

IEEE Std 957™-2005
(Revision of
IEEE Std 957-1995)

IEEE Standards

957™

IEEE Guide for Cleaning Insulators

IEEE Power Engineering Society

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3 Park Avenue, New York, NY 10016-5997, USA

20 September 2005

Print: SH95333

PDF: 957-2005



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IEEE Guide for Cleaning Insulators

Sponsor

**Transmission and Distribution Committee
of the
IEEE Power Engineering Society**

Approved 25 April 2005

IEEE-SA Standards Board

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

Keywords: cleaning, electrical insulators

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Print: ISBN 0-7381-4689-7 SH95333
PDF: ISBN 0-7381-4690-0 SS95333

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Introduction

This introduction is not part of IEEE Std 957-2005, IEEE Guide for Cleaning 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 Cleaning Insulators

1. Overview

1.1 Scope

The scope of this guide for cleaning insulators is to document the procedures used for cleaning contaminated electrical insulators (excluding nuclear, toxic, and hazardous chemical contaminants), of all types, 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 insulator cleaning 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 cleaning contaminated insulators.

The methods 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 cleaned contaminated insulators. The guide is intended to serve as a reference source for a company, or persons, seeking information on insulator cleaning procedures so that they may consider the experience of others in modifying or formulating insulator cleaning programs and practices.

2. Normative references

The following referenced documents are indispensable for the application of this 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, 2001.¹

¹EUSA publications are available from the Electrical & Utility Safety Association, 5580 Explorer Drive, Suite 200, Mississauga, Ontario 4Y1 Canada (<http://www.EUSA.on.CA>).

IEC 60479-2:1987, Effects of Current Passing Through the Human Body.²

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

IEEE Std 80TM-2000, IEEE Guide for Safety in AC Substation Grounding.

IEEE Std 516TM-2003, IEEE Guide for Maintenance Methods on Energized Power Lines.

IEEE Std 1048TM-2003, IEEE Guide for Protective Grounding of Power Lines.

3. Definitions, acronyms, and abbreviations

For the purposes of this document, the following terms and definitions apply. *The Authoritative Dictionary of Standards Terms* [B22] should be referenced for terms not defined in this clause.

3.1 Definitions

3.1.1 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.

3.1.3 equivalent salt-deposit density (ESDD): A measure of contamination level.

3.1.4 insulator: In this guide, IEEE Std 957-2005, this refers to individual insulators and also the external insulating members of other apparatus; e.g., transformer bushings and surge arresters.

3.1.5 non-conducting or non-conductive: Made of a material of high dielectric strength.

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

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

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

3.1.9 qualified worker: A person qualified to perform various line-work operations, including aerial and groundwork.

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

3.1.10 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.

²IEC 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 (<http://www.iec.ch/>). 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 (<http://www.ansi.org/>).

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

⁵Information on references can be found in Clause 2.

⁶Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

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

3.1.12 water conductivity: Conductivity (reciprocal of resistivity) of water is expressed in microsimens/centimeters ($\mu\text{S}/\text{cm}$)

3.1.13 water resistivity: Resistivity of water is expressed in ohm-cm ($\Omega\cdot\text{cm}$) or ohm-inch ($\Omega\cdot\text{in}$).

3.2 Acronyms and abbreviations

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
m^3/s	cubic meters per second
PTO	power takeoff
rpm	revolutions per minute
RTV	room temperature vulcanizing

4. Insulators to be cleaned

4.1 Introduction

Line insulators and arresters are made of ceramic and polymeric materials. Cleaning distribution insulators entails different concerns than transmission line insulators due to the lesser voltage involved and the respective clearance distances. 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.

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 used should not damage or deteriorate the item to be cleaned.

Ceramic insulators can be cleaned in a number of ways, and they can either be energized or de-energized. 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

4.2.2 Polymer

Manufacturers should be consulted prior to cleaning for advice on their respective products and applicability of cleaning methods.

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
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.

4.2.2.3.1 De-energized cleaning

If the insulators can be de-energized for cleaning, they may be hand washed with rags or wiping cloths in mild detergent water. This should be followed by a low-pressure flood rinse with clean water to remove any residue. Solvents or harsh abrasives are normally not recommended. Wetting agents or additives can be used to improve the washing action of the cleaning water. Solvents may be used, provided all cleaning residue is removed by the final clean water rinse and only after manufacturer approval.

