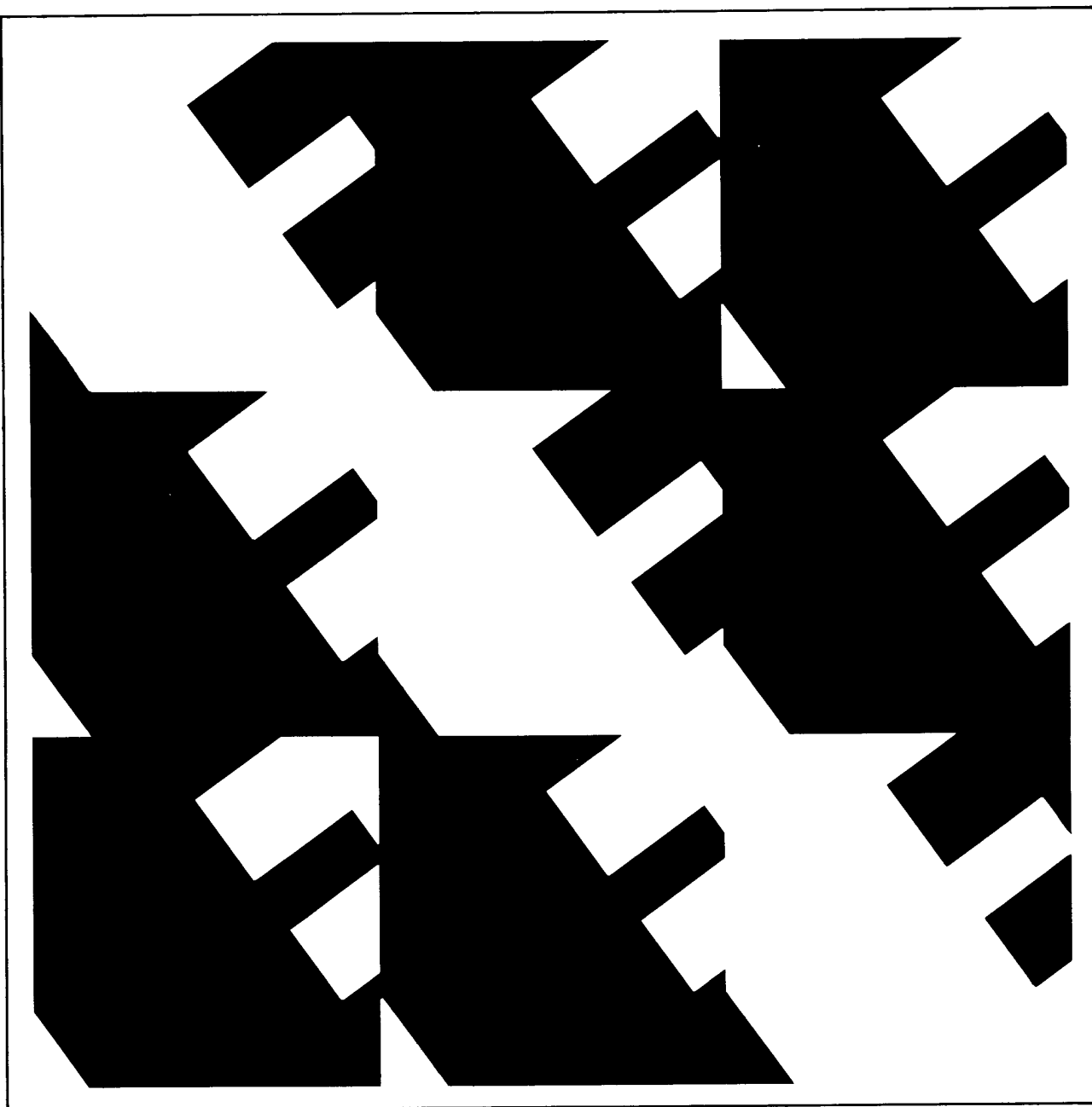


IEEE Guide for Cleaning Insulators

IEEE Std 957-1987



Published by The Institute of Electrical and Electronics Engineers, Inc 345 East 47th Street, New York, NY 10017, USA

April 13, 1988

SH11502

IEEE Guide for Cleaning Insulators

1. Scope and Purpose

1.1 Scope. The scope of this guide for cleaning insulators is to document the present day state of the art for cleaning contaminated electrical insulators (excluding nuclear contaminants), of all types, using varied equipment and techniques.

