

IEEE Guide for Cleaning Insulators

Sponsor

**Engineering in Safety, Maintenance, and Operation of Lines (ESMOL) Subcommittee
of the
Transmission and Distribution Committee
of the
IEEE Power Engineering Society**

Approved March 16, 1995

IEEE 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

The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street, New York, NY 10017-2394, USA

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ISBN 1-55937-519-1

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Introduction

(This introduction is not part of IEEE Std 957-1995, 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 the cleaning of insulators. The information for this guide was drawn from electric utilities, suppliers, universities, related industries, 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 have required newer and more 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(s). 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

This guide for cleaning insulators documents the procedures used for cleaning contaminated electrical insulators (excluding nuclear, toxic, and hazardous chemical contaminants) of all types, using various equipment and techniques.

Because of the great variety of conditions, practices, electrical system designs, and contamination possibilities, this guide describes a number of approaches to insulator cleaning on power systems. The IEEE makes no representation or warranty as to the adequacy, accuracy, economy, or safety of this guide. When determining whether or not, and/or how, to use the information in this guide, all factors shall be considered with regard to the specific situation(s).

1.2 Purpose

This guide presents information on the equipment needed and the methods that can be used when cleaning contaminated insulators. The methods or equipment, or both, presented are not intended to prescribe specific procedures, but to show 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. References

This guide shall be used in conjunction with the following publications:

IEEE Std 4-1995, IEEE Standard Techniques for High-Voltage Testing.¹

IEEE Std 516-1995, IEEE Guide for Maintenance Methods on Energized Power Lines.²

IEC 479-2 (1987), Effects of current on human beings and livestock, part 2: Special aspects. Chapter 4: Effects of alternating current with frequencies above 100 Hz. Chapter 5: Effects of special waveforms of current. Chapter 6: Effects of unidirectional single impulse currents of short duration.³

¹As this standard goes to press, IEEE Std 4-1995 is approved but not yet published. The draft standard is, however, available from the IEEE. Anticipated publication date is September 1995. Contact the IEEE Standards Department at 1 (908) 562-3800 for status information.

²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

³IEC publications are available from IEC Sales Department, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

3. Definitions

3.1 Terms

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

3.1.2 cubic meters per second (m^3/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 kilopascal (kPa): Metric unit for water or air pressure.

3.1.5 line worker: A person qualified to perform various work operations on electric transmission or distribution, including on the ground or from aerial devices.

3.1.6 nonceramic insulator: Insulators made from polymer materials.

3.1.7 nonconducting: Made of a material of high dielectric strength.

3.1.8 nonconductive: *See:* **nonconducting**.

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

3.1.10 polyplastic: A synonym for polyethylene-coated, nylon-reinforced hose, usually considered to be nonconductive. (In terms of this guide, the hose is used to carry water.)

3.1.11 skiving: 1) The process of assembling a fitting to a hose. 2) The process of trimming outside of a hose to fit the inside dimensions of a fitting.

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

3.1.13 water resistivity: Resistance of water is expressed in Ωcm or Ωin .

3.2 Acronyms and symbols

3.2.1 ESDD: Acronym for equivalent salt-deposit density. *See also:* **3.1.3**.

3.2.2 gal/min: Symbol for gallons per minute.

3.2.3 gal/s: Symbol for gallons per second.

3.2.4 id: Acronym for inside diameter.

3.2.5 kPa: Symbol for kilopascals. *See also:* **3.1.4**.

3.2.6 L/s: Symbol for liters per second.

3.2.7 m^3/s : Symbol for cubic meters per second. *See also:* **3.1.2**.

3.2.8 pto: Acronym for power takeoff.

3.2.9 r/min Symbol for revolutions per minute (rpm).

3.2.10 RTV: Acronym for room temperature vulcanizing.

4. Application

This guide is intended to present a reference source of methods and equipment presently used for safe cleaning of insulators, which should be considered as cleaning practices when reviewed by utilities. Safety considerations are presented throughout the guide in the application of safe and efficient methods and equipment. Criteria for the voltage versus washing distance requirements are under consideration and will be added to future revisions of this guide.

