



IEEE Guide for Monitoring, Managing, and Cleaning of Contaminated Insulators

STANDARDS

IEEE Power & Energy Society

Developed by the
Transmission & Distribution Committee

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(Revision of IEEE Std 957-2005)



IEEE Guide for Monitoring, Managing, and Cleaning of Contaminated Insulators

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of the
IEEE Power & Energy Society

Approved 20 May 2024

IEEE SA Standards Board

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Abstract: Procedures for cleaning contaminated electrical insulators (excluding nuclear, toxic, and hazardous chemical contaminants) of all types, using various equipment and techniques, are provided in this guide.

Keywords: cleaning, electrical insulators, IEEE 957™

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Introduction

This introduction is not part of IEEE 957™-2005, Guide for Monitoring, Managing and Cleaning of Contaminated Insulators.

The guide for cleaning insulators is the result of the dedicated efforts of individuals and companies with practical experience in cleaning insulators. The information for this guide was drawn from electric utilities, suppliers, universities, related industries, published papers and reports, and personal observations. Included in this guide are proven, practical methods for cleaning insulators that are considered safe and up-to-date.

This revision of the guide started several years ago as the result of a desire to update and modernize the represented methodology. Changes to cleaning procedures, tools, equipment, and insulating materials have been dramatic in the last several years. These changes required newer and modern techniques, which have been incorporated into this guide. The result is a guide that represents a consolidation and accumulation of methods that have been satisfactorily used in the industry.

During preparation, the equipment, methods, tests, and safety features were investigated. The information presented is thought to be of particular benefit to a company or industry that may be initiating a cleaning program or trying to address a particular problem. It is also thought to be of value to those with an existing program.

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IEEE Guide for Monitoring, Managing, and Cleaning of Contaminated Insulators

1 Overview

1.1 Scope

The scope of this guide for cleaning insulators is to document the procedures used for monitoring, managing, and cleaning contaminated electrical insulators (excluding nuclear, toxic, and hazardous chemical contaminants),⁷ of all types,⁷ using varied equipment and techniques.

Because of the great variety of conditions, practices, electrical system designs, and contamination possibilities, this guide is offered to describe a number of approaches to monitoring, managing and insulator cleaning of insulators on power systems. All factors must be considered to specific situations in deciding whether and how to use the information in this guide.

1.2 Purpose

The purpose of this guide is to present information on the equipment ~~needed~~ and the methods that can be used when monitoring, managing and cleaning contaminated insulators.

The methods and/or equipment,~~or both,~~ presented in this guide are not intended to prescribe specific procedures, but to present the successful experience of many individuals who have safely monitored, managed, and cleaned contaminated insulators. The guide is intended to serve as a reference source for a company, or persons, seeking information on insulator monitoring, managing, and cleaning procedures so that they may consider the experience of others in modifying or formulating insulator monitoring, managing, and cleaning programs and practices.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall equals is required to*).^{6,7}

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2 Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained) **guide**. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

~~Electrical Equipment Washing/Cleaning, Electrical & Utility Safety Association (Ontario) Safe Practice Guide, 2001.[†]~~

IEC 60479-2 ~~60479-2:1987~~, Effects of Current Passing Through the Human Body.^{8,2}

IEC/TS 60815-1, Selection and Dimensioning of High-Voltage Insulators Intended for the Use in Polluted Conditions – Part 1: Definitions, Information and General Principles

~~IEEE Std 4™-1995, IEEE Standard Techniques for High Voltage Testing.^{3,4}~~

~~[†]EUSA publications are available from the Electrical & Utility Safety Association, 5580 Explorer Drive, Suite 200, Mississauga, Ontario L4Y 1Canada (<http://www.EUSA.on.ca>).~~

~~^{8,2} IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<https://www.iec.ch>) <http://www.iec.ch/> and the IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<https://www.ansi.org/> <http://www.ansi.org/>).~~

~~⁴IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).~~

IEEE Std [80™](#), ~~80™-2000~~, IEEE Guide for Safety in AC Substation Grounding.^{9,10}

IEEE Std [516™](#), ~~516™-2003~~, IEEE Guide for Maintenance Methods on Energized Power Lines.

IEEE Std [1048™](#), ~~1048™-2003~~, IEEE Guide for Protective Grounding of Power Lines.

[IEEE Std 1264™](#), IEEE Guide for Animal Deterrents for Electric Power Supply Substations.

3 Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The [IEEE Standards Authoritative Dictionary Online of Standards Terms \[B22\]](#) should be [consulted](#) ~~referenced~~ for terms not defined in this clause.¹¹

ceramic insulator: Insulators made from porcelain, glass, or a general class of rigid material.

~~3.1.2—cubic meters per second (m³/s): Volume of water or liquid discharged per second under standard conditions.~~

equivalent salt-deposit density (ESDD): A measure of [water-soluble](#) contamination level.

insulator: [Any material designed](#) ~~In this guide, IEEE Std 957-2005, this refers~~ to [physically support a conductor and to electrically separate it from another conductor or object, including an individual unit, a combined set of units or](#) ~~insulators and also the~~ external insulating members of other apparatus (, e.g., transformer bushings and surge arresters).