Because of the great variety in conditions, practices, electrical system designs, and contamination possibilities, this guide is offered simply to describe a number of possible 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. Each utility must consider all the factors applicable to its situations in deciding whether and how to use the information in this guide.

1.2 Purpose. The purpose of this guide is to present pertinent information on the equipment needed and the methods that can be used in a safe and efficient manner 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 their own insulator cleaning program and practices.

2. References

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

[1] YAMAMOTO, MITSUYOSKI, and KENZO OHASHI. The Salt Contamination of the External Insulation of High-Voltage Electric Apparatus and its Counter-Measures. *IEEE Transaction Paper* 61-6.

[2] LAMBETH, P.J., LOOMS, J.S.T., SFORZINI, M., MALAGUTI, C., PORCHERON, Y., and CLAVERIE, P. International Research on Polluted Insulators, *International Conference on Large Electric Systems at High Tension*. CIGRE, Paris, vol II, 23rd session, 1970.

[3] FIJIMURA, TETSUO, OKAYAMA, MASAMI and ISOZAKI, TAKASHI. Hot-line Washing of Substation Insulators. *IEEE Transactions on Power Apparatus and Systems*, vol PAS May / June 1970.

[4] IEEE COMMITTEE REPORT. Application Guide for Insulators in a Contaminated Environment. IEEE Working Group on Insulator Contamination, Lightning and Insulator Subcommittee. IEEE paper F77 639-8, 1977.

[5] IEEE COMMITTEE REPORT. Electrostatic Effects of Overhead Transmission Lines, Part 1. Hazards and Effects. *IEEE Transactions on Power Apparatus and Systems*, vol PAS-91, Mar / Apr 1972, pp 422-426.

[6] DALZIEL, C.F. The Effect of Electric Shock on Man. *IRE Transactions on Medical Electronics*, CPGME-5, May 1976.

[7] HILL, LESLIE, AIEE TECHNICAL PAPER *Tests and Developments in Connection With Hot-Line Insulator Washing*. July 1947 (provides some excellent basic data for anyone starting or modifying an insulator washing program).

[8] Contamination and Hot-Wash Performance of Zinc Oxide Station Arresters. *IEEE Transactions on Power Apparatus and Systems*, vol PAS-101, no 5, May 1982.

[9] FUJIMURA, T., OKAYAMA, M., and ISOZAKI, T., Hot-Line Washing of Substation Insulators *IEEE Transactions on Power Apparatus and Systems*-PAS-70, May / June 770-774.

- [10] *Hot Washing of Distribution Insulators*. IEEE Paper 835M451-2.
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- [13] ELY, C.H.A., LAMBETH, P.J., LOOMS, J.S.T. The Booster Shed: Prevention of Flashover of Polluted Substation Insulators in Heavy Wetting. *IEEE Transactions on Power Apparatus and Systems* PAS-97, no 6, p 2187, 1978.
- [14] LAMBETH, P.J., LOOMS, J.S.T., STALEWSKI, A., TODD, W.G. Surface Coatings for HV Insulators in Polluted Areas. *Proceeding IEE*, vol 113, May 1966.
- [15] BENNETT, G.E. HV Insulator Protective Grease Technology. *IEEE Conference Paper* 69 CP 608-PWR.