When using this guide, it should be noted that the term “insulator(s)” is used in a general sense to describe individual insulators and also the external insulating members of other apparatus (e.g., transformer bushings and surge arresters).

5. Methods

The method used for insulator cleaning is dependent on the insulator material, construction, whether or not the line is energized, and on the type of contaminant to be removed [B11].⁴ Additional methods currently under development will be covered in future revisions of this guide.

5.1 Energized

5.1.1 High-pressure water

High-pressure water washing utilizes a narrow stream of water with typical pressures ranging from 2750–6900 kPa (400–1000 psi) at the nozzle. Four types of nozzles are most often used with high-pressure water: hand-held jet, remote-control jet (pea shooter), fixed-spray, and helicopter mounted.

5.1.1.1 Hand-held jet nozzle

The hand-held 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 connect a detachable hose and nozzle to a standpipe permanently installed on the tower.

Substation insulators may also be washed by qualified workers using a hand-held nozzle while on the ground or in an aerial basket.

5.1.1.2 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).

⁴The numbers in brackets preceded by the letter B correspond to those in the bibliography in clause 16.

5.1.1.3 Fixed-spray nozzle

Two basic washing systems are used.

- 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 1 provides general information on this system.

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.

Table 1—Fixed-nozzle washing equipment and usage

Type of nozzle	Spray
Number of nozzles	Multiple
Water pressure	350–3000 kPa (50–430 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 usage is usually controlled automatically.
Disadvantage	Affected by wind

5.1.1.4 Helicopter mounted nozzle

This washing method involves the use of a self-contained high-pressure wash system borne by a helicopter. The system is controlled by a wash operator or by the pilot. The helicopter hovers in place with the nozzle positioned to direct the water stream.

5.1.2 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 hand-held and remote-control jet nozzle procedures.

While effective washing is maintained, the advantages are reduced equipment demands, less employee fatigue than with the high-pressure method, and increased production. Decreased leakage current through the water stream was evident as the method was tested. The pressures used for this method are in the 2070–2760 kPa (300–400 psi) range.

5.1.3 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 also piped to direct a water stream to flood 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 1380 kPa (200 psi) with a pump output of 2.524 L/s (40 gal/m) per nozzle. The nozzle size, pipe size, and tower height should be considered when selecting pump capacity and pressure.

5.1.4 Low-pressure water fixed-spray nozzle

Low-pressure washing employs a fixed-spray nozzle system operating at low pressure, typically 350–1030 kPa (5–150 psi). These systems are used primarily in areas where frequent washing is required. Because of the low pressure and spray nozzle system, the effectiveness in removing contaminants, other than sea salt, is diminished. Therefore, most fixed-spray nozzle installations are used in or near sea coast areas, mainly to remove sea salt contamination. This method can be used for contaminants that are found inland. See table 2.

Table 2—Low-pressure spray washing equipment design data

Design data	Automatic spray system	
	275 kV	400 kV
Minimum permissible water resistivity (Ωcm)	10 000 Ωcm (3937 Ωin)	20 000 Ωcm (7874 Ωin)
Water pressure at nozzle	700 kPa (100 psi)	1000 kPa (150 psi)
Type of nozzle	Spray	Spray
Minimum distance from nozzle to live conductor	3.1 m (122 in)	4.3 m (170 in)
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 (1.24 gal/s) Others: 3.5 L/s (0.92 gal/s)	CB: 7.4 L/s (1.96 gal/s) CT: 6.2 L/s (1.64 gal/s) Others: 5.5 L/s (1.45 gal/s)
Duration of wash (dependent on type of insulator)	25 s	25 s

CB: circuit breaker

CT: current transformer

NOTE—[B8] summarizes work of Fijimura, Orayama, and Isozaki.

5.1.5 Compressed air-dry cleaning

This method of cleaning insulators involves the use of compressed air and a dry cleaning compound. This procedure requires an air compressor capable of supplying a minimum of 0.052 m³/s (110 ft³/min) at 860 kPa (125 psi), an air dryer, a pressure blaster, an applicator wand, adequate supply hoses, and cleaning compound.

