even in the infancy of outdoor power transmission that a combination of airborne contaminants with moisture on the surface of the insulator could result in uncontrolled leakage current leading to flashover. Leakage current leads to increased watts loss, electromagnetic interferences, pole fires, and other safety concerns. It was understood that in order to prevent flashover, the leakage current must be minimized. The practices used by utilities to minimize flashover, with varying degrees of success, can be classified into the following groups:

a) Remove accumulation of contamination by periodic cleaning.
b) Minimize accumulation of contamination on the insulator surface with the use of aerodynamic profiles.
c) Increasing insulator length (BIL) leakage distance by increasing length or by using extra high leakage design units.
d) Keep a large area of the insulator dry for a long time during natural wetting either by the use of resistive glaze or the use of a fog bowl design, which has a profile that is difficult to wet the underskirt area.
e) Use of creepage extenders, which also prevent cascading of water droplets and hence provide a better utilization of leakage or creepage distance.
f) Prevent water filming on the insulator surface by coating insulators with water-repellent compounds (e.g., grease, RTV silicone rubber).

This guide deals specifically with RTV silicone rubber coatings. As all the methods mentioned are successful to various degrees (See Gorur [B3]), the decision to use a particular method is normally based on factors such as location, number of insulators, and total life-cycle costs involved.

5. Types of RTV coatings

Commercially available RTV insulator coating systems typically consist of a base silicone polymer, alumina trihydrate, or alternative fillers for increased tracking and erosion resistance, a catalyst, reinforcing filler, pigment, and a cross-linking agent. Several systems also contain an adhesion promoter, reinforcing filler, or a pigment. These systems are dispersed in a solvent such as naphtha. The solvent merely acts as a carrier medium to transfer the RTV rubber to the insulator surface. As the solvent evaporates from the surface, moisture from the air triggers vulcanization forming a solid rubber coating. The speed at which this takes place depends on the type of solvent, the cure system chemistry, temperature, and humidity (See Gorur [B3]).

There are several types of RTV coatings that are commercially available. The electrical and physical properties of the coating systems can vary depending on their formulation. These properties are the result of the amount of inorganic fillers, degree of cross linkage, and adhesion promotion. The formulation could play an important part as well. The properties of adhesion to the ceramic surface, retention of hydrophobicity under wet ambient conditions, and the arc degradation resistance are of paramount importance to coating performance.

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6. Application guidelines

6.1 Application on deenergized equipment or lines

Refer to IEEE Std 957-1995[5] for the preparation of insulators for coating application and RTV silicone coating application. A brief description of the application guidelines are presented in 6.1.1 and 6.1.4.

6.1.1 Insulator surface preparation

All surfaces must be clean and dry. This will help ensure proper adhesion of RTV to the insulator surface. High-pressure water washing is an effective cleaning method to remove common contaminants, such as accumulated dust and salt. More tenacious contaminants, such as cement dust, will likely require a dry abrasive cleaner, such as ground corncob. Previously greased insulators should be prepared by first wiping away the bulk of grease. The surface is then hand wiped with cloth rags and oil-less solvent to remove all grease residues.

Generally, RTV silicone coatings are applied directly to ceramic insulators without primers. For other insulators, the manufacturer should be contacted for specific recommendations.

6.1.2 Material preparation

Material preparation involves the final mixing and dispensing of RTV into the application equipment. However, the user should first verify that the material is still within its shelf life. Today's RTV coatings have a shelf life of about 6 months from date of shipment.

The RTV should be mixed thoroughly to ensure an even dispersion for spraying. Solvent dilution may be required depending on the viscosity of the RTV and the spray equipment used. Consult with the manufacturer of the coating for solvent recommendations.

Material preparation refers to mixing of settled material prior to its use, which is necessary if the coating has been kept in storage for some time. Thick coatings must be thinned with a solvent in the field to facilitate spray application. In the field, thinning is time-consuming and requires the use of hazardous solvents. Furthermore, field application is not very conducive to careful measurement of additives, which means that every pot used has a different consistency. Therefore, it is desirable that coating be specified ready for use after sample mixing.

6.1.3 Equipment

RTV silicone rubber coatings can be applied with several types of spray equipment commonly available. The types vary in cost and features. Conventional air spray equipment involves an air-pressurized material pot, which delivers fluid through a short hose to a spray gun. The low-pressure stream of fluid is finely atomized by pressurized air at the gun tip. This equipment is generally less expensive and provides a great degree of pattern control and quality of finish. However, it is limited in fluid pot capacity of 5–25 liters. Also, the pot must be carried by the operator because the low fluid pressures have limited ability to push fluid through long lengths of hose.