3. Abbreviations, Definitions, Mnemonics, and Symbols

pto Power takeoff

id Inside diameter

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

lineman. A person qualified to perform various work operations on electric transmission or distribution, including on the ground or aerial.

nonceramic insulator. Insulators made from polymer materials.

nonconducting or nonconductive. The resistivity of material when properly maintained is

sufficiently high so that the leakage current through it will not expose people to electric shock hazards who may come in contact with it.

overspray. A portion of the water stream that is 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.

poly-sol. Plastic additive used in some washing applications to break down surface adhesion.

skiving. The process of assembling a fitting to a hose. Process of trimming outside of a hose to fit inside dimensions of fitting.

water resistivity. Resistance of water usually expressed in Ω/cm^3 ($\Omega\cdot\text{cm}$) or Ω/in^3 ($\Omega\cdot\text{in}$).

ESDD Equivalent salt-deposit density—a measure of contamination level.

gal/min Gallons per minute

r/min Revolutions per minute

kPa Kilo pascals—metric unit for water or air pressure.

L/s Liters per second

gal/s Gallons per second

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

m³/s Cubic meters per second. Volume of water or liquid discharged per second under standard conditions.

4. Application

This guide is intended to present a reference source of methods and equipment presently used to clean insulators which should be considered as practices are reviewed. Safety considerations are presented throughout the guide in the application of efficient methods and equipment.

5. Methods

The method used for insulator cleaning is dependent on whether the line is energized and on the type of contaminant to be removed (see [2]).

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 kPa–6900 kPa (400 psi–1000 psi) at the nozzle. Three types of nozzles are most often used with high-pressure water. They are the portable, hand-held jet nozzle, the remote-controlled jet nozzle (peashooter), and the fixed-spray nozzles.

5.1.1.1 Hand-Held Jet Nozzle. The hand-held nozzle is the most common type of nozzle used for high-pressure washing. This method requires the lineman to climb the tower, or use an aerial lift to raise the hose and nozzle to the wash position, or to connect a detachable hose and nozzle to a standpipe permanently installed on the tower.

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

5.1.1.2 Remote-Control Jet Nozzle. The second type used is the remote-controlled jet-nozzle system. This equipment consists of a nozzle mounted on an extendable, truck mounted boom. Both the nozzle and the boom are controlled from a console connected to the boom turret. This system permits better positioning of the water stream when washing is difficult to perform from a tower or station structure, as for outer phase vee - string insulators on high-voltage lines.

5.1.1.3 Fixed-Spray Nozzles. There are two basic washing systems used

- (1) Spray washing for calm wind conditions
- (2) 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.

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

Table I provides general information on this system.

Table 1
Fixed-Nozzle Washing Equipment and Usage

Type of nozzle	Spray
Number of nozzles	Multiple
Water pressure	350 kPa to 3000 kPa (50 psi–430 psi)
Nozzle installation	Permanently installed on steel structure
Wash control	Fixed
Washing coverage	Water envelops and swamps insulator in one surge
Operation	Eliminates both climbing and skill in washing
Application	Suitable in area 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 high.

5.1.2 Medium-Pressure Water. The relatively new concept of medium-pressure washing has been effectively used by one major utility. 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 the high-pressure method, enhanced safety, 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 kPa–2760 kPa (300 psi–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 pre-directed pattern toward the porcelain 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.

Table 2
Low-Pressure Spray Washing Equipment Design Data

Design Data	Automatic Spray System	
	275 kV	400 kV
Minimum permissible water resistivity ($\Omega \cdot \text{cm}$)	10000 $\Omega \cdot \text{cm}$ (3937 $\Omega \cdot \text{in}$)	20000 $\Omega \cdot \text{cm}$ (7874 $\Omega \cdot \text{in}$)
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 & CT-6—Others-4	CB-8—Others-6
Quantity of water	CB & CT-4.7 L/s (1.24 gal/s)	CB-7.4 L/s (1.96 gal/s)
	Others-3.5 L/s (0.92 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)	25s	25s

Reference 3 summarizes work of Fijimura, Orayama, and Isozaki

5.1.4 Low-Pressure Water—Fixed-Spray Nozzle (see Table 2). Low-pressure washing employs a fixed-spray nozzle system operating at low pressure, typically 350 kPa to 1030 kPa (50 psi to 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 (May not be as effective but often accomplishes the task).