Commonly used abrasive cleaning compounds consist of ground corn cob mixed with ground walnut or pecan shells. In some cases, powdered limestone may be added for increased abrasiveness.

To clean insulators, the cleaning compound is directed onto the insulator surface through a specially designed applicator wand. The wand consists of a hot stick/nozzle combination that allows work to be done on energized systems. This method has been used on energized lines and substations through 500 kV.

The actual cleaning process for dry cleaners is very similar to sandblasting in that a high-pressure stream of air is used to bombard the surface of the specimen to be cleaned with the cleaning medium. By choosing the proper medium, virtually any contaminant can be removed from the insulator surface. Caution shall be exercised to prevent glaze erosion or deterioration to the galvanized hardware.

CO₂ pellets are a commonly used nonabrasive component. In the CO₂ process, the pellets of frozen CO₂ strike the surface of the insulator penetrating through the contaminant to the insulator surface. The pellet then sublimates into a gas, which blasts the contaminant from the surface. There is no abrasive action to the insulator.

An air dryer should be used between the air compressor and the air blaster to remove moisture from the compressed air.

5.1.6 Wiping (hot cleaning)

A procedure using hot sticks and a special hammock (usually made from burlap) to hot clean insulators is used on equipment operating at voltages from 4–69 kV.

The need for hot cleaning depends upon the level of contamination and the risk of flashover during washing. This procedure may also be used prior to hot washing to reduce the possibility of flashover.

The line worker performing the hot cleaning may do this task from a ladder, on the ground, in a bucket truck, or from a steel tower.

The technique requires one hot stick, which is hooked into an eye of the hammock, to be positioned around the insulator or bushing and to engage a second eyelet in the hammock with the hook of the second hot stick.

When this is accomplished, the porcelain can be cleaned with a seesaw motion. The hot sticks with the hammock shall be kept tight enough so that the eyelet does not drop from the hammock's loop. Generally, cleaning begins adjacent to the energized conductor and ends at the tower.

The hot stick used for this purpose is usually approximately 19 mm (0.75 in) in diameter and 3050 mm (10 ft) long.⁵ The end loop is attached to the stick with a bolt and nut.

One company using this method recommends the following:

- a) The hammock material be 540 g/m² weight (10 oz/yd²).
- b) The cleaning hammocks should be cut 460 mm (18 in) wide by 610 mm (24 in) in length for 46 kV and 760 mm (30 in) in width by 910 mm (36 in) in length for 69 kV post, cap and pin insulators. A 25 mm (1 in) hem should be folded on both short ends. Then, 25 mm (1 in) pleats should be folded. A 3.8 mm diameter (#9) iron wire, 305 mm (12 in) in length, should be threaded through the pleated hem so that the necessary loop and hook may be formed.

See figures 1 and 2.

⁵Max 345 kV—Use appropriate hot stick for higher voltages.