Line ~~qualified~~ worker: A person qualified to perform various line-work operations, including [elevated](#) aerial and groundwork. [See also: qualified electrical worker.](#)

~~NOTE—Refer to IEEE Std 516-2003.^{5,6}~~

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¹¹ [IEEE Standards Dictionary Online](#) is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

non-ceramic (polymer) insulator: Insulators made from polymeric materials.

non-conducting or non-conductive: Made of a material of high dielectric strength [that does not conduct electricity](#).

overspray: A portion of the water stream that is unintentionally directed away from the device being washed.

polyplastic: A synonym for polyethylene-coated, nylon-reinforced hose (used in this case to carry water), usually considered to be non-conductive.

qualified electrical worker: Having been trained in and having demonstrated adequate knowledge of the installation, construction, or operation of lines and equipment and the hazards involved, including identification of, and exposure to, electric supply and communication lines and equipment in, or near, the workplace. An employee, who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training, and who is under the direct supervision of a qualified person, is considered to be a qualified person for the performance of those duties.

skiving: The process of assembling a fitting to a hose, by trimming the outside of a hose to fit the inside dimensions of a fitting.

system voltage: Phase-to-phase voltage of the circuit(s). When phase-to-ground voltage is the intention, it should be so noted.

water conductivity: Conductivity (reciprocal of resistivity) of water is expressed in [microsiemens](#) ~~microsimens~~/centimeters ($\mu\text{S}/\text{cm}$)

water resistivity: [Electrical](#) resistivity of water is expressed in ohm-cm ($\Omega\cdot\text{cm}$) or ohm-inch ($\Omega\cdot\text{in}$).

3.2 Acronyms and abbreviations

[ATH](#) [alumina trihydrate](#)

[AWG](#) [american wire gauge](#)

~~ESDD~~ ~~equivalent salt deposit density~~

~~gal/min~~ ~~gallons per minute~~

gal/s	~~gallons per second~~
ID	inside diameter
kPa	~~kilopascals, metric unit for pressure~~
L/s	~~liters per second~~
LZ	landing zone
mhp	metric horsepower
NCI	non-ceramic insulator
m ³ /s	~~cubic meters per second~~
PTO	power takeoff
rpm	~~revolutions per minute~~
RTV	room temperature vulcanizing
WPV	water physical variables

4 Insulator application and wash considerations

4.1 Introduction

Cleaning of power insulators is normally conducted on transmission and distribution lines, in stations, and sometimes on equipment insulation.

4.2 Transmission and distribution line insulators ~~to be cleaned~~

Transmission and distribution line insulators ~~arresters~~ are made of glass, porcelain or ~~ceramic and~~ polymeric materials. The insulator should be washed so that the watersheds just cleaned will maintain adequate insulation. (For example, on vertical insulators the washing would be started at the bottom and work upwards.) One of the main concerns of washing is the potential problem of overspray. When overspray presents a problem, washing from different positions may help, but will take more time and reduce production.

Cleaning distribution insulators entails different concerns than transmission line insulators due to the lesser voltage involved and the respective clearance distances.

It is important to properly plan for cleaning lines with underbuilt circuits. Consideration should be taken for washing the lower circuit first, working up the structure, while avoiding overspray on the upper circuit. The lower circuit needs to be cleaned first to avoid a flashover from the contamination and watershed created by washing the upper circuit. Once the upper circuit is cleaned, the lower circuit needs to be washed again to remove any residual contamination. (For example, wash the lower circuit, then the upper circuit and finish with a final wash on the lower circuit).

~~4.2.2.1—General guidelines for water pressure washing~~

~~Table 1 shows a general guide for washing different types of polymer insulators with water pressure washing.~~

~~**Table 1—Water pressure washing for polymer insulators**~~

1. Direct molded units	
Silicone	Low- to high-pressure water washing (1400 kPa to 7000 kPa)
EPDM/EPR	High-pressure water washing (2750 kPa to 7000 kPa)
Alloy EPDMs	High-pressure water washing (2750 kPa to 7000 kPa)
Epoxy	High-pressure water washing (2750 kPa to 7000 kPa)
Polymer ceramic	Medium- to high-pressure water washing (2100 kPa to 7000 kPa)
2. Individual weathershed bonded to a polymer sheath or to each other	
Silicone	Low- to high-pressure water washing (1400 kPa to 7000 kPa)
EPDM/EPR	High-pressure water washing (2750 kPa to 7000 kPa)
Alloy EPDMs	High-pressure water washing (2750 kPa to 7000 kPa)
3. Individual weathershed with an unbonded interface	
All compounds	1400 kPa at the pump with a 6 mm nozzle and no closer than 4.6 m

~~(Deleted)~~

~~NOTE—For types 1 and 2, the water stream may be directed at any angle to the insulator axis. Type 3 requires the water stream to be directed on the upper (tapered) surface of the weathersheds at an angle no greater than 90° (perpendicular) to the insulator axis.~~

~~NOTE—For English units, see Annex C.~~

4.2.2.2—Washing frequency

~~Polymer insulators that require washing do not require it as often as porcelain or glass insulators. They may be washed if caution is used during the washing procedure along with the manufacturer's approval.~~

4.2.2.3—Other procedures

~~Polymer insulators may be cleaned by methods other than water washing.~~

4.3 Station and line equipment

4.3.1—Insulators

4.3.1.1—Ceramic

~~Same as for transmission line insulators.~~

4.3.1.2—Polymeric

~~Same as for transmission line insulators.~~

4.3.1 Bushings and arresters

Bushings are made of ceramic or polymeric materials and must be treated with great care. It is important to consider the impact of any mechanical loads that may be imparted to this apparatus as well as its ~~Consideration of pressure and volume and the~~ mechanical support during the cleaning process to determine how to clean these devices ~~of the bushing are required prior to washing.~~

4.3.3—Surge arresters

~~Surge arresters can be made of ceramic or polymeric materials.~~

4.3.3.1—Ceramic

Energized cleaning ~~washing~~ may impose severe electrical stresses on these devices ~~the surge arresters~~ due to voltage imbalance and should not be performed without the concurrence of the apparatus ~~arrester~~ manufacturer.

~~4.3.3.2—Polymeric~~

~~Some Energized washing of these also imposes severe electrical stresses due to voltage imbalance.~~
polymer-housed bushings and distribution arresters such as modularly-constructed types should not be exposed to the direct stream of high-pressure water washing. Consult the bushing or arrester manufacturer for water washing recommendations.