Spray systems with high-pressure pumps overcome the hose length limitation. It moves fluid at high pressure through long lengths of hose to one or several spray guns. The pumps and material pail can then be left on the ground while sprayers move about on lifts. One operator on the ground can handle material preparation to keep several sprayers supplied continuously. Due to the higher fluid pressures, properly rated spray guns are required for safety. These guns are of the airless type or air-assisted airless type. Airless guns rely

[5]Information on references can be found in Clause 2.

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solely on the force of pressurized fluid flows through a specially designed orifice and pressurized air to atomize the fluid. As the air can be adjusted, a more controllable spray pattern can be achieved. Airless guns allow for pattern control only by changing the interchangeable tip. The complicated geometries of insulators are more efficiently sprayed with guns capable of pattern adjustment. Although high-pressure pump systems are more costly than pressure pot systems, the additional expense is usually recovered by the greater efficiency and speed on large projects.

6.1.4 Spraying technique

RTV silicone coatings are sprayed in much the same manner as other coatings. Flat, wide spray patterns are good for open accessible surfaces such as tops of insulator sheds. The more protected underskirt areas are better reached with a smaller, circular pattern to confine the material to a smaller area.

Several coatings are typically required to reach manufacturer's recommended film thickness. An individual coat may vary from 0.125–0.25 mm depending on RTV viscosity, solvent amount and type, equipment type, and environmental conditions. The RTV surface must become tack free before application of subsequent coats; otherwise, flow will occur giving rise to drops and icicles.

6.2 Application on energized equipment and lines

6.2.1 Insulator preparation

The preparation of the insulator surface is the most important aspect under application. In most instances, the insulators need only to be high-pressure demineralized water washed. Insulators contaminated with cement like materials must be cleaned using a dry abrasive cleaner such as crushed corncob or walnut shells mixed with limestone. Both methods of cleaning are covered in IEEE Std 957-1995. Coating can begin once the insulators are dry.

Previously greased insulators must be cleaned de-energized.

6.2.2 Material preparation

See 6.1.2.

6.2.3 Solvent details

Current formulations of coatings are normally dispersed in a hydrocarbon naphtha solvent or a nonflammable solvent. Only the nonflammable solvent is suitable for live application. Such a solvent has no measurable flashpoint and therefore is safe to use on live equipment by qualified personnel. Naphtha formulations are not to be applied to energized insulators.

Normally, the amount of solvent used is in the range of 40%. The rate of evaporation of the solvent affects the "skin over time" and cure time of the coatings. The type of solvent will affect the appearance of the cured coatings such as gloss and smoothness.

Due to environmental restrictions or concerns, some chlorinated solvents have been phased out. Unlike chlorinated solvents, hydrocarbon solvents have relatively low flash points and are classified as flammable. Care must be exercised in using the coatings, and therefore, the coating should not be applied to live insulators. The coatings containing flammable solvents should not be applied near electric motors that can cause sparks or near open flame or other source of combustion.

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Any rags containing flammable solvent or spills have to be treated or disposed of, in accordance with the applicable regulations. The applicator of the coating should review the Material Safety Data Sheets from the manufacturer before using the material to review the hazardous properties of the material.

6.2.4 Equipment

Hot sticks employing airless systems are suitable for energized application. This must be done under strict supervision and performed only by experienced live line crews. It should be noted that energized application does not permit thickness measurement and that material loss is considerably higher than with conventional application.

Application equipment should be dedicated to RTV silicone coatings. Other coating materials may leave residues, which could contaminate the RTV silicone coating. Pumps, hoses, and guns must be flushed with solvent following use. All hoses should be nonconductive when used in high-voltage environments.

6.3 Safety and handling

With proper precautions, silicone RTV coatings can be safely and efficiently applied to insulators both in shop and field environments.

6.4 Worker protection

RTV silicone coatings are solvent dispersions, which cure while exposed to atmospheric moisture. As such, workers are exposed to solvent fumes and any volatile byproducts of the curing process. Safety glasses or goggles, gloves, and an organic vapor respirator are minimum, generally, recommended protection equipment.

6.5 Fire hazard

Although the silicone fluid is not considered a fire hazard, the solvent in which it is dispersed should be evaluated for fire hazard. This is particularly important when applying RTV to energized insulators. Spray equipment should be properly grounded. Sparks and open flame should be avoided in the presence of RTV coatings containing a flammable solvent.