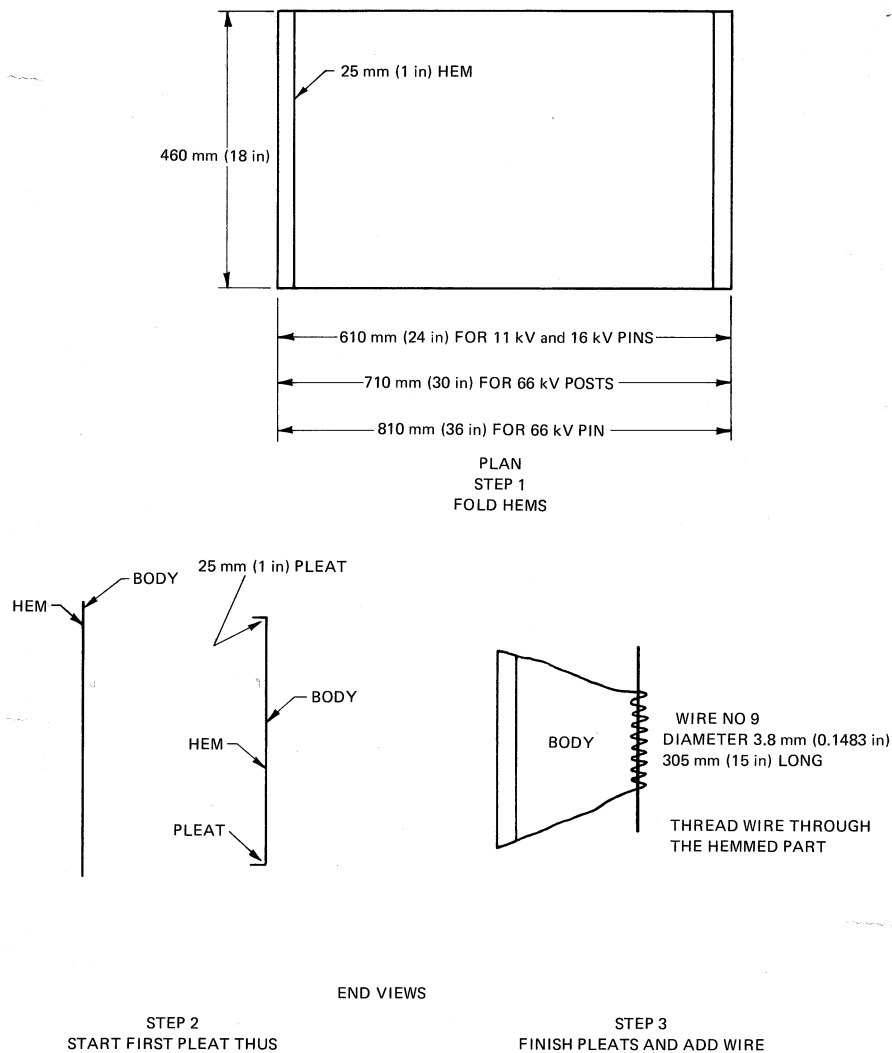


Figure 1—Hot wiping material

5.2 De-energized

All of the methods discussed in 5.1 may also be utilized in addition to the hand cleaning and low-pressure water methods discussed below if the facility is de-energized.

5.2.1 Hand cleaning

Cleaning insulators by hand wiping is thorough and effective, but is also a tedious, time consuming, and expensive process that requires equipment outages. Hand wiping is generally used only when washing is impractical because of problems of access by heavy vehicles, height or design of structures, or type of contamination. Hand wiping is normally used on station insulators where high-pressure washing is either impractical due to proximity of energized equipment or ineffective due to hardness of surface deposits. The

