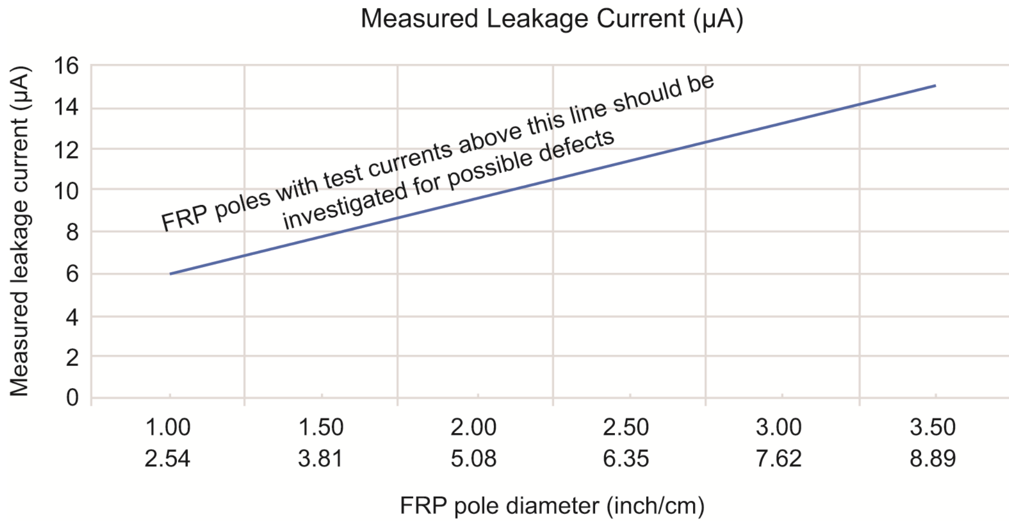

Figure 7—Typical accept/reject values of equipment current for FRP pole of various diameters using 60 Hz, 100 kV per 30 cm (1 ft), with the voltage applied between two electrodes in contact with the surface of the pole

5.6.3 Maximum operating voltage

The maximum power frequency operating voltage (V_M) is the voltage to which the tools and equipment could be subjected during routine employment in work operations. For example, for 345 kV systems, the maximum power frequency operating voltage (V_M) is 362 kV. In cases where the bus voltage is unregulated, the user should recognize the possible voltage transformation ratio as well as the maximum voltage that can appear under normal situations from the source line, which can then be reflected through the transformer.

5.6.4 Evaluation of tools and equipment

Tools and equipment should be evaluated using the applicable standard(s), as follows:

a) ASTM F 712 for electrically insulating plastic guard equipment
b) ASTM F 1236 for visual inspection of electrical protective rubber products
c) IEC 60060-1:2010 for high-voltage test techniques (general definitions and test requirements)
d) IEC 60060-2:2010 for high-voltage test techniques (measuring systems)
e) IEC 60060-3:2006 for high-voltage test techniques (on-site testing)
f) IEC 60855-1:2016 for insulating foam-filled tubes and solid rods
g) IEC 60903:2014 for gloves and mitts of insulating material
h) IEC 60984:2014 for sleeves of insulating material
i) IEC 61057:2017 for aerial devices with insulating boom
j) IEC 61229:1993 for rigid protective covers
k) IEC 61235:1993 for insulating hollow tubes
l) IEC 61236:2010 for saddles, pole clamps (stick clamps) and accessories
m) ANSI/SIA A92.2 for vehicle-mounted elevating and rotating aerial devices

The previously listed documents do not discuss equivalence of withstand voltages for the tools and equipment under ac and impulse voltage stresses. Ongoing research has indicated support for the use of the ratio of 1.3 for testing flexible insulating equipment. For rigid insulating covers, the ratio appears to be affected by the geometrical details of test electrodes used in testing. Research is ongoing to obtain precise values of the ratios. Based on tests for line guards, the 1.3 ratio applies to equipment such as blankets and line hoses. The ratio of withstand voltage (peak) under impulse conditions to the withstand voltage (peak) with ac energization is not equal to 1.0.

IEC 61472:2013 does not provide a value for the ratio of impulse-to-power-frequency (peak) withstand voltage.

5.7 Typical tests for insulating tools

The fundamental reason for testing insulating tools and other equipment used in live working is to verify tool safety. Basically, there are three categories of tests:

a) Design and certification tests. The purpose of design and certification tests is to show that the tools or equipment has the electrical strength to withstand the maximum electrical stress in a work location. These tests must show that the tools or equipment being tested can withstand the maximum anticipated TOV.
b) Periodic tests, referred to as *proof test*, *double rated test*, or *in-service tests*. The purpose of the proof test, double rated test, or in-service test is to demonstrate the safety of the insulating tools or equipment for work and to check for indications of deterioration. These are periodic tests. The test voltage is higher than the maximum use voltage but lower than the certification test voltage. Usually the test voltage is twice the maximum use or rated voltage (L-G) on which the tools or equipment is used.
c) Before-work tests. The purpose of the before-work test is to demonstrate the safety of the insulating tools or equipment for work. The test voltage is usually the phase-to-ground voltage of the system on which the tools or equipment is to be used.