6.6 Quality control after application

6.6.1 Adhesion to insulators

Adhesion to the insulator is of paramount importance. Improperly adhered coatings can be lifted off the insulator surface by strong winds and during high-pressure water-washing maintenance. Corona activity can take place in areas where the contaminant builds rapidly. Coating performance is somewhat reduced over time and due to containment encapsulation; therefore, water washing on an extended cycle may be necessary to maintain insulator protection. These areas are generally where cement-like forms of contaminant are present and usually in close proximity to the source. Maintenance cleaning using high-pressure water to remove the adhered contaminant can remove both the contaminant and the coating.

To test for adhesion, a boiling water test is suggested. An insulator sample, prepared in the prescribed way, is first coated using the equipment that is at hand. The sample is then immersed in water, boiled for 100 hours and removed. Coating that does not adhere to the porcelain will exhibit water blisters at the interface between the porcelain and the coating.

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6.6.2 Coating thickness

The nominal thickness suggested by several manufacturers has been 0.5 mm.[6] This thickness is a practical "rule of thumb guide" that has been used for years in the coating industry and as such has little significance to coating of electrical insulators. The experience to date suggests that coating thickness is not a factor in either the performance or the life of the coating. Coating thickness in the range of 0.125 to 0.7 mm have been applied in the field with equal success.[7]

Laboratory tests indicate that when leakage current of a damaging magnitude develops on coatings, then thickness plays a role in the coating life. Thick coatings provide increased thermal resistance to heat generated by dry band arcing and as such do not allow the heat to be conducted away to the porcelain substrate as quickly as thinner coatings. Thick coatings can result in higher hot spot temperatures during dry band arcing, thereby causing thermal degradation of the coating sooner than thinner coatings. A coating that is too thin, however, can also degrade quickly due to wearing from environmental forces. Tests indicate a thickness in the range of 0.38 mm is optimum.[8]

There are two nondestructive tests that can be performed on RTV coatings to verify thickness. These are as follows:

a) **Wet film gauge:** Wet film gauges give a reading on thickness as applied. To determine the dry film thickness, subtract the percentage of solvent. For example, 0.5 mm of wet material at 70% solids would provide 0.35 mm of cured coating. Applicators typically take frequent wet film readings.[9]
b) **Ultrasonic thickness gauge:** Ultrasonic thickness gauges will read the thickness of cured silicone coating on porcelain surfaces. These gauges must be calibrated and checked prior to use.

6.6.3 Finish

Coating formulation must be such that when sprayed, the material will flow sufficiently on an insulator surface, amalgamating to form a smooth continuous finish yet not to flow too much on vertical surfaces resulting in drips and icicles of coating along the ribs of insulator sheds.

6.6.4 Uniformity

Film build properties dictate the maximum thickness that can be attained in a single pass using spray equipment and, therefore, have a major impact on the time and coat of a coating project. Material viscosity, sag characteristics, and the surface finish of the substrate affect film build and therefore uniformity. Sag is affected by the adhesion and skinning characteristics of the RTV silicone rubber, the type of carrier solvent, ambient temperature, and humidity conditions.

7. Factors that affect coating life

Coating life can be defined by its ability to prevent flashovers. Coating life is more accurately defined as the condition in which hydrophobicity is no longer transferred to deposited layers or where maintenance becomes no different from uncoated insulators. There are, however, special conditions that must be considered, and these are corona degradation and reversion.

In some applications, coating performance is less than desirable because of the high rate of contamination buildup and insufficient natural washing. In these situations, coating performance can be extended by main-

[6] 0.5 mm = 20 mils.
[7] 0.125–0.17 mm = 4–29 mils.
[8] 0.38 = 15 mils.
[9] 0.5 mm = 20 mils. 0.35 mm = 14 mils.

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tenance washing. The physical composition and characteristics of the coating will obviously play a role in coating performance. In other applications, where cement-like materials adhere readily to ceramic surfaces and require dry cleaning methods for removal, coatings cannot be expected to perform for long periods without frequent removal of the contaminant. However, in these applications, as very few materials will adhere to silicone rubber, a crust of material is formed and is quite easily removed with high-pressure water, thereby greatly reducing the maintenance cost.