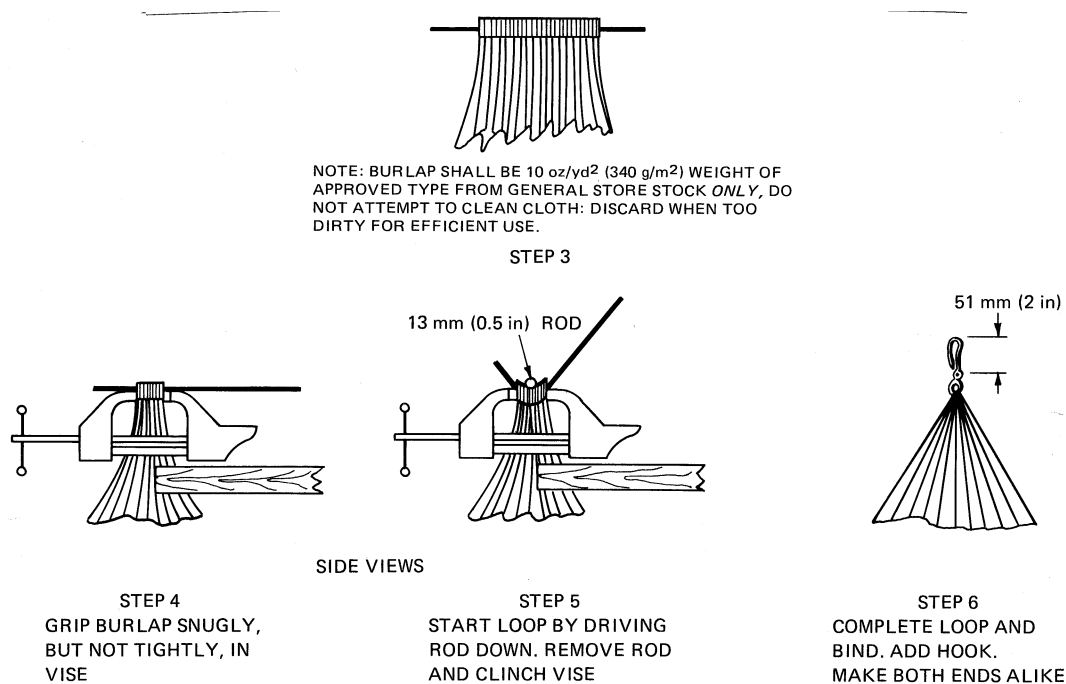


Figure 2—Hot wiping material assembly

line worker carries a personal grounding device, necessary rags, steel wool, etc., safety and body belts, and an adjustable safety life line, if required.

5.2.1.1 Steel wool/nonabrasive nylon pads

Steel wool or nonabrasive nylon pads are used when rags and paper towels are ineffective. Caution shall be exercised to remove all the metal particles left by the steel wool.

5.2.1.2 Solvents

Solvents may be used to aid the cleaning. Care shall be taken with strong cleaning agents because of fumes or residue. After cleaning, the insulator should be rinsed with clean water to remove residue.

6. Cleaning equipment

6.1 High-pressure water equipment

6.1.1 Pump

6.1.1.1 Type

The pump may be either a centrifugal or positive displacement type.

- a) *Centrifugal*. This pump type utilizes a rotary impeller or series of impellers in one to four stages, and is commonly used in fire fighting applications. Water is drawn from the tank by suction to the first stage; then the pressure is compounded through the remaining stages. A flooded suction is best,

however, once the pump is primed, a negative head or draft can be pulled from several feet below the pump. A gear set is directly bolted to the flywheel of the gasoline or diesel power unit, or can be driven from a truck power takeoff (pto).

A single four-stage pump may develop up to 6900 kPa (1000 psi) with 0.005 m³/s or 5.05 L/s (80 gal/min) discharge and may rotate at a speed up to 9600 r/min. A separate, single-stage centrifugal pump can be run from an engine crankshaft or from opening two pto's to supercharge the main four-stage pump where high water volume is required. An engine with the capacity of 70–90 bhp (52–67 kW) may be required to power this pump. The centrifugal design allows internal slippage when the wash gun or remote monitor is abruptly shut off, cushioning the shock force to hose, fittings, valves, gun, and operator. Therefore, no dampers or cushioning devices are required. The pump produces even flow without pulsations. Adequate bearings, steel wear rings, and balanced impellers are required to provide long, trouble-free service.

- b) *Positive displacement.* One or more pistons are utilized to produce high pressure. The pump may be driven by sheaves and vee-belts from an engine-driven pto, capable of absorbing belt loading, or a chassis-powered pto, with pulleys of various sizes to match engine rpm to the pump crankshaft rpm required to produce proper flow and pressure. In one such system, an oil-filled crankcase is utilized. Suction damper or shock absorber is usually required together with an exhaust damper and pressure accumulator.

An unloading valve in the system is usually utilized for engine/pump cranking to eliminate start-up back pressure. Flows of 0.004–0.006 m³/s or 3.8–5.7 L/s with pressures to 6900 kPa (1000 psi) are nominal for two gun simultaneous washing operation.

Piston pumps of this size are available from several manufacturers. Sheave/vee-belt combinations of cog type, or multi-vee-type are also available. Unloading valves and accumulators cushion system shock. Total pump/damping and vee-belt drive usually make this package more expensive than the centrifugal system.