4.2.2.3.2 Energized cleaning

Compressed air/dry abrasive cleaning—This procedure involves the use of compressed air and dry abrasive cleaning media. The abrasive cleaning compounds often consist of ground corncob mixed with ground walnut or pecan shells.

The actual cleaning process is similar to sandblasting in that a pressurized air stream is used to bombard the insulator surface with abrasive media. After cleaning, the contaminant and abrasive residue remaining on the insulator surfaces are blown off with dry, clean, compressed air.

With proper cleaning media and procedures, virtually any contaminant can be safely removed from the insulator surfaces without the need for area cleanup of the abrasive residue. Abrasive cleaning techniques are not recommended for silicone rubber insulators since they can temporarily destroy the surface hydrophobicity of the polymer.

4.3 Station 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.

4.3.2 Bushings

Bushings are made of ceramic or polymeric materials and must be treated with great care. Consideration of pressure and volume and the mechanical support 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 washing may impose severe electrical stresses on the surge arresters due to voltage imbalance and should not be performed without the concurrence of the arrester manufacturer.

4.3.3.2 Polymeric

Energized washing of these also imposes severe electrical stresses due to voltage imbalance. Polymer housed distribution arresters should not be exposed to the direct stream of high-pressure washing. Consult the arrester manufacturer for 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.

4.5 Large diameter equipment

Large diameter equipment may require the application of more than one simultaneous water stream from opposite sides of the equipment.

4.6 Greased insulator cleaning

Greased insulators may be cleaned either in the energized or de-energized condition.

If it is possible to de-energize the facilities, the insulators may be cleaned by hand. Simply wipe off the contaminated grease with cloths. If the grease coating has hardened and caked on the insulator, it may be necessary to chip or scrape the coating or use a high-pressure air blast that delivers ground-up corncobs, walnut or pecan shells against the insulator. The air blast should not be directed against one spot for too long as the ground material may damage the porcelain glaze. Residual dust can be blown off with clean air.

If the insulators must be cleaned in the energized state, the air-blast corncob method should be considered. Cleaning equipment with properly insulated wands is available commercially. Solvents can also be used to soften the grease before removal by hand or by high-pressure water spray.

It is well known that alumina trihydrate (ATH) fillers improve the arc resistance of organic polymer systems used for high-voltage insulator applications (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.

ATH-filled silicone grease can be used under severe contamination when conventional silica filled greases have experienced service problems due to hot-spot arcing or flashovers, or both. The method for application and cleaning are the same as for conventional greases.

The application of fresh silicone grease over contaminated silicone grease is not recommended. The contaminated grease must be removed prior to coating a new layer. Simple hand wiping with disposable paper towels, burlap, or porous hand pads is all that is required.

For cleaning silicone grease insulators on energized lines, use of demineralized water spray, at a relatively low pressure of 850 kPa (125 psi) and a high capacity of 3.2 L/s (50 gal/min) is recommended. Removal of silicone grease is relatively simple compared to the removal of petroleum jellies from insulators.

4.7 Resistive glazed insulator cleaning

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.

4.8 Room temperature vulcanizing coated ceramic insulator cleaning

When the room temperature vulcanizing (RTV) begins to get contaminated and loses some of its water repellency, it can easily be washed. Some RTV coatings can be high-pressure washed, but there are RTV coatings where low-pressure washing or flooding is recommended. Once clean, the hydrophobicity is restored. If recoating is necessary, the old coating can be removed by cleaning with an abrasive media, such as corn cob. This is simple compared to grease, which requires rags and a solvent; a messy and time-consuming operation. Detergents should not be used. A new top layer can also be achieved by application over existing coating without removal of the existing layer. Some cleaning may be recommended; however, lately, dry cleaning methods for removing the spent RTV coatings are available. However, the new RTV coating may be more effective if the old coating is removed completely and then recoated.

5. 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.

A number of types of contaminants have been identified as sources of surface deposits on insulators affecting insulator performance. These contaminants are distinguished primarily by the source of the impurities. 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 characteristics of the mixture.

5.1 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, 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.

5.2 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, 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.

5.3 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.

5.3.1 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).