5.1.5 Compressed Air—Dry Abrasive Cleaner. A relatively new method of cleaning insulators involves the use of compressed air and a dry, abrasive 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), a pressure blaster, an applicator wand, adequate supply hoses, and abrasive 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 by this method, 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 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 abrasive cleaning medium. By choosing the proper mixture of ground corn cobs, walnut or pecan hulls, and perhaps some powdered limestone, virtually any contaminant can be removed from the insulator surface. Caution must be exercised to prevent glaze erosion or deterioration to the galvanized hardware.

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 made from burlap to *hot clean* is used on equipment operating at voltages from 4 kV to 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 water washing to reduce the possibility of flashover.

The man 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 burlap, to be positioned around the insulator or bushing and to engage a second eyelet in the burlap with the hook of the second hot stick.

When this is accomplished, the porcelain can now be cleaned with a *seesaw* motion. It is important to keep the hot sticks with the burlap tight enough so that the eyelet does not drop from the burlap loop. Generally, cleaning begins

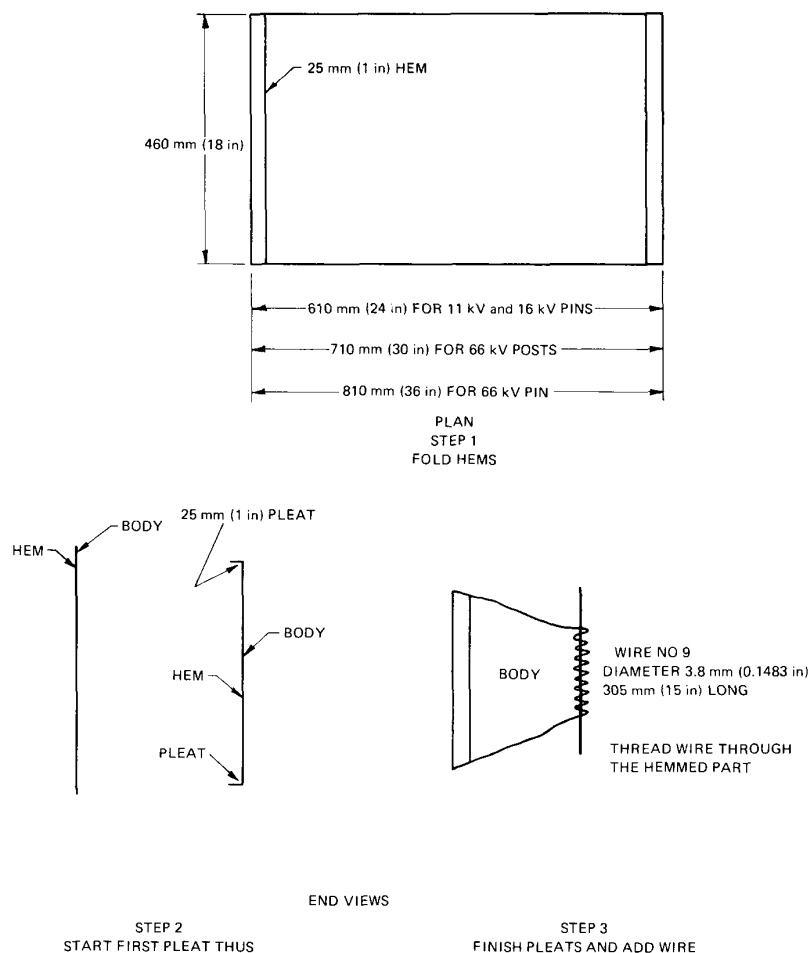


Fig 1
Hot Wiping Material

adjacent to the energized conductor and ends at ground potential.

The hot stick used for this purpose is approximately 19 mm ($\frac{3}{4}$ in) in diameter and 3050 mm (10 ft) long¹. The end loop is attached to the stick with a bolt and nut.

One company using this method recommends

(1) The burlap material is 540 g/m² weight (10 oz/yd²). (2) The cleaning hammocks are cut

¹ Max 345 kV—Use appropriate Hot Stick for higher voltages.