6.1.1.2 Power source

- a) Truck engines (separate engines, either gasoline or diesel) power the pumps. The engine rpm torque curve shall match the demand of the pumping system. Gasoline engines operate at higher rpm than diesels; four- or six-cylinder engines will develop maximum torque at lower rpm than a V8. These factors shall be considered when matching the engine to the pump. Gear set or belt-driven sheave size variations can be used to arrive at proper match for optimum engine/pump match. The main advantage in using separate engine power is not having to run the motive vehicle engine (often large and expensive) for intermittent pump power. The disadvantage to using a separate engine is that the added weight can limit the water carrying capacity of the vehicle as well as add complexity to the system.
- b) Power takeoff (pto) (from truck chassis) pumps of centrifugal or piston design producing the L/s (gal/min) and kPa (psi) required to support washing at high head and for two-gun, simultaneous, use in substations will require 50–67 kW (68–90 bhp). The truck chassis pto shall have the capability to produce this horsepower. A pto driven from an eight-hole SAE from the opening on the main transmission (manual shift type) or from an automatic transmission with converter lock-up is required for this horsepower. The truck-engine horsepower output and torque shall be tailored to the pump rpm and power requirement through the pto ratio. Speed variation from 60–115% of engine speed is usually available through gear set selection. Note that most medium to large gasoline or truck engines are governed as to top revolutions per minute. This fact, and the best revolutions per minute (rpm) for maximum engine torque, should be considered on all-wheel drive chassis. A full torque (same as output at crankshaft of engine) is usually available from the transfer case of the all-wheel drive. When this pto is utilized, it shall be of the full-oiled type, which guarantees lubrication under sustained speed and load.

Pump clearance and piping availability to the pump are major considerations. Often chassis frame, cross members, or exhaust will interfere with the pump location. Remote pump location can be accomplished by adding a driveline from pto pump. However, due to the high rpm required under demand load, this shall be a tubular balanced driveline with proper U-joint angles at both ends.

Any of the pto drives described here require running the chassis engine to provide water flow and pressure. Usually, the truck engine is too large and too expensive to operate for pump power only. If production cleaning is being done where the vehicle moves structure to structure and washing is done repetitively, chassis pto power can be effectively utilized. The use of a pto versus separate engine-driven pump should be carefully considered.

- c) A demand throttle should be considered for use as a control. This may improve the efficiency for both the engine and operators. This device drops the pump engine rpm to idle when the hand-held gun valve is closed. As soon as the trigger on the gun valve is pulled, the pump engine is automatically speeded up to a preset rpm and nozzle pressure.

6.1.2 Tank

6.1.2.1 Material types

Three basic materials have been used to carry the wash water: fiberglass, coated mild steel, or stainless steel. For any of the above tank types, a rigid, firm base of support, such as a truck or trailer frame or steel-aluminum skid, shall be provided. In larger capacity tanks, where bending or rocking occurs, spring-loaded mountings shall be utilized or damage will occur. Truck or trailer chassis may flex while carrying the load, therefore, the tank and its base or skid must move as the twisting and rocking of the frame occurs. A solid skid or base for the tank is essential. The mounting to the carrier shall provide the compensation for the chassis movement.

Fiberglass/plastic type tanks may be limited in capacity. Tanks of 1.9 m³ (500 gal) or less are most popular. If higher capacity is required, steel tanks should be considered.

Mild steel tanks shall be coated inside and primed and painted outside to prevent rust. Before coating the inside, it is essential that the entire inside of the tank be thoroughly sandblasted and then cleaned. All weld flux-mill coating shall be removed.

Cleanliness of all joints and welds, including filler dome weldments, inlet and outlet bosses, is essential. An epoxy or similar type coating should then be applied by qualified personnel. The coating shall be suitable for water immersion.

Tank capacity length, width, and height will govern selection of material, gauge of metal, type of header, and number and location of baffles. In 1.9–4.5 m³ (500–1200 gal) mild steel tanks, 10 gauge (3.4 mm or 0.1345 in) heads with 10 gauge (3.4 mm or 0.1345 in) wrap is adequate, again with the proper base. If stainless steel is utilized in 1.9–9.5 m³ (500–2500 gal) capacity, 12 gauge (2.7 mm or 0.1046 in) throughout or 12 gauge (2.7 mm or 0.1046 in) heads with 10 gauge (3.4 mm or 1345 in) wrap is adequate. Again, baffles and base are important considerations in choosing the thickness of metal required.