~~4.4—Distribution line equipment~~

~~4.4.1—Insulators~~

~~4.4.1.1—Porcelain and glass~~

~~Same as for transmission line insulators.~~

~~4.4.1.2—Polymeric~~

~~Same as for transmission line insulators.~~

~~4.4.2—Distribution class surge arresters~~

~~Polymer housed distribution arresters should not be exposed to the direct stream of high pressure washing. Consult the arrester manufacturer for washing recommendations.~~

3.2 Large diameter equipment

Large diameter equipment, typically in substations or switchyards, may require the application of more than one simultaneous water stream from opposite sides of the equipment during water washing. For example, it might be easier and more effective during live washing to simultaneously reach both sides of insulators with diameters of 25.4 cm (10 in) or more by using two water streams. The use of just a single stream might cause minimal wetting to the contamination on the opposite side of the insulator, creating a potential flashover before the single stream can be moved to reach the opposite side. When using other cleaning methods, it will be necessary to clean the insulator from various sides around the unit. Location and configuration of the equipment may also dictate if two water streams are required.

5. Insulator materials

Insulators used for power utility applications fall under two main categories:

- Ceramic
- Non-Ceramic

Situations exist where additional coatings are added to ceramic insulators to improve their performance in particularly aggressive environments. Some of the more commonly used coatings include:

- Semi-conductive glaze
- Greases
- Room temperature vulcanized silicone

5.1 Ceramic

The most common type of ceramic (porcelain or glass) insulators are the pin and cap type where individual units are connected to each other with metal hardware. Voltage ratings can be adjusted by changing the number of units that are connected together.

In addition to the traditional types of insulator surfaces noted above, there are also porcelain material insulators that may have a special semiconducting glaze applied to the surface.

5.2 Non-ceramic

Non-ceramic insulators (NCI) vary significantly from their ceramic counterparts in that they tend to be single units designed to match the application. Non-ceramic insulators have a dielectric fiberglass rod that is covered by a polymer housing attached to metal end fittings. The housing could be modular or made using single piece molds.

5.3 Semi-conducting/resistive glazed insulators ~~insulator cleaning~~

Semi-conductive glazed porcelain insulators are made by adding semi-conducting oxides to the glaze glassy material before firing. This glaze produces a well-defined surface resistivity on the order of several megaohms and such insulators are sometimes referred to as resistive graded. A small continuous current, about 1 mA, through the glaze provides for a slight heating of the insulator surface and a nearly linear voltage distribution across it. These characteristics may result in improved performance under some atmospheric contamination conditions (e.g., fog, light rain).

~~Resistive glaze (or semiconducting glaze) insulators can be treated the same as ordinary glaze porcelain insulators in all matters concerning cleaning techniques as cleaning will not damage their resistive glaze surface. However, it is unlikely that properly functioning resistive glaze insulators will require cleaning due to their superior contamination performance.~~

~~Pressure washing may overwhelm resistive glaze properties so that resistive glaze insulators become as susceptible to accidental flashover as ordinary glaze insulators due to poor washing techniques.~~

5.4 Greases and room temperature vulcanized silicone materials

The original coatings used to protect porcelain or glass insulators were primarily of a grease type. Grease is normally used on porcelain or glass insulators in an effort to improve their performance under contaminated conditions. Of these greases, silicone-based materials provides the best results.

~~It is well known that~~ Alumina trihydrate (ATH) fillers improve the arc resistance of organic polymer systems used for high-voltage insulator applications. ~~ATH-filled (silicone grease) An ATH-filled silicone grease~~ has the water repellency of conventional grease but with much improved arc resistance. This permits operation under severe wet contamination conditions such as salt fog without encountering a critical failure condition where hot-spot arcing can lead to the fracture of porcelain or glass, ~~or both,~~ insulators. The limitation of the ATH-filled silicone grease is the reduced mobility of the free fluid due to the high filler loading.

RTV materials (known as room temperature vulcanized silicone materials) provide similar benefits as ATH fillers with easier application.

6. Insulator contamination

6.1 Types of contaminants

Exposed insulators are subject to surface dirt deposits to some degree in all operating areas. Most commonly encountered contaminants have little effect on insulator performance as long as the surface is dry. Fog, mist, or light rain usually creates conditions that produce a conducting film on the dirty insulator surface, without washing the impurities from the surface. [Some contamination layers are self-wetting, drawing moisture from air with relative humidity above 70%.](#)

A number of types of contaminants have been identified as sources of surface deposits on insulators affecting insulator performance. [These contaminants are classified \(See IEC TS 60815-1:2008\) first by their solubility in water.¹²](#)

[Insoluble deposits do not change the electrical conductivity of the pollution layer but they do stabilize the wetting process and may affect the rate of increase of soluble deposits. The non-soluble deposit density \(NSDD\) is expressed in mg/cm². For a constant equivalent salt-deposit density \(ESDD\) of 0.1 mg/cm², an NSDD < 0.1 mg/cm² represents “medium”, 0.1 to 1 mg/cm² is “heavy” and > 1 mg/cm² is “very heavy” pollution \(see IEC TS 60815-1:2008\). Extensive regions of Northern Africa, the Middle East, India, and Northern China have non-soluble dust flux on upward-facing surfaces that exceeds 1.0 \(mg/cm²\)/year \(0.0027 \(mg/cm²\)/day.\) \(see Farzaneh and Chisolm, \[B11\]¹³\). Long-term buildup of NSDD, taking several months or years to reach severe levels, is a problem that can be managed with insulator cleaning.](#)

¹² ⁵ Information on references can be found in Clause 2.

¹³ ⁷ The numbers in brackets correspond to those of the bibliography in Annex A.