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 is folded on both short ends. Then 25 mm (1 in) pleats are folded. A 3.8 mm diameter (#9) iron wire 305 mm (12 in) in length is then threaded through the pleated hem so that the necessary loop and hook may be formed.

See Figs 1 and 2.

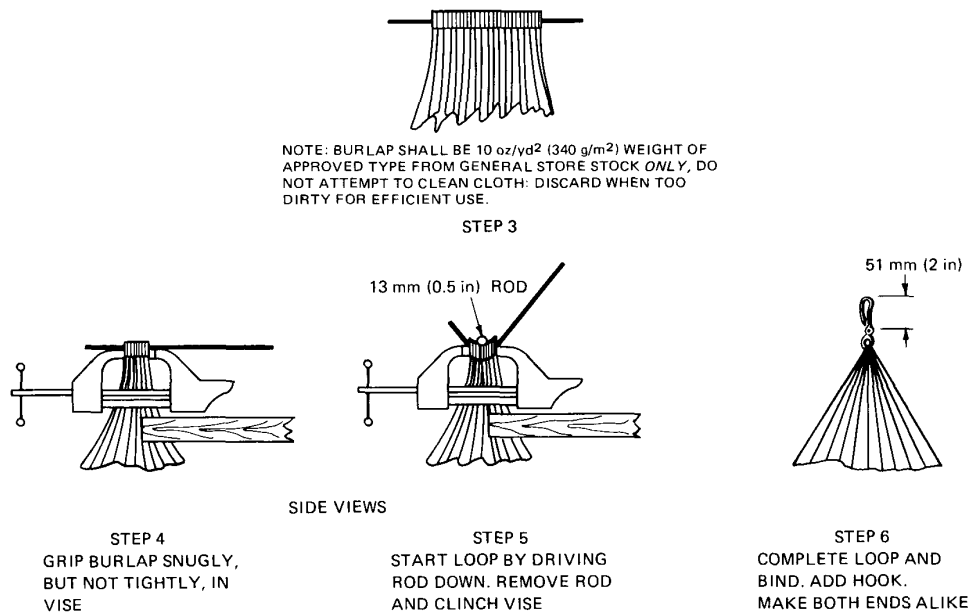


Fig 2
Hot Wiping Material Assembly

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 deenergized.

5.2.1 Hand Cleaning. Cleaning insulators by hand wiping is thorough and efficient, but it 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 heavy vehicular access, 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 workman carries with him 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 is used when rags and paper towels are ineffective. Caution must be exercised to remove all the metal particles left by the steel wool.

5.2.1.2 Solvents may be used to aid the cleaning. Care must be taken with strong cleaning agents because of fumes or residue. After cleaning the insulator, it 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.

(1) *Centrifugal.* This pump type utilizes a rotary impeller—or series of impellers in 1 to 4 stages. It 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 4-stage pump will 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 utilized—from an engine crankshaft or from two opening pto to supercharge the main 4-stage pump where high water volume is required. An engine with the capacity of 70 bhp to 90 bhp (52 kW to 67 kW) is 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 dampeners or cushioning devices are required. The pump produces even flow without pulsations. Adequate bearings, steel wear rings, and balanced impellers will provide long, trouble-free service.

(2) *Positive Displacement*. One or more pistons are utilized to produce high-pressure water. The pump is 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 revolution-per-minute to the pump crankshaft revolution-per-minute required to produce proper flow and pressure. In this system, an oil-filled crankcase is utilized, and a suction damper or shock absorber is required, and an exhaust damper and pressure accumulator.

An unloading valve in the system is utilized for engine/pump cranking to eliminate start-up back pressure. Flows of 0.004 m³/s to 0.006 m³/s or 3.8 L/s to 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 make this package more expensive than the centrifugal system.