6.1.2.2 Capacity

Tanks from 0.19–1.9–9.5 m³ (50–500–2500 gal) have been used for insulator washing. Helicopters to ten-wheel off-highway trucks provide the motive power. Water source, amount of washing to be done, availability of tanker supply vehicles, and type of right-of-way terrain, all will affect tank and carrier size. For helicopter washing with small on-board tanks, a water supply vehicle is usually provided at the landing zone/staging area.

6.1.2.3 Fill method

Where overhead discharge of water supply is utilized, a top opening type dome is available. This shall be a vented design. A filler screen of stainless-steel material should be utilized to filter any foreign matter. Access from the ground to the dome is necessary. The dome should be securely fastened before travel to prevent sloshing and water loss.

When hydrant fill or pressure filling from ground level is used, valving and system plumbing is usually fitted at the rear or curb side of the vehicle. Some washer pumping systems permit using the wash pump with valve selection changes to pull high-volume/low-pressure water from a hydrant or carrier into the tank. A water level indication, a visual sight gauge, or electronic indicator is essential. Modern level systems may be tied electronically to low-level water indicators and engine throttle shutdown systems.

Tank back-flow restrictions may be required for portable tanks to meet local codes.

6.1.2.4 Design

Capacity, vehicle dimensions, and terrain to be traversed are important design parameters. A low center of gravity and proper baffling are most important. Tank manufacturers offer a limited number of standard head and intermediate tank baffle configurations.

Round, elliptical, and semi-elliptical tanks are popular types, as are flat, square, or rectangular tanks. Strength, weight, and appearance are all considerations in basic tank design. Liquid highway transports do not experience the same water movement as an off-highway insulator washer. The tank manufacturer shall be made aware of the anticipated usage. Openings of adequate size for suction, pressure bleeder return, sight gauge, level probe, and resistivity probe should be provided when the tank is fabricated. A vortex straightener may be provided at the suction outlet boss to improve efficiency.

6.1.3 Piping

Efficient piping is important. Water restriction between the pump and the tip of the nozzle affects the efficiency of the entire wash system. The suction system, pipe, and hose need to be large enough to provide a surplus of flow capacity to the high-pressure pump when it is working at maximum flow and pressure. If 3.75–5 L/s (60–80 gal/min) of water is to be pumped at a maximum usage, 63.5 mm (2.5 in) suction piping and hose should be provided; 38.1 mm (1.5 in) heavy duty pressure discharge piping is used to the tee and to the hose reels. Valves of minimum 25.4 mm (1.0 in) id dimension will ensure minimum pressure loss. It is important in ball valves that a clear 25.4 mm (1.0 in) throat be provided; not a valve with 25.4 mm (1.0 in) female threads and 1.9 mm (0.75 in) throat; 90° elbows, sharp hose bends, union, nipple, and valve cluttered plumbing should be avoided. Pressure lines from the pump should travel to the hose reels or tip monitor in as straight a line as possible. A filter at the outlet of the tank suction or pump inlet, if installed, should be of a monitoring type. If it becomes blocked, an immediate by-pass should allow flow around.

NOTE—Due to cavitation danger, some pump manufacturers will not warrant a pump if a filter is placed ahead of the inlet.

6.1.4 Hose

6.1.4.1 Type

The insulator cleaning standards of utilities vary depending on the type of washing and the structure to be cleaned. Both conductive and nonconductive hose are utilized. Fire hoses of nonconductive material and poly-plastic nylon reinforced hoses are being utilized where nonconductive practices are utilized. When the practices call for conductive hose, wire braid, rubber covered hoses with stapled couplings are used.

6.1.4.2 Size

Hose from 15.8–25.4 mm (0.625–1.0 in) id are used. The larger the id, the less the pressure loss. The larger size hose is heavier, more expensive, requires larger reels, and greater bend radius, etc., but is much more efficient. A short piece of smaller id hose can be attached to the outlet end. A 2.43–3.05 m (8–10 ft) jumper will cause no measurable pressure drop, and the operator will have more flexibility.