Insulator pollution that is soluble in water will also change the electrical conductivity. Many sources
These contaminants are distinguished primarily by the source of the impurities are present in the
atmosphere affected by the - local agricultural, industrial, and geographic conditions determine
which are present in the atmosphere. ~~The various types of contaminants identified are: salt,~~
~~cement/lime, dusts, bird excrement, chemicals, smog (automobile emissions), cooling tower~~
~~effluents, smoke, organic and ice/snow. Ordinarily, wind and rain provide sufficient washing action~~
~~to remove most of the common deposits.~~ More than one of these contaminants may be deposited on
a group of insulators at a particular location. The mix and rates of deposit of these contaminants
determine the electrical characteristics of the fully wetted pollution layer. The electrical
characteristics of multi-component pollution layers are brought to a common measure, which is the
equivalent density of common salt (NaCl) that gives the same conductivity. The ESDD is expressed
in mg/cm² ~~characteristics of the mixture.~~

ESDD can build up rather quickly and change the state of an insulator from acceptable to vulnerable
in a period of hours. Instantaneous pollution problems cannot be managed with practical insulator
cleaning before problems occur, but cleaning may be needed if electrical performance is not restored
after a salt fog, conductive fog or road-salt splash episode has ended.

Some indication of the rate of increase of ESDD can be obtained by totaling the contributions of
individual ion species to the dry deposition rate, measured in pollution studies.

Insulator cleaning by the washing action of wind and rain removes many of the common non-
soluble and salt deposits.

6.1.1 Salt

In areas near a body of salt water and in areas adjacent to highways, particularly elevated roads,
where salt is used to melt snow or ice, rapid increases in ESDD ~~substantial salt deposits~~ may result
from windblown spray. Such deposits may make it necessary to clean insulators in these areas
where long, dry periods are followed by intervals of misty rain or fog.

Salt spray may lead to flashovers and leakage current fires. This condition is common on structures
adjacent to high traffic roads, particularly along elevated roadways. Insulators should be cleaned
before the mist or fog occurs, not afterward.

Salt will quickly dissolve and wash off in a heavy rain or a stream of water. [Road salt can be removed by power washing at temperatures above \$-10^{\circ}\text{C}\$ \(\$14^{\circ}\text{F}\$ \).](#)

6.1.2 Cement/lime

Insulators located near cement plants, construction sites, and rock quarries may accumulate deposits of cement or lime. These materials may build up a thick crust ~~that,~~~~which~~ becomes firmly bonded to the insulator surface and may require hand scrubbing. A chemical agent may be needed to remove the cement layers. The dry method of cleaning also has proven quite effective.

6.1.3 Dusts

The kinds of dust that can be deposited on insulators originate from a wide variety of sources. Some of the types of dust affecting insulator performance are earth dust, fertilizer, metallic dust, coal dust, feedlot dust, and volcanic ash. This is not a complete list, but does cover many dust sources.

6.1.4 Earth

Earth dust can arise from plowed fields, earth moving on construction projects, etc. Various methods of cleaning earth dust are: water washing, compressed air cleaning, and wiping (both hot and hand cleaning).

6.1.5 Fertilizer

Fertilizer dust is emitted from fertilizer plants and [during use](#) ~~from fertilizer application~~ in farming. Fertilizer dust ~~can~~ ~~has been known to~~ create a thick [insoluble contaminant](#) coating [on insulators](#) that [cannot be removed with](#) high-pressure washing ~~could not remove~~. In these cases, [it is necessary to](#) hand [scrub](#) ~~scrubbing~~ or dry [wash](#) ~~washing is needed to clean~~ the insulators. ~~Liquid fertilizer of the~~ Urea-type [liquid fertilizer](#) is [best](#) cleaned with water.

6.1.6 Metallic

Metallic dust originates from various mining and mineral handling processes. Metallic dust can be cleaned using compressed air and wiping (hot and hand cleaning).

6.1.7 Coal

Coal mining and coal handling operations and industrial burning of coal are major sources of coal dust. Soot and fly ash resulting from the burning of coal may form compounds that adhere firmly to insulator surfaces and may be removed only with high-pressure washing or compressed air with an abrasive substance. Coal dust can be cleaned by water washing or compressed air or wiping.

6.1.8 Feedlot

Provender dust and earth dust stirred by animals in large feedlots can settle on nearby insulators in dry weather. This dust is normally removed with water.

6.1.9 Volcanic ash

Volcanic activity can emit large quantities of pollutant into the atmosphere in a short period. Thick layers of volcanic ash accumulate on exposed insulators during and shortly after periods of volcanic activity. This ash is not easily removed unless it is cleaned soon after it is deposited. Water washing or compressed air cleaning or wiping can be used.

6.1.10 Bird excrement

Insulators located in the vicinity of roosts of birds are subject to contamination by excrement. These deposits are usually washable and are often cleansed by heavy rain, but may present serious problems of system reliability. All the methods, such as water washing, compressed air cleaning, and wiping can be used to clean this contaminant.

6.1.11 Chemical

Atmospheric pollutants from a wide variety of industrial chemical processes, aerial spraying of agricultural chemicals, and fire-fighting chemicals (~~borate~~) are deposited on insulators. The characteristics of these chemical contaminants vary widely. Agricultural areas tend to have equal dry deposition levels of NH_4 and HNO_3 , whereas urban areas have mainly HNO_3 at levels of about 10 g/km^2 per year. Both of these ions, and many other chemical pollutants ~~Some chemicals~~ are highly soluble and can be washed easily, while others bond firmly and can be removed only by hand scrubbing.