5.3.2 Fertilizer

Fertilizer dust is emitted from fertilizer plants and from fertilizer application in farming. Fertilizer dust has been known to create a thick coating that high-pressure washing could not remove. In these cases, hand scrubbing or dry washing is needed to clean the insulators. Liquid fertilizer of the urea type is cleaned with water.

5.3.3 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).

5.3.4 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.

5.3.5 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.

5.3.6 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.

5.4 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.

5.5 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. Some chemicals are highly soluble and can be washed easily, while others bond firmly and can be removed only by hand scrubbing.

5.6 Smog (vehicular emission)

In urban areas automobile emissions introduce a significant amount of particulate matter into the environment. In addition, diesel engine emissions from trains particularly affect areas adjacent to rights-of-way. Normally, industrial chemicals are 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.

5.7 Cooling tower effluent

Cooling tower effluent is composed of water vapor and a small amount of dissolved solids. 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.

5.8 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 can be washed using water or dry ice or wiping.

5.9 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.

5.10 Ice/snow

Ice is an electrical insulator if its temperature is less than $-2\text{ }^{\circ}\text{C}$ but can cause electrical flashovers if it starts to soften and melt at $-1\text{ }^{\circ}\text{C}$. Heavy ice or snow accumulation on insulators can sometimes be cleaned using preheated water that has a resistivity of more than $50\,000\text{ }\Omega\cdot\text{cm}$ (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 $25\text{ }^{\circ}\text{C}$ to $70\text{ }^{\circ}\text{C}$.

5.11 Frequency of cleaning

Frequency of cleaning varies depending upon the degree of contamination, the weather conditions, and the particular insulator design. Where frequent 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 washed prior to the time of reaching the critical contamination level. This point can be estimated from the following:

- a) Past experience on periods between flashovers, or pole fires
- b) Allowable equivalent salt-deposited density (ESDD) obtained from de-energized test insulators or from energized insulators
- c) Degree of scintillation during damp weather conditions
- d) Complaints of radio/television interference
- e) Proximity and exposure to the pollution source
- f) Type of contaminant, and its rate of buildup on the insulator
- g) Weather conditions (it is noted that the danger of flashover and pole fires is particularly great after a long, dry period, either in winter or summer, followed by a light drizzle or fog condition)
- h) Sensor insulators that indicate contamination level (to be used for areas of consistent contamination levels or worst-case areas)

6. Methods

The method used for insulator cleaning is dependent on the insulator material, construction, whether or not the line is energized, and the type of containment to be removed.

6.1 Energized

6.1.1 High-pressure water

High-pressure water washing utilizes a narrow stream of water with typical pressures ranging from 2750 kPa to 7000 kPa (400 psi to 1000 psi) at the nozzle. Four types of nozzles are most often used with high-pressure water: handheld jet, remote-control jet (pea shooter), fixed spray, and helicopter mounted.

6.1.1.1 Handheld jet nozzle

The handheld nozzle is the most common type of nozzle used for high-pressure washing. The line worker either climbs the tower or uses an aerial lift to raise the hose and nozzle to the wash position. The line worker may also connect a detachable hose and nozzle to a standpipe permanently installed on the tower.

Substation insulators may also be washed using a handheld nozzle while on the ground or in an aerial basket.

The resistivity/conductivity of the water from the wash truck reservoir should be checked by a resistivity/conductivity meter each time water is added. The wash truck is positioned so that the wash hose will come off the hose reels at the tower leg to be climbed. In this way, the hose does not have to be dragged around the tower.

Some utilities specify wire braid conductive hose to bond the truck to the tower. The continuity of this bonded connection is checked prior to the start of the job. Routinely, all bonding connections should be checked for corrosion and cleaned, as required. Since the wash truck may acquire a relatively high potential, it is important when washing that no person gets on or off the truck and that all persons on the ground are kept away from the truck. Persons on the truck must also avoid reaching out and touching adjacent trees, poles, towers, or other objects. Refer to IEEE Std 516-2003 for more details on grounding.

Some utilities use non-conductive wash hose and do not bond the truck to the tower so that the truck is unlikely to acquire a high potential. However, good practice is to allow no one to get on or off the truck and that all persons on the ground be kept away from the truck during the actual washing operation.