7.1 Corona

Corona discharge, from the hardware of coated insulators, impinging on coated porcelain, can cause the coating to lose its hydrophobicity and result in further degradation. The mechanism is one in which splitting off of organic groups takes place under the influence of oxygen, which leads to an ever increasing degree of cross-linking and therefore increased hardness. The coating can become brittle and prone to break with cracks resembling dried mud, which extend below to unexposed coating. Although diffusion of low-molecular-weight components of polydimethylsiloxane is the mechanism of hydrophobic recovery, corona exposure will eventually form a wettable silica layer on the surface. At this point, the coating has reached the end of its useful life and should be removed. There is no need to remove all of the coating; only the region affected should be removed.

If the corona discharge occurs during moist conditions, then water will act in the absence of oxygen and depolymerization of the high-molecular-weight linear polysiloxane will take place, whereupon the high viscosity silicone rubber is degraded to siloxanes of lower molecular weights, and therefore, the vulcanization becomes softer. In this case, hydrophobicity remains and the coating will still perform its intended function until it becomes laden with contaminants; at which time, the coating will need to be removed.

7.2 Reversion

The polysiloxane chain is reckoned to be hydrolytically stable, but there seems to be evidence that the weathering of the polymers is best accounted for by a slow depolymerization that occurs in the presence of moisture and must therefore be regarded as a hydrolytic breakdown. Hydrolysis causes random scission of the polymer chain leading to rapid decrease of molecular mass. Under electrical stress, water could be dissociated due to electrolysis to speed the process. Temperature is also a factor. The reduction of the polymer to a sticky mass is called *reversion*.

For reversion of a coating to take place, moisture must reside within the coating. In other words, the coating must be porous. In addition, certain types of fillers used in coating formulations will also increase moisture intake. A simple test for reversion of a coating applied to ceramics is a boiling water test. After boiling in water for 100 hours, most coatings will exhibit some softening. However, they should not reduce to a mass that resembles ordinary putty.

8. Field inspection

Normally, in the operation of manned substations, maintenance personnel make yard inspections at least once per shift. This inspection is sometimes called a “walk around” and is nothing more than a visual and audible check as to the service conditions in the yard. After a coating operation and during wet conditions, the first thing that maintenance personnel detect in a switchyard is the near absence of audible noise. The reason for this is the elimination of dry band activity on insulation and a reduction in corona from insulator hardware, both of which are a consequence of the hydrophobicity exhibited by the RTV coating.

An increase in audible noise on insulation during moist conditions is the first sign of a loss of hydrophobicity, at least near the electrodes. When this occurs, it is imperative that a visual check be made. This should

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begin by using night vision detection equipment during moist conditions to check for dry band arcing as opposed to corona from the insulator hardware. Corona from hardware impinging on RTV coatings, in time, will cause physical and possibly chemical deterioration of the RTV coating. In the absence of night vision equipment, binoculars will help to locate the regions of discharge activity. Generally speaking, these areas become discolored, sometimes black or brown in color, and almost always in close proximity to the energized end of insulator hardware. When this is observed, a close-up visual inspection during an outage is recommended.

During the close-up visual inspection, if the RTV coating shows either a hard crust-like or soft putty-like appearance, then it will be necessary to take remedial action. The affected coating must be removed and fresh coating reapplied.

Crust-like deterioration is easily removed by high-pressure water washing at 8.3 MPa.[10] The entire insulator should be water washed for recoating. Coating that is not bonded to the insulator will be removed quite easily and must be removed prior to recoating with fresh material. Coating that shows soft putty-like deterioration may not be removed by high-pressure water washing and must be cleaned using standard dry cleaning techniques involving the use of sand or corn cob and followed by water cleaning of the entire insulator. Fresh coating may be reapplied by spraying.

To check for surface hydrophobicity, the STRI Guide 1 [B5] could be used. The visual guide to determine hydrophobicity classification (HC) is included in Annex A. Large areas of a coated insulator surface that exhibit poor hydrophobicity (HC 6 or 7) may be indicative of an insulator that needs maintenance (either washing or recoating) in the near future.

9. Recoating

When the coating on the insulator is seriously damaged (e.g., the surface of the original coating is peeling off, the coating shows poor adhesion, or large areas of the coating are wettable), the surface should be recoated with a new RTV coating.

Preliminary background information for recoating:

- Make sure that the existing coating that is visually loosely adhered to the insulator is removed by either corncob or some other method.
- It is recommended that hard contaminants like cement dust that adhere strongly to the insulator surface be removed.
- It is also recommended that the surfaces should be cleaned and dried before applying the new coating on top of the existing coating.