6.1.12 Smog (vehicular emission)

In urban areas, automobile emissions introduce a significant amount of particulate matter into the environment. [For example, this is overlaid on uniform background levels of dry SO₂ deposition on the order of 30 to 100 g/km² per year in the Eastern USA, compared to less than 10 g/km² per year West of the Mississippi.](#)

In addition, diesel engine emissions [of carbon black](#) from trains particularly affect areas adjacent to rights-of-way. Normally, [volatile organic](#) ~~industrial~~ chemicals are [also](#) present in areas with heavy smog problems. Resulting insulator contaminants have varying characteristics, depending on the combination of pollutants present. Various methods, such as water washing, compressed air cleaning, or wiping can be used to clean smog.

6.1.13 Cooling tower effluent

Cooling tower effluent is composed of water vapor and a small amount of dissolved solids. [Usually, the cooling water quality is maintained to reduce corrosion inside the tower. In some cases the effluent can also contain chlorine, which is a very aggressive corrosive component.](#)

Under normal wind and temperature conditions, cooling tower effluent should quickly disperse and not affect insulator performance. However, under certain weather conditions, it is possible for the effluent to create a localized fog. This fog may moisten dry, dirty insulators or, if the temperature is cold enough, ice glazing on insulators may occur. Either situation can affect the performance of the insulator. Water washing or dry ice cleaning is an effective way to clean cooling tower effluent.

6.1.14 Smoke

Industrial and agricultural burning or wildfires can, with other compatible conditions (such as moisture and humidity), cause the resulting contamination to accumulate on the insulation. Smoke [deposits of fine carbon black should](#) ~~can~~ be washed using water or dry ice or wiping.

6.1.15 Organic

Organic contamination consists of living or dead organisms, or by-products produced by them. Common examples are mold and algae. Wiping and compressed air cleaning and washing can be effective in cleaning.

6.1.16 Ice/snow

Ice is an electrical insulator if its temperature is less than $-2\text{ }^{\circ}\text{C}$ ($28.4\text{ }^{\circ}\text{F}$) but can cause electrical flashovers if it starts to soften and melt at $-1\text{ }^{\circ}\text{C}$ ($30.2\text{ }^{\circ}\text{F}$). Heavy ice or snow accumulation on insulators can sometimes be cleaned using preheated water that has a resistivity of more than $50\,000\text{ }\Omega\text{ cm}/\mu\text{S}$ ([water](#) conductivity less than $20\text{ }\mu\text{S/cm}$). Generally, a vertical pass to split the ice cover, followed by injection of the hot water stream between the ice and the insulator, can be effective. The high-water purity is needed because the resistivity of water decreases by a factor of two as temperature increases from $25\text{ }^{\circ}\text{C}$ ($77\text{ }^{\circ}\text{F}$) to $70\text{ }^{\circ}\text{C}$ ($158\text{ }^{\circ}\text{F}$) and also because any remaining water that freezes to ice should be as clean as natural ice, which seldom causes problems on its own in the absence of a pre-contamination layer.

6.1.17 Fire retardant

A fire retardant is a substance that is used to slow or stop the spread of fire or reduce its intensity. Fire retardants used to fight wildfires are typically a mixture of water with chemicals designed to retard the progress of the fire. Borate salts used in the past to fight wildfires have been found to sterilize the soil and be toxic to animals so are now prohibited. Newer retardants use ammonium sulfate or ammonium polyphosphate with attapulgite clay thickener or diammonium phosphate with a guar gum derivative thickener. These are not only less toxic but act as fertilizers to help the regrowth of plants after the fire. Fire retardants often contain wetting agents, preservatives and rust inhibitors and are colored red with ferric oxide or fugitive color to mark where they have been dropped.

Utilities should work with the firefighting agencies in their state, province or local area to educate fire fighters regarding the impact of fire-retardant pollution on line insulators and substations. To the extent possible, the application of fire retardants from planes or helicopters should be directed in a manner to avoid dumping retardant on electrical equipment. Education and communication during fire prevention and firefighting preparation can save many hours of insulator cleaning.

After firefighting operations are completed, insulators should be inspected to determine if insulators can be cleaned or should be replaced prior to energization.

7. Managing insulator performance and cleaning

Good data collection and management of insulator performance is crucial to properly establish the most cost-effective insulator cleaning program for a particular line or geographic area of lines. It is important to understand that a program, cleaning method, and frequency that works for one line may not be effective for another line.

7.1 Monitoring analysis of data

To optimize an insulator cleaning program it is necessary to collect good data for each specific line of concern. This data must then be properly analyzed in order to establish an optimal cleaning program. It is necessary to periodically revisit the effectiveness of each program because changes in the environment, the topography, surrounding development, etc. in the vicinity of that line may change with time.

7.1.1 Frequency of cleaning

Frequency of cleaning varies depending upon the degree of contamination, the weather conditions, and the particular insulator design. Where frequent water washing is required, it is sometimes economical to install either piping systems on towers or permanent fixed-spray nozzle systems for ease in washing.

Insulators should be cleaned ~~washed~~ prior to the time of reaching a ~~the~~ critical contamination level. This point can be estimated from the following:

- Past experience on periods between flashovers, or pole fires

- [Relative experience \(versus historical data\) of buildup and/or discharges at different line voltages or installation types.](#)
- Allowable ~~equivalent salt deposited density~~ (ESDD) obtained from de-energized test insulators or from energized insulators
- Degree of scintillation during damp weather conditions
- Complaints of radio/television interference
- Proximity and exposure to the pollution source
- Type of contaminant⁷ and its rate of buildup on the insulator [and associated hardware](#)
- Weather conditions

[NOTE](#) (It is noted that the danger of flashover and pole fires is particularly great after a long, dry period, either in.¹⁴)

- Sensor insulators that indicate contamination level (to be used for areas of consistent contamination levels or worst-case areas)

[There is sufficient experience to demonstrate that polymer insulators do not require cleaning as frequently as porcelain or glass insulators. If necessary, polymer insulators can be cleaned. It is recommended to consult with the insulator manufacturer to determine the cleaning method and modality to be used.](#)

7.1.2 Results

[The](#) results of [effectiveness and](#) efficient insulator cleaning can be judged by the following.