6.1.4.3 Reel

Live hose reels, or reels with end transfer of water through a live rotary joint, may be utilized. Again, the swivel size should be no smaller than 25.4 mm (1 in) id. The reel can be powered either by hand, electrically, or hydraulically. A roller guide for the hose should be provided. All fittings should be the submersible type. A brake is essential to lock the reel where desired. Continual on/off operation will cause hose crawl unless a manual brake is installed and used.

6.1.4.4 Coupling

Safety is most important. Compression type fittings, as specified by the fitting and hose manufacturer, should be used. A qualified crafts person should make the assembly, carefully checking the hose, inside and outside, (skiving if specified) and visually measuring and marking the depth of male hose insert as it passes inside the hose. When the coupling is completed, the outer crimped member shall be at the premeasured depth. Nonconductive nylon or plastic hoses should be coupled per the hose and fitting manufacturer's specifications.

6.1.5 Nozzle

6.1.5.1 Hand held

The last item the water passes through is the nozzle. Proper design and finish will produce a good straight stream of water with a minimum of break-up. A flow straightener located ahead of the nozzle changes turbulently rotating water into a straight stream as it enters the nozzle. Orifice sizes vary from 3.2–7.94 mm (0.125–0.3125 in) varying with distance and water pressure. Effective cleaning is accomplished by the impact of the water, followed by the rinsing of the contaminant from the insulator. Efficient utilization of the water is the objective. A fine polished tip may be difficult to obtain commercially. Many users hand finish and polish their own. Brass or aluminum bodies with steel, stainless steel, ceramic, or metal compounded tips may be used. The nozzle is attached to a hand-held wash gun. A trigger opens and closes the water source. A fore-end or handle and bracketing with shoulder pad are added operator features. Pressure drop across gun, weight, cost of manufacture, positive shutoff, and "deadman trigger" are to be considered when selecting washing guns.

6.1.5.2 Remote/standpipe

Transmission towers can be piped with top-mounted nozzles predirected toward the insulators and line. A pumper/tanker then connects to the standpipe to wash the insulators remotely.

6.1.6 Carrier

6.1.6.1 Trucks

Chassis, from small four-wheel drive vehicles to ten-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 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 19.8–41.1 m (65–135 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 nonconductive hose that is equipped with a hand-held gun is used. Existing user manlift equipment can be used seasonally for washing both transmission, distribution, and substation insulators. Skid or trailer wash equipment is also utilized.

6.1.6.2 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 10.6–19.8 m (35–65 ft) aerial lift for distribution washing or an existing 27.4–38.1 m (90–125 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 himself or herself. Two people can wash from one trailer on HV 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. Used with a boom of 9.1–12.2 m (30–40 ft), higher bus insulators can be cleaned. 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 fire-fighting vehicle.

6.1.6.3 Helicopter

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. Such aircraft are limited in the amount of wash water they can carry. 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.

6.1.7 Water

6.1.7.1 Quality

Water of high resistivity or low conductivity should be utilized in cleaning energized insulators. Rain water, snow melt, and steam plant distillate are known in general to have good resistivity characteristics. Constant testing of the water being used is important; resistivities can quickly change due to temperature. Water of poor resistivity, in the range of 750–1000 Ωcm (295–394 Ωin) can be purified by deionizing systems or filtering. Minimum water characteristic should be determined based on planned operating practices and expected voltages. A resistivity greater than 1500 Ωcm (591 Ωin) is desirable.

6.1.7.2 Additives

No soaps or detergents should be added to the water. Cleaning is accomplished by the impact of the water and rinsing.

In northern and arctic climates, no antifreeze or alcohol is added. Flame danger and residual contaminants and environmental considerations eliminate their use. Warm (not hot) water will remove contaminants, and although freezing will occur as the ice or frozen contaminated water melts, contaminants will be flushed away. Ice should not be left bridging the air gaps between insulator sheds.