Note that it is not necessary to remove all of the old coating because the new coating will adhere to an existing clean, intact coating.

10. Practical considerations in the application of RTV coatings to insulators

In laboratory tests and in service, insulators with polymeric surface have exhibited higher withstand voltages than have conventional insulators with porcelain or glass surfaces. This performance advantage is primarily attributed to significant differences in the resistance wet, polluted polymers and ceramic surfaces. In practice, pollution deposits vary considerably along the insulator body. Flashovers may be initiated by intense local dry-band discharge and/or associated severe distortion of electrical field.

[10] 8.3 MPa = 1200 psi.

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The RTV contains low-molecular-weight (LMW) mobile silicone polymers that migrate to the surface. An important factor in the RTV coating's protective capability is its ability to keep the resistance high along the overall leakage path of the insulator. This is particularly important for substation insulators and bushings (used for breakers, transformers, arresters, switches, measuring devices, and buses). Many of these applications involve external and internal shields for shaping and controlling the electric stress. The effectiveness of these shields and voltage capability of insulation systems are strongly related to surface resistance along the insulator body.

Excessive deposits of contamination and/or excessive stresses causing surface discharges can significantly reduce the local surface resistance of the RTV-coated insulator. If the RTV is exposed to higher levels of dry-band discharges (≥10 mA) for longer periods, degradation of the silicone polymer may occur. In some cases, blackening of RTV surface has been reported, and in extreme cases, flaking of the RTV coating has been observed.

Caution should be observed in application of RTV coatings to substation insulators. The insulator design and shielding should be carefully reviewed before the RTV substation insulators. The probability of discharge activity on the surface under wet, polluted conditions should be reviewed. The corona ring design or lack of rings should be considered for post insulators and disconnect switches. The design of the internal or external shields of bushings should also be reviewed to assess the risk of local dry-band discharges. Presently, there is insufficient data regarding the threshold value of discharge activity that are considered to be harmful to the coating.

Although overhead applications normally use grading devices at 230 kV and higher, the pollution conditions in substations can be so severe that grading devices may be needed at 69 kV and at higher system voltages. It is not recommended to use RTV coatings as a solution to a bad design such as

a) Too low leakage distance for the specific contamination condition
b) Lack or misuse of grading devices
c) Bushings and lightning arresters with internal design problems

The RTV coating provides the best protection from flashovers when operating under conditions of no or low levels of discharges (energy). Its need for repair or replacement will depend on the amount of dry-band discharging it has been subject to. In some instances, periodic RTV replacement may be the solution to a particular severe contamination problem.

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Annex A

(normative)

Hydrophobicity classification guide

A.1 Scope[11]

The superior electrical performance of composite insulators and coated insulators stems from the hydrophobicity (water-repellency) of their surfaces. The hydrophobicity will change with time due to exposure to the outdoor environment and partial discharges (corona).

Seven classes of the hydrophobicity (HC 1-7) have been defined. HC 1 corresponds to a completely hydrophobic (water-repellent) surface and HC 7 to a completely hydrophilic (easily wetted) surface.

These classes provide a coarse value of the wetting status and are particularly suitable for a fast and easy check of insulators in the field.

A.2 Test equipment

The only equipment needed is a common spray bottle that can produce a fine mist (Figure A.1). The spray bottle is filled with tap water. The water shall not contain any chemicals, as detergents, tensides, solvents.

Complementary equipment that could facilitate the judgement are a magnification glass, a lamp, and a measuring tape.

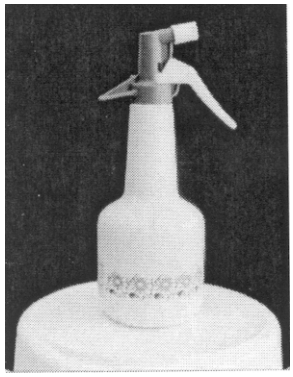


Figure A.1—Example of suitable spray bottle for the test

A.3 Test procedure

The test area should be 50 to 100 cm^2. If this requirement could not be met, it should be noted in the test report.

[11]Information appearing in A.1 to A.6 is made available to IEEE by STRI, Sweden, from STRI Guide 1, 92/1.

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Squeeze 1–2 times per second from a distance of 25 ± 10 cm. The spraying shall continue for 20–30 seconds. The judgment of the hydrophobicity class shall be performed within 10 seconds after the spraying has been finished.