7.1.2.1 Visible (clean-shiny)

Surface condition of both the top and bottom of the insulator skirts should be visually clean and shiny after the water or solvents have dried. [There should be no visible residue.](#)

¹⁴ ⁶ Notes in text, tables, and figures [of a standard](#) are given for information only and do not contain requirements needed to implement [this](#) ~~the~~ standard.

7.1.2.2 Insulator vibration (ringing)

Mechanical vibration (ringing) of insulator skirts under impact of high-pressure washing and exhibiting evidence of efficient swirling cleaning action.

7.1.2.3 Absence of corona

Blue corona discharges extend from the metal cap to the porcelain during energized high-pressure washing and may be heard for a few seconds after completion of cleaning.

If this discharge continues for more than a few seconds, it may indicate incomplete washing of the insulators, in which case the wash stream should be reapplied.

7.1.2.4 Clarity of runoff

Clarity of the water runoff may also indicate the effectiveness of contamination removal. Clarity of water runoff may be difficult to observe due to distance, sunlight, wearing of sunglasses, etc.

7.2 Work methods

~~4.2 Transmission line insulators~~

~~4.2.1 Ceramic~~

Porcelain and glass insulators ~~with galvanized hardware~~ are the most common insulators to be cleaned. Any cleaning technique or solvent used should not damage or deteriorate the units ~~item~~ to be cleaned.

Ceramic insulators can be cleaned in a number of ways, and electrical circuits can remain ~~they can either be~~ energized or de-energized, depending on potential risk. De-ionized water (versus filtered) or specialty solvents may be more effective or lower risk solutions. ~~The most common methods used are the following:~~

- ~~a) High pressure water (2750 kPa to 7000 kPa) (400 psi to 1000 psi)~~
- ~~b) Medium pressure water (2100 kPa to 2750 kPa) (300 psi to 400 psi)~~
- ~~c) Low pressure water (flood wash) (1400 kPa) (200 psi)~~

- ~~d) Low pressure water fixed spray nozzle~~
- ~~e) Compressed air cleaning—corncob and CO₂ pellets~~
- ~~f) Hot wiping (using a live line tool)~~
- ~~g) Hand cleaning~~

7.2.1 Energized

It is a very common practice to clean ceramic insulators with lines in an energized mode and reclosing devices disabled. There are certain conditions that can exist that make energized insulator cleaning prohibitive.

7.2.2 De-energized

All of the methods discussed in [this document 6.1](#) may ~~also~~ be utilized ~~in addition to hand cleaning,~~ when the facility is de-energized (and grounded). When the system is de-energized (and grounded), the requirements of water resistivity are the same as for an energized system. However, the clearance issue is not there, thereby allowing different washing conditions.

8. Insulator cleaning

8.1 Wash equipment location

The wash equipment location is defined as the physical equipment location from which insulator cleaning is performed. Examples of work equipment location can be ground/vehicle-based, structure-based or helicopter-mounted.

8.1.1 Ground/Vehicle-based

~~7.1.6 Carrier~~

8.1.1.1 Trucks or aerial lifts

Truck types ~~Chassis~~, from small 4-wheel-drive ~~vehicles~~ to 10-wheel-drive ~~diesels, of 27 216 kg (60 000 lb)~~ are being used. Small all-wheel-drive trucks equipped with water pump only pick up water from tanker trucks or trailers. Medium and heavy trucks pump/engine or power takeoff (PTO)-equipped may carry the water and accomplish the washing. The truck may also carry a skid-mounted tank pump and aerial manlift to use when cleaning from a basket.

A chassis-mounted boom with a remotely controlled tip monitor is a popular arrangement. ~~Ground-to-tip heights of 19.8 m to 41.1 m (65 ft to 135 ft) are in use.~~ Washing requires many more extensions/retractions than the use of a crane/derrick in line construction or maintenance. Wear and tear require a tough rigid boom that can tolerate the repetitive cycles required in the washing function. ~~Articulated aerial units to 41.1 m (135 ft) are in use.~~ An insulated upper arm and a basket with non-conductive hose that is equipped with a hand-held gun are used. Existing aerial lift equipment can be used seasonally for washing transmission, distribution, and substation insulators. Skid or trailer wash equipment is also utilized.

8.1.1.2 Trailer

A wash trailer can be towed behind existing truck equipment. Trailer brake actuation, electric vacuum, air, or combinations provide stopping ability and allow towing vehicles with varying brake systems to tow the trailer. The trailer can be towed behind an existing ~~10.6 m to 19.8 m (35 ft to 65 ft)~~ aerial lift for transmission or distribution washing ~~or an existing 27.4 m to 38.1 m (90 ft to 125 ft) lift for transmission.~~ Metal towers can be climbed, with the line worker carrying a hand line up the tower, and then pulling the gun to him/_her. Two people can wash from one trailer on high-voltage vee-string requirements if the pump power unit is equipped to produce pressure and flow for two-gun simultaneous operation. Voltages of up to 800 kV are being washed by this method.

Substation washing often requires a vehicle, low in height, with flotation tires to avoid substation gravel disturbance. A short-coupled trailer can be used in a substation, and two-gun cleaning can be accomplished. The throttle can be lowered for flood washing the more delicate apparatus. Higher bus insulators can be cleaned ~~Used~~ with a boom of 9.1 m to 12.2 m (30 ft to 40 ft). The same self-contained trailer can be used in various applications, providing increased vehicle utilization in all the maintenance functions. During dry summer months, the trailer becomes an excellent firefighting vehicle.