6.1.1.2 Power Source

(1) Separate engines, gasoline or diesel, power the pumps. The engine revolution-per-minute—torque curve must match the demand of the pumping system. Gasoline engines operate at higher revolution-per-minute than diesels; four or six cylinder engines will develop maximum torque at lower revolution-per-minute than a vee-8. These factors must 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 sep-

arate engine power is not having to run the motive vehicle engine (often large and expensive) for *intermittent* pump power.

(2) Power takeoff (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 kW to 67 kW (68 bhp to 90 bhp). The truck chassis pto must 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 must be tailored to the pump revolution per minute and power requirement through the pto ratio. A variable of 60% of engine speed to 115% is *usually* available through gear set selection. Note that most medium to large gasoline or truck engines are governed as to top revolution per minute; this fact *and* the best revolution per minute 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 must 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. This must be, however, a tubular *balanced* driveline with proper U-joint angles at both ends, due to high revolution per minute required under demand load.

Any of the pto drives in 6.1.1.2 (2) require running the chassis engine to provide water flow and pressure. Usually, the truck engine is large and expensive to operate for pump power only. If production cleaning (that is, distribution circuits) 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.

(3) *Controls*. A demand throttle is available, which is efficient as far as both the engine and operators of the equipment are concerned. This device drops the pump engine revolution per minute 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 revolution per minute and nozzle pressure.

6.1.2 Tank

6.1.2.1 Type of Material. Three basic materials; fiberglass, mild steel epoxy-coated, or stainless steel are currently being utilized to carry the wash water. *For any of the above tank types*, a rigid, firm base of support must be provided: truck or trailer frame, or steel-aluminum skid. In larger capacity tanks, where bending or rocking occurs, spring loaded mountings must be utilized or damage will occur. Truck or trailer chassis must 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 must provide the compensation for the chassis movement.

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

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

Cleanliness of all joints and welds, including filler dome weldments, inlet and outlet bosses, is essential. An epoxy coating should then be applied by qualified personnel. The epoxy must be *suitable for water immersion*, and no other type should be considered.

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 m³ to 4.5 m³ (500 gal to 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 m³ to 9.5 m³ (500 gal to 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 1.9 m³ to 9.5 m³ (500 gal to 2500 gal) are in use today in insulator washing. Helicopters to 10-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.

6.1.2.3 Fill Method. Where *overhead discharge* of water supply is utilized, a top opening type dome is available. This must be a *vented* design. A filler screen of stainless-steel material should be utilized to pick up 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 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 are tied electronically to low-level water indicators and engine throttle shutdown systems.

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 semielliptical 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 must 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 tank is fabricated. A vortex straightener *must* be provided at the suction outlet boss.

6.1.3 Piping. Efficient piping is important. Water restriction between the pump and the tip of the nozzle affect the efficiency of the entire wash system. This portion of the package is the one generally ignored. 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 L/s to 5 L/s (60 gal/min to

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: Some pump manufacturers will not warrant a pump if a filter is placed ahead of the inlet. This is due to cavitation danger.

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. Rubber *fire* hose of nonconductive material, poly-plastic nylon reinforced hose, is being utilized where nonconductive practices are utilized. When the practices call for conductive hose, wire braid, rubber covered hose with *stapled* couplings, guaranteeing electrical continuity, are used.

6.1.4.2 Size. Hose from 15.8 mm to 25.4 mm ($\frac{5}{8}$ in–1 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 m–3.05 m (8 ft–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 should 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 lash 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 craftsman 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 must be at the premeasured depth. Nonconductive nylon or plastic hoses should be coupled per the hose and fitting manufacturer's specifications also.

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 cuts the turbulently rotating water into a straight stream as it enters the nozzle. Orifice sizes vary from 3.2 mm to 7.94 mm ($\frac{1}{8}$ in– $\frac{5}{16}$ 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 is so difficult to obtain commercially today; many users hand finish and polish their own. Brass or aluminum bodies with steel, stainless steel, ceramic, or metal compounded tips are 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 shut-off 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 jeeps to ten-wheel-drive diesels, of 27.216 kg (60 000 lb) are being used. Small all-wheel-drive trucks, such as jeeps 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 the basket.