Test requirements and testing methods for specific insulating tools and equipment are provided in standards published by, for example, ASTM and IEC (see Clause 2).

5.8 Worksite procedures

5.8.1 Field care, handling, and storage

When not in use, insulating tools should be stored where they will remain dry and clean and they are not subjected to abuse and excessive ultraviolet light. Wood insulating tools should be stored in a temperature-controlled environment, such as a control room, and should be adequately supported or hung vertically to prevent warping. Insulating tools used for energized-line maintenance should not be laid on the ground because of possible contamination or wetting. They should be placed on clean, dry tarpaulins; on moisture proof blankets; or in tool racks. They may also be leaned against dry supports. When transporting insulating tools, ventilated containers should be provided to prevent damage to the surfaces of the individual tools, or the tools should be mounted on racks in trucks or trailers. These racks should be well padded and constructed so that the tools are held firmly in place to prevent abrasive or bumping action against any surface that would damage the glossy surface of the tools.

5.8.2 Before-work inspection and checking

Insulating tools should be visually inspected before use for indications that they may have been mechanically or electrically overstressed. Tools that show evidence of overstress (such as damaged, bent, worn, or cracked components) should be removed from service and evaluated for repair. Elongated or deformed rivet ends, for instance, indicate that excessive mechanical loading has occurred and has weakened or sheared the bond between the ferrules and the insulating pole. Any moisture penetration reduces the insulating properties of these tools.

The surface of each tool should be inspected before and after each use for contamination such as dirt, creosote, grease, or any other foreign material. If any of the above contaminants exist, the tool surface should be cleaned (see 4.7.2.4).

When the insulating member of a tool shows signs of accumulated contamination, surface blisters (delamination), excessive abrasion, nicks, or deep scratches, the tool should be removed from service, cleaned or refinished as recommended by the manufacturer, and retested. If it is not possible to retest the tool, then it should not be used.

When tools have been exposed to excess moisture, their moisture content can be measured with a moisture meter, which is commercially available, or their general condition can be determined on the basis of ac power loss measurements (see 5.8.5).

5.8.3 Cleaning

Before each use, wipe insulating tools with a clean, absorbent paper towel or cloth. This may be followed by wiping with a silicone-treated cloth.

If simple wiping does not remove the contaminant, then apply a solvent or cleaner recommended by the manufacturer of the insulating tool with a clean, absorbent paper towel or cloth and wipe with a silicone-treated cloth, if available.

5.8.4 Field test equipment

Portable live tool testers provide a means for conveniently field-testing insulating tools without auxiliary equipment except for a power supply. It is very important to note that some portable units are designed to test the entire insulating tool's cross-sectional areas for conductivity. To be certain of the tester's capability, the user should check the applicable literature or contact the equipment manufacturer.

Reliance on electrical testing is the prerogative of the user who is responsible for maintaining equipment calibration, application, and interpretation and responsible for the safety of the user.

5.8.5 Use of moisture or dielectric property determination meters

Moisture meters are portable devices that can be used for worksite inspection of insulating tools for indications of excessive moisture or tracking. One model employs a radio frequency (RF) power loss circuit at 10 MHz. By way of roller electrodes, this meter applies an RF field through the sample and measures the power loss as affected by moisture. The meter scale can be set arbitrarily at either of two levels of intensity.

Another dielectric meter employs a measurement of the real part of an RF field transmitted through part of the cross section of the tool. The real part of the transmitted field is related to conductive faults caused by moisture, carbon tracking, or conductive elements in the sample. The response of this meter is adjustable according to the sample diameter and wall thickness. An internal standard is used to set the instrument response to the prescribed level for each tool configuration to be measured.

When using either meter, measurements should be made at several points along the circumference of the insulating tool even for small-diameter tools.

CAUTION

Reliance on moisture and dielectric property determination meter readings should be the prerogative of the user who is responsible for maintaining equipment calibration, application, and interpretation and responsible for the safety of the user.

5.9 Shop or laboratory procedures

5.9.1 General

All testing should be performed using methods and criteria set forth in the appropriate standards. The following testing standards cover most of the laboratory testing:

a) IEC 60060-1:2010 for high-voltage test techniques (general definitions and test requirements)
b) IEC 60060-2:2010 for high-voltage test techniques (measurement systems)
c) IEC 60060-3:2006 for high-voltage test techniques (on-site testing)
d) IEEE Std 62 for oil-filled power transformers, regulators, and reactors

5.9.2 Periodic inspection and testing

5.9.2.1 When to perform shop or laboratory testing

Insulating tools should be shop maintained and tested at an interval dependent on their exposure, manner of use, care they receive, individual company policy, and field inspections. Wood tools should be checked more frequently during periods of high humidity or after exposure to moisture.