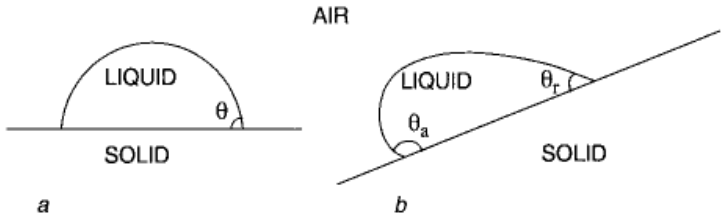
A.4 Criteria

The actual wetting appearance on the insulator has to be identified with one of the seven hydrophobicity classes (HC), which is a value between 1 and 7. The criteria for the different classes are given in Table A.1. Typical photos of surfaces with different wetting properties are shown in Figure A.3.

Table A.1—Criteria for the hydrophobicity classification

HC	Description
1	Only discrete droplets are formed. $\theta_r = 80^\circ$ or larger for the majority of droplets.
2	Only discrete droplets are formed. $50^\circ < \theta_r < 80^\circ$ for the majority of droplets.
3	Only discrete droplets are formed. $20^\circ < \theta_r < 50^\circ$ for the majority of droplets. Usually they are no longer circular.
4	Both discrete droplets and wetted traces from the water runnels are observed (i.e., $\theta_r = 0^\circ$). Completely wetted areas < 2 cm^2. Together they cover < 90% of the tested area.
5	Some completely wetted areas > 2cm^2, which cover < 90% of the tested area.
6	Wetted areas cover > 90%, i.e., small unwetted areas (spots/traces) are still observed.
7	Continuous water film over the whole tested area.

Also, the contact angle (θ) between the water drops and the surface must be taken into account. The contact angle is defined in Figure A.2. There exist two different contact angles, the advancing contact angle (θ_a) and the receding contact angle (θ_r). A drop exhibits the angles on an inclined surface (Figure A.2).



a = horizontal plane
θ_a = advancing angle

b = inclined plane
θ_r = receding angle

Figure A.2—Definition of contact angles

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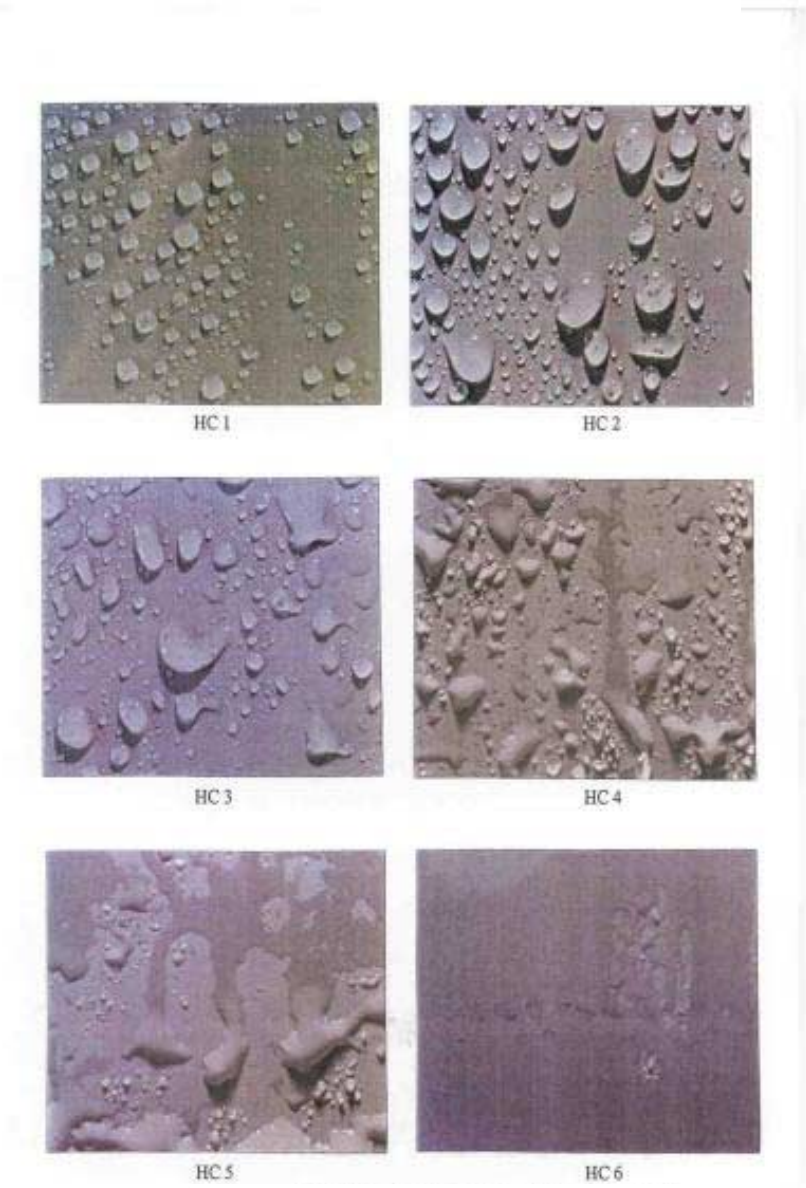