Next, the qualified worker climbs the tower carrying a hand line. The truck driver sends up the hose, gun, and nozzle. The qualified worker bonds the nozzle to the tower steel or pole bond wire. The point is that the qualified worker, the nozzle, and the tower must be at the same potential.

The qualified worker then directs the truck driver to increase the water pressure. If the unit is equipped with a demand throttle, the pressure (revolutions per minute—rpm) will be automatically increased when the gun is opened. The water is directed away from the insulator string until full pressure has been achieved. The line worker on the tower then directs the wash stream at the insulator. The nozzle-to-conductor distance shall not be less than the established minimum wash distance. See Table 4.

Suspension insulator strings are washed by first directing the stream of water at the insulator nearest the energized conductor in such a manner as to take advantage of both the impact and the swirling action of the water to remove deposits. After the bottom insulators in the string are washed, the wash stream is moved up a few units. These units are washed and the stream then is directed on the clean units below to re-rinse them. This process is repeated, moving up a few insulators at a time until the entire string is clean. Failure to re-rinse lower insulators before moving further up the string can lead to flashover. The stream must be moved away from any energized part of the insulators before the water pressure is reduced. Care should be taken to prevent the spray from unduly moistening nearby dirty insulators, particularly in the station.

Deadend insulators must be washed carefully to keep overspray from causing flashover. Begin washing on the downwind end of the insulator string and then work upwind.

It is important that the above procedures and the established wash parameters are strictly adhered to when conducting hot-line washing.

6.1.1.2 Remote-control jet nozzle

The remote-control jet nozzle system consists of a nozzle mounted on a truck-mounted boom. Both the nozzle and the boom are controlled from a console connected to the boom turret. This system permits

positioning of the water stream when washing is difficult to perform from a tower or station structure (such as for outer phase vee-string insulators on high-voltage lines).

The technique for washing with a remote-control nozzle is very similar to that for the handheld nozzle. The primary difference in the two techniques is that the nozzle positioning is done remotely from an operator's console at the base of the truck boom. A knowledgeable operator is required to position the boom in a location that will provide a good washing angle in addition to maintaining safe working clearances.

6.1.1.3 Fixed-spray nozzle

Fixed-spray nozzle hot-line washing has proven to be effective in preventing sea-salt contamination flashover problems. The wash parameters and equipment should be developed and established for each installation. This is mainly due to various local parameters that influence the washing. Such parameters are precipitation, water resistivity, wind, contamination severity, and design and installation arrangement of the insulators to be washed.

Two basic washing systems are used, as follows:

- a) Spray washing for calm wind conditions
- b) Water-screen washing for strong wind conditions

For spray washing, the electrical apparatus is divided into groups, and nozzles are firmly fixed on piping arranged around apparatus insulators. The apparatus is washed sequentially from one group to another, according to a preset washing order. Table 2 provides general information on this system.

Table 2—Fixed nozzle washing equipment and usage

Type of nozzle	Spray
Number of nozzles	Multiple
Water pressure	350 kPa to 3000 kPa (50 psi to 430 psi)
Nozzle installation	Permanently installed on steel structure
Wash control	Fixed
Washing coverage	Water envelopes and swamps insulator in one surge
Operation	Eliminates both climbing and special skill requirements for washing
Application	Suitable in areas where washing is frequent (at least once a month) and where tower or station structures are very high
Other features	Piping to nozzle is required for each insulator assembly. Water usually controlled automatically.
Disadvantage	Affected by wind

For water-screen washing, nozzles are installed only on the windward side of the apparatus. Washing water is discharged upwards and carried onto the insulators by the strong winds.

6.1.1.4 Helicopter-mounted nozzle

This washing method involves the use of a self-contained high-pressure wash system carried aloft by a helicopter. The system is controlled by a wash operator in the aircraft or by the pilot. The helicopter hovers near the insulator string and the operator positions the nozzle to direct the stream at the insulator string.

The actual washing techniques employed are similar to those for washing with the handheld nozzle. A knowledgeable pilot, or pilot/wash operator team, is required to position the aircraft/wash-boom in a location that will provide a good washing angle in addition to maintaining safe working clearances to other phases, tower equipment, and/or obstructions. Three techniques have been employed when using water to wash or clean insulation contamination.

6.1.1.4.1 Fixed nozzle

A fixed nozzle is extended from the helicopter along the path of a runner or guide to outside the direct prop wash. The pilot controls the direction of the water stream by movement of the helicopter. The pilot controls the water stream pump as necessary.