The following field observations, if present, should warrant the removal of tools from service and their return to the laboratory or shop for repair and electrical testing:

a) A tingling or fuzzy sensation when the tool is in contact with energized conductor or hardware
b) Failure to pass the electric test or the moisture meter test (see 5.8.5)
c) Deep cuts, scratches, nicks, gouges, dents, or delamination in the stick surface
d) A mechanically overstressed tool showing evidence of damaged, bent, worn, or cracked components
e) A loss or deterioration of the glossy surface
f) A pole inadvertently cleaned with a soap solution (see 5.9.3)
g) Improper storage or improper exposure to weather
h) An electrically overstressed tool showing evidence of electrical tracking, burn marks, or blisters (delamination) caused from heat

5.9.2.2 Inspection procedure

Tools should be carefully inspected and/or tested before returning them to service. Elongated or deformed rivet ends indicate that excessive mechanical loading has occurred and has weakened or sheared the bond between the ferrules and the insulating pole.

Hardware bolts and pins should be replaced only with high-strength material, the same as the original part. Nondestructive testing (e.g., magnetic particle inspection, dye penetrant inspection, ultrasound, and X-ray) should be performed on the mechanical end fittings after a tool has been subject to possible overstressing or vibrating loads for any extended period of time.

5.9.3 Cleaning, waxing, refinishing, and repair

5.9.3.1 Fiberglass-reinforced plastic (FRP) tools

FRP tools should be cleaned and waxed or refinished in accordance with the tool manufacturer's recommendations.

5.9.3.2 FRP tools cleaning and waxing

Waxing is not necessary after every use of the tools, but rather as needed to maintain a glossy surface that may cause any moisture or water to bead on the surface. Before a tool is rewaxed, the pole should always be cleaned with a solvent or cleaner recommended by the tool's manufacturer to avoid a wax build-up. Waxing not only imparts a glossy finish to the surface of the fiberglass, but also adds to the electrical integrity of the tool by providing a protective barrier against dirt, creosote, and other contaminants and against moisture.

5.9.3.3 FRP tools repair or refinishing

In view of various available repair or refinishing processes, the decision is left to the user about the adequacy of the repair process and the quality of workmanship.

Only competent personnel should repair or refinish FRP insulating tools. Light spots are caused by impact blows and may have a noticeable effect on the mechanical strength or electrical properties of the tool. Numerous light spots may show excessive abuse and, coupled with surface contamination, may lower the sparkover voltage or contribute to insulation degradation. If there is no roughness on the surface, there is no need for repair. Small surface ruptures can be seen with the naked eye and should be repaired by competent personnel by removing the damaged fibers and cleaning the void following the manufacturer's recommended procedure for repair.

If there is any indication that the outer layer of material has separated and leaves a void beneath the surface, the tools should be removed from service and refinished as recommended by the manufacturer. Such voids can accumulate moisture or, under electrical stress, become ionized and lead to degradation in the organic materials. The resulting conductive deposits act as an extension of the electrode and cause further progressive degradation.

All repairs and refinishing should be followed by a high-potential dielectric leakage (see 5.8.4 and 5.8.5) or ac power loss test. An insulating tool should not be used unless it is tested.

5.9.3.4 Wood tools

Replacement of wood tools with FRP tools is recommended. However, if wood tools are still being used, it is important to refer to this subclause for the proper care and handling of wood tools. Although the surface of the tool may appear to be perfectly dry and the finish in excellent condition, the wood may have absorbed excessive moisture from the air if the tool has been exposed to high humidity conditions. Therefore, extra precautions should be taken during wet seasons of the year. Treatment in a drying cabinet is recommended if high leakage currents are encountered. In these cases, tools should be dried at 32 °C (90 °F) for approximately 48 h in a 31.6% to 38% relative humidity controlled and ventilated area to provide air circulation and subsequently subjected to a high-potential leakage or ac power loss test. Prompt touch-up is recommended where the finish is worn or damaged to prevent dirt or moisture from entering and becoming absorbed by the wood fibers where it might form dangerous conductive paths.

When general refinishing is required, wood tools should be thoroughly dried to 6% or 7% moisture content. After the old varnish and foreign material have been removed, the surface should be rendered smooth with flint paper and finished with two or three coats of varnish. Finishing includes sanding lightly between coats. Damage to the finish should be repaired according to the manufacturer's recommendations.

Repairs and refinishing should be performed by competent personnel and followed by a high-potential leakage or ac dielectric loss test. A tool should not be used unless it is tested.

5.9.4 High-potential ac test method

The entire length of the tool should be divided into test segments for testing. In some cases, the test segments may overlap. One test segment should include the area adjacent to the metal fittings with one electrode making contact to the end fitting. The test contacts may be two helical springs (see Figure 8).