8.1.2 Structure-based

Structure-mounted equipment can include fixed nozzles mounted on various structure types. For example, towers can be equipped with nozzles permanently mounted and directed toward the insulators. A portable or fixed water supply can be connected to the standpipe to wash the insulators remotely. Standpipe systems are permanently fixed to the structure and can be operated manually or automatically through electronic controls.

8.1.3 Helicopter-mounted platforms

When access to insulators is difficult, rugged, or remote, or when high mobility is required for rapid washing operations over long distances, overhead washing by helicopter is an option. However, as with any piece of equipment, helicopter-mounted wash systems have limitations to be considered when evaluating their use. In addition to considering the structure type and helicopter accessibility, the following are some other factors to be considered before deciding to use helicopter-mounted washing equipment:

- Structure access: While an aircraft is isolated from ground, there are minimum approach distances that must be maintained at all times. Unless a wash boom is tested and certified, and the water resistivity is monitored, minimum approach distances as per IEEE Std 516 must be maintained from the structure and adjacent phases while washing is in progress. By design, many structures, do not allow access for aerial-mounted wash booms while maintaining necessary minimum approach distances.

- Wind: Wind has a significant impact on insulator washing from a helicopter. It affects the maneuverability and positioning of the aircraft around the structure, and the effective spray distance of the system. Attention needs to be given to affect of the wind on overspray so as not to compromise the functionality of adjacent insulators to the ones being washed.
- Risk: Washing insulators with a helicopter is a cost effective method of managing insulator contamination, but great attention must be given to managing the associated risks and hazards. Working in or around populated areas, industrial areas have high public exposure and special mitigations may be required to do the work.
- Perception: The general perception of the public needs to be managed as there is a tendency to misinterpret the work being performed. Besides the concerns associated with risk and hazard, people are suspicious of the spray. Any effort to keep the public informed removes some of the associated anxiety associated with the work
- Scheduling: Performing aerial insulator washing is influenced by a variety of circumstances that make accurate scheduling difficult. Planning and flexibility are essential for effective operations.
- Logistics: Planning is an essential aspect for safe, cost effective, and efficient operations. Access to lines, location of resupply locations, and access to water are critical considerations.

The mounting framework for the system components must be designed to support the weight and be in compliance to any OSHA and FAA regulations. The configurations can be internal, external, or a combination of internal and external components.

Helicopter aircraft have ~~Such aircraft are~~ limited ~~in the amount of~~ wash water carrying capacity ~~they can carry~~. To compensate for this, the pumping system and hand-held or guided gun with wand are usually powered with a higher pressure, lower volume system than ground-carried systems. With this self-contained, isolated, and ungrounded system, the spray nozzle can be safely positioned closer to the insulators that are to be cleaned. ~~Considerations have to be made for the structure type and helicopter accessibility before using a helicopter mounted nozzle.~~

Most helicopter-mounted cleaning equipment consists of 5 main components. The information regarding the pump, the water tank and nozzle is covered in other areas of this document. In addition to these devices, the helicopter must also be equipped with a special spray boom and a specially designed and certified mounting system.

8.1.3.1 Wash boom

Wash booms are the medium of delivering the water from the tank to the nozzle. They can be constructed of insulated material or aluminum alloy and are designed in accordance with all associated regulations and specifications. Booms can be fixed in place extending out the front of the aircraft and operated by a specially trained and qualified pilot. Other boom designs are moveable and are operated by a second person, also trained and certified, positioned in the passenger area of the aircraft. To reduce the potential of conflict between the main rotor of the helicopter and the structure or insulators being washed, the boom extends out beyond the diameter of the rotor disk. Under no circumstances can the operation of the wash system impair the safe operation of the aircraft.

8.2 Cleaning methods and equipment

The types of contaminants present on the insulator surface can influence the cleaning method that should be used. Some contaminants, such as bird excrement, can become very conductive when wet. For contaminants that become conductive when wet, the high-pressure wash or flooding method should not be used on energized lines. The high-pressure wash and flooding methods are most effective when used to clean soluble contaminants. Adhesive insoluble deposits may limit the effectiveness of water cleaning methods. These types of deposits and extremely stubborn compounds may constrain the cleaning methods to either hand cleaning with chemical agents and scrubbing or through use of the compressed-air, dry-cleaning method. Hand cleaning is an expensive procedure. Only by experience with a particular contaminant can the most effective and economical cleaning process be determined.

The method used for insulator cleaning is [also](#) dependent on the insulator material, construction, whether or not the line is energized, and the type of containment to be removed. [Cleaning insulators at distribution voltages entail different concerns than higher voltages due to lesser clearance distances. However, the methodology is consistent, regardless of voltage.](#)

8.2.1 Water [washing](#)

[Methods used to wash insulators will vary depending on voltage, application, and physical properties of the insulators.](#)

[There are circumstances where washing with the line energized is prohibitive. Following are situations where an assessment should be completed to make the decision to wash under energized condition:](#)

- [— Damaged insulators: Damage to single or multiple insulators may compromise the insulating characteristics to the extent the spraying of water may result in a flashover.](#)
- [— Cement growth: This is a condition where the grout holding the insulator together has deteriorated and cracked. This cracking can extend into the porcelain and reduce both electrical and mechanical capabilities. It is more common in insulators located in deadends and angles where the grout is more accessible to moisture. Introducing water under pressure may cause failure of insulator\(s\).](#)

[When water washing insulators using the live-line work method, they should be washed so that the watersheds just cleaned will maintain adequate insulation. \(For example, on vertical insulators the washing would be started at the bottom and work upwards.\) One of the main concerns of washing is the potential problem of overspray. When overspray presents a problem, washing from different positions may help, but will take more time and reduce production.](#)

~~7.5—Fixed spray~~

[The equipment required to conduct power washing](#) is composed of: a water tank, pump and motor, various valves, nozzles, piping system, and control system.