Figure A.3—Typical examples of surfaces with HC from 1 to 6 (natural size)

The receding angle is the most important when the wetting properties of an insulator shall be evaluated. The inclination angle of the surface affects the θ_r, but will not be corrected for in the test report.

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A.5 Test report

The test report shall include the following information:

a) General information
   1) Location, station, line
   2) Date and time of the judgement
   3) Weather conditions (temperature, wind, precipitation)
   4) Performed by
b) Test object
   1) Type of insulator
   2) Identity (item number, position)
   3) Voltage
   4) Date of installation or application of coating (type of coating)
   5) Mounting angle (vertical, horizontal, inclined x deg)
c) Hydrophobicity class
   1) HC for different positions: along the insulator[12] (shed number), along the surface within each shed sequence (top, bottom, core, large shed, small shed, etc.)
   2) Differences (if any) around the insulator circumference

A.6 Comments

The hydrophobicity classification could be difficult to perform in high winds. If such difficulties, or other, are present, this should be noted in the test report.

The test report form could preferably be drawn in advance and fastened on a plate for an easier recording during the examination.

A.7 Tests for evaluating certain electrical properties of RTV coatings

The interpretation of physical and electrical data for polymeric materials, such as RTV coatings, is made difficult by the introduction of degradation as another prime factor in material selection. Time is not considered to change the mechanical and electrical properties of porcelain or glass. From the work with this inert material, electrical engineers come to think of original properties as permanent properties, but polymeric materials may be subject to different forms of deteriorative influences. An environment of heat, oils, vapors, water, chemicals, sunlight, weather, and so on, may change the properties of a polymer compound. Therefore, to the concept of original properties, the engineer must add the concept of resistance or endurance properties.

Normally, the primary dielectric or insulating characteristics of a material for outdoor applications are dielectric strength, dissipation factor, arc resistance, insulation resistance and resistivity, and tracking resistance. These values are often obtained from accelerated aging tests. As the primary objective of accelerated aging is the prediction of material performance prior to its application and the development of service history, accelerated aging tests must, within a short time, attempt to duplicate the effects of long-term exposure in the field. Extreme reductions in the time to failure are accomplished by increasing the intensity of one or more of the destructive forces of normal operation. For example, increased electric stress, electrolyte conductivity, temperature, water immersion, or intense ultraviolet radiation, are often used. The acceleration in the time depends on the type of accelerated aging performed and can vary from ten to several hundred.

[12]For long insulators, only some selected sheds from the upper, middle, and lower part of the insulator are examined.

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As in all accelerated tests, care must be exercised to ensure that the degradation mode under study is preserved. Often, a major increase in the intensity of an environmental effect will alter the response of the material to a new degradation mode.

For the reasons outlined, judgment and experience are required to make predictions of lifetime from a series of tests, which by their very definition are unrealistic. Often, this is done using a battery of accelerated aging tests against the background of an unfolding service record of various applications. Thus, the passage of time tends to assist in the development of more realistic tests and interpretations by revealing the errors of previous conclusions.

A.7.1 Dielectric strength

ASTM D 149-1997, Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies.

This test gives an indication of electrical strength of a material as an insulator at power frequencies. The dielectric strength of materials varies greatly if bubbles, voids, contaminants, or moisture are present in the specimens being tested. Electrode geometry is also a significant factor influencing strength. Because of these factors, dielectric strength test results are of relative rather than absolute value. As such, the method is useful for detecting changes in dielectric strength from the norm resulting from aging conditions, thereby allowing an assessment to be made of the aging.

A.7.2 Dissipation factor

ASTM D 150-1998, Standard Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation.