6.1.1.4.2 Movable nozzle on a fixed wand

This system is similar to the fixed nozzle except the single pilot controls a movable nozzle. The helicopter is moved to the general location and the movable nozzle controls the direction of the water stream.

6.1.1.4.3 Fixed nozzle in a movable wand

This method employs a second person to control the direction and availability of the water stream. The helicopter gets to the required general position and then washing is actually controlled by the second person.

Each of the three methods has their advantages and can be used on transmission circuits effectively. The greatest plus for helicopter cleaning is its production and easy access to isolated structures. However, the expense and special equipment required suggest the importance of careful analysis of the cost to benefits before considering everyday use.

6.1.2 Medium-pressure water

The concept of medium-pressure washing has proven to be effective. This system involves many of the same procedures used in the high-pressure handheld and remote-control jet nozzle procedures.

While effective washing is maintained, the advantages are reduced equipment stress and employee fatigue because of the lower operating pressures. Tests indicate that the leakage currents through the water stream using this method are within safe operating limits. The pressures used for this method are in the 2100 kPa to 2750 kPa (300 psi to 400 psi) range.

6.1.3 Low-pressure water (flood wash)

In some circumstances, such as for cleaning power transformer bushings, a fixed nozzle system may be used. The nozzles spray the water in a predirected pattern toward the bushing so as to encompass the entire bushing. Frequent washing is used to prevent any severe build-up of contaminant.

Some transmission towers are fitted with plumbing so as to direct a water stream to deluge the suspension insulators. The piping is generally brought down through the tower to ground level where a tank and pump unit are connected. The frequency of such washing is dictated by the degree of contamination present. The pressure at the ground level pump is usually 1400 kPa (200 psi) with a pump output of 2.5 L/s (40 gal/min)

per nozzle. The nozzle size, pipe size, and tower height should be considered when selecting pump capacity and pressure.

6.1.4 Low-pressure water fixed-spray nozzle

These systems employ a fixed-spray nozzle system operating at low pressure, typically 350 kPa to 1030 kPa (50 psi to 150 psi). They are used primarily in areas where frequent washing is required. Because of the low pressure and spray nozzle system, the effectiveness in removing nonsoluble contaminants, other than sea salt, is diminished. Fixed-spray nozzle washing has proven to be effective in preventing sea-salt contamination flashover problems. Therefore, most fixed-spray nozzle installations are used in or near seacoast areas, mainly to remove sea-salt contamination. This method of washing is widely used in Japan. This method can also be used for soluble contaminants that are found inland. See Table 3.⁷ The wash parameters and equipment must be developed and established for each installation. This is mainly due to various local parameters that influence the washing. Such parameters are precipitation, water resistivity, wind, contamination severity, and design and installation arrangement of the insulators to be washed.

Table 3—Low-pressure spray washing equipment design data

Design data	Automatic spray system	
	275 kV	400 kV
Minimum permissible water resistivity	10 000 $\Omega\cdot\text{cm}$	20 000 $\Omega\cdot\text{cm}$
Water pressure at nozzle	700 kPa	1000 kPa
Type of nozzle	Spray	Spray
Minimum distance from nozzle to live conductor	3.1 m	4.3 m
Number of nozzles per insulator	CB and CT: 6 Others: 4	CB: 8 Others: 6
Quantity of water	CB and CT: 4.7 L/s Others: 3.5 L/s	CB: 7.4 L/s CT: 6.2 L/s Others: 5.5 L/s
Duration of wash (dependent on type of insulator)	25 s	25 s
NOTE 1—CB: circuit breaker; CT: current transformer.		
NOTE 2—Refer to Fujimura, T., Okayama, M., and Isozaki, T. [B10].		

NOTE—For English units, see Annex C.

6.1.5 Compressed air cleaning

This method of cleaning insulators involves the use of compressed air and an abrasive cleaning compound. This procedure requires an air compressor capable of supplying a minimum of 0.05 m³/s (110 ft³/min) (52 L/s) at 850 kPa (125 psi), an air dryer, a pressure blaster, an applicator wand, adequate supply hoses, and cleaning compound. An air dryer should be used between the air compressor and the air blaster to remove moisture from the compressed air.

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