8.2.1.1 Technical considerations for energized cleaning with water

~~8.1 Leakage current~~

For the purpose of this guide, leakage current is defined as the current that flows through normally non-conducting elements such as hoses. Refer to IEEE Std [80-2000](#) and IEC [60479-2:2019](#) ~~60479-2:1987 for safe values of let-go current for the average person.~~

~~A~~ The level of 1 mA is the approximate perception threshold current that a person detects as a slight tingling sensation in his hands or fingers due to current flow. When the nozzle grounding braid is properly grounded, no appreciable leakage current should flow through a person's body during the washing operation. Nevertheless, a person should anticipate the possibility that the nozzle grounding braid can accidentally open or become disconnected. For this reason, leakage current in the wash stream should be limited to 2 mA.

The washing equipment, the wand, the structure, and the washing ~~equipment operator~~ ~~person~~ should be at the same potential [at all times during insulator cleaning](#). Refer to IEEE Std [1048](#) ~~1048-2003~~ for more details about [temporary](#) grounding.

In substations, nozzle operators using hand-held nozzles [should](#) wear rubber boots, rain clothes, and rubber gloves to avoid getting wet. In addition, the wet hose is in direct contact with the ground. The operator has both hands on the nozzle while the stream is contacting energized equipment. It should not be difficult under these circumstances to limit the leakage current by adjusting washing distance, pressure, orifice, and water resistivity.

The parameters that influence the leakage current in the wash water stream are as follows:

- Line voltage
- Distance from the nozzle tip to the energized parts
- Water resistivity or conductivity
- Water pressure
- Nozzle orifice diameter
- [Nozzle design \(continuous stream or intermittent pulses\)](#)

Currents exceeding 1 [mA](#) or 2 mA are to be guarded against by the following:

- Using water that falls within the acceptable range of conductivity or resistivity
- Replacing worn nozzles
- Carefully maintaining safe working distance

8.2.1.1.1 Working distance

Nozzle-to-conductor distance for a given line voltage and nozzle diameter is the most important parameter that influences the leakage current and the washing effectiveness of the water stream. Washing effectiveness and the magnitude of leakage current [both](#) decrease with increasing nozzle-to-conductor distance. In cases where the wash distance is limited by the tower dimensions, demineralized water can be used.

Table [1 4](#) gives minimum distance between ~~the~~ energized parts and the nozzle tip for various line voltages [when working from conventional platforms such as ground-based, vehicle and structure-mounted equipment](#).

Table 1—Minimum distance for energized washing^a

Line voltage (kV)	Minimum nozzle- to-conductor distance m (ft)	Minimum water resistivity $\Omega \times \text{cm}$ ($\Omega \times \text{in}$)	Minimum nozzle pressure kPa (psi)	Maximum orifice diameter mm (in)
13 and below	1.82 (6)	1300 (512)	2758 (400)	4.76 (3/16)
13 and below	1.82 (6)	1300 (512)	2758 (400)	6.35 (1/4)
16	2.13 (7)	1300 (512)	2758 (400)	4.76 (3/16)
34.5	2.44 (8)	1300 (512)	2758 (400)	6.35 (1/4)
34.5	2.44 (8)	1300 (512)	2758 (400)	4.76 (3/16)
69	2.74 (9)	1300 (512)	2758 (400)	4.76 (3/16)
69	3.66 (12)	1300 (512)	2758 (400)	6.35 (1/4)
115	3.05 (10)	1300 (512)	2758 (400)	4.76 (3/16)
115	3.96 (13)	1300 (512)	2758 (400)	6.35 (1/4)
230	3.66 (12)	1300 (512)	2758 (400)	4.76 (3/16)
230	4.57 (15)	1300 (512)	2758 (400)	6.35 (1/4)
345	3.92 (13)	1300 (512)	2758 (400)	4.76 (3/16)
345	5.22 (17)	1300 (512)	2758 (400)	6.35 (1/4)
500	4.27 (14)*	50 000 (19 685)	5516 (800)	6.35 (1/4)
500	6.10 (20)	3000 (1181)	3792 (550)	7.94 (5/16)
500 dc	6.10 (20)*	50 000 (19 685)	5516 (800)	6.35 (1/4)

[\(New\)](#)

Line voltage	Minimum nozzle-to-conductor distance	Minimum water resistivity	Minimum nozzle pressure	Maximum orifice diameter
(kV)	(m)	($\Omega\cdot\text{cm}$)	(kPa)	(mm)
13 & below	1.82	1300	2758	4.76
13 & below	1.82	1300	2758	6.35
16	2.13	1300	2758	4.76
34.5	2.44	1300	2758	6.35
34.5	2.44	1300	2758	4.76
69	2.74	1300	2758	4.76
69	3.66	1300	2758	6.35
115	3.05	1300	2758	4.76
115	3.96	1300	2758	6.35
230	3.66	1300	2758	4.76
230	4.57	1300	2758	6.35
345	3.92	1300	2758	4.76

(Deleted)

Table 4—Minimum distance for energized washing^a (continued)

Line voltage	Minimum nozzle-to-conductor distance	Minimum water resistivity	Minimum nozzle pressure	Maximum orifice diameter
(kV)	(m)	($\Omega\cdot\text{cm}$)	(kPa)	(mm)
345	5.22	1300	2758	6.35
500	4.27	50 000	5516	6.35
500	6.10	3000	3792	7.94
500 dc	6.10	50 000	5516	6.35

(Deleted)

NOTE—The 345 kV distances were interpolated using 230 kV and 500 kV and found to be in line with industry practice.

^a The distance is limited by tower dimensions and configuration. Because of the limited nozzle-to-conductor distance, demineralized water with resistivity of 50 000 $\Omega\cdot\text{cm}$ (19 685 $\Omega\cdot\text{in}$) or greater can be used.

NOTE—For English units, see Annex C.