Dissipation factor gives an indication of the dielectric loss of the insulating material that is being measured. When adequate correction data are available, dissipation factor may be used to determine the characteristics of a material in other respects such as moisture content, degree of cure, and deterioration from any causes. Although the initial value of dissipation factor may not be significant, the change in dissipation factor is a measure of material aging.

A.7.3 Arc resistance

ASTM D 495-1999, Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation.

The test is a rapid method for screening materials. The method can be used to detect the effects of changes in formulations and for quality control testing if correlation can be established with other types of simulated service arc tests and field experience. As the method is frequently referenced in specifications, and unfortunately, track resistance may be inferred from the arc resistance test, the method is not tracking test. In general, the method will not permit conclusions to be drawn concerning the relative arc resistance rankings of the materials that may be subject to other types of arcs, for example, high voltage at high currents and low voltage at low or high currents promoted by surges or by conducting contaminants.

A.7.4 Insulation resistance

ASTM D 257-1999, Standard Test Method for DC Resistance or Conductance of Insulating Materials.

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It is generally desirable to have the insulation resistance as high as possible. As insulation resistance combines both volume and surface resistance, its measured value is most useful when the test specimen and electrodes have the same form as is required in actual use. Resistivity is often used as an indirect measure of moisture content, degree of cure, mechanical continuity, and deterioration of various types.

A.7.5 Erosion and tracking resistance

ASTM D 2132-1998, Standard Test Method for Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials.

ASTM D 2303-1997, Standard Test Methods for Liquid-Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials.

The long-term performance of a polymer material used in electrical insulation design is related to the leakage current and surface discharges that develop in service. Service experience has shown that the amplitude and frequency of surface discharges on electrical insulation are not only dependent on design, but also on the properties of the polymer material used.

There are a number of standard tests that claim to evaluate the performance of polymeric materials under accelerated surface discharge arcing conditions. In these tests, the experimental conditions of electrical stress and/or wetting are more severe than those normally encountered on outdoor electrical insulation. A high leakage current is thus promoted in a very short time, which gives rise to intense surface discharge activity.

Although these tests are useful in obtaining a comparative evaluation of the tracking and erosion resistance of materials, they must be used with caution. It has been shown that the erosion and tracking phenomena and the ranking of materials are strongly related to the mode and nature of the artificial contamination method used in a test. It is therefore necessary to evaluate discharge and arc resistance at more than one level of wet and contaminated stress conditions.

It has also been found that the coatings can vary in their capability of suppressing leakage current. Therefore, a better evaluation of materials may be possible if the materials were subjected to test conditions that produce a gradual increase in leakage current with time, as occurs in service, rather than to test conditions that produce high leakage current right from the start of the test, as is the case in normal accelerated laboratory tests.

Assessments of materials in a fog chamber have the advantages that sample configuration and test condition can be easily varied. In this manner, the polymer material can be evaluated over a range of discharge and dry band conditions.

A.7.6 Other “nonstandard” test methods

Wheel tests and fog chamber tests can be used to assess the leakage current suppression, and arc tracking and erosion performance of coatings, provided proper care is taken in the selection of experimental conditions. It has been shown that fog chamber tests that use water conductivity in the range 200–2000 mS/cm, and the tracking wheel tests are suitable for obtaining a relative ranking among various coatings. The ultimate performance in the field is influenced by a combination of factors, such as insulator design (includes hardware and corona rings), coating type, and outdoor location.

The tracking wheel test imposes wet and dry cycles on a stressed surface of specimens in order to simulate the formation of dry band arcing as it is experienced in service. It is designed to evaluate insulator shapes or materials or both for outdoor applications. Surface degradation, either erosion or tracking, in outdoor applications take place in association with arcing over dry bands that develop during or immediately after

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precipitation. The surface damage, erosion, or carbonization results from the heat of the arc, and this damage accumulates until the surface between the electrodes can no longer sustain the applied voltage.

A fog chamber test subjects samples to continuous or cyclic conditions of fog and electrical stress. The contamination conditions can easily be varied by the rate of water flow and the conductivity of the water. Experience on simple rod samples and insulators show that at lower conductivity (<1000 mS/cm) levels, there is a gradual increase in dry band activity leading to intense arcing that can cause tracking in materials that do not show tracking in other standard track tests. Such tests have to be conducted over periods as long as 300 to 500 hours to provide meaningful results. Please refer to this committee's report on Round Robin Test Results for more information on fog chamber tests [B4].

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Annex B

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[B5] STRI Guide 1, 92/1, Hydrophobicity Classification Guide, 1992.

[13]IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (http://www.ansi.org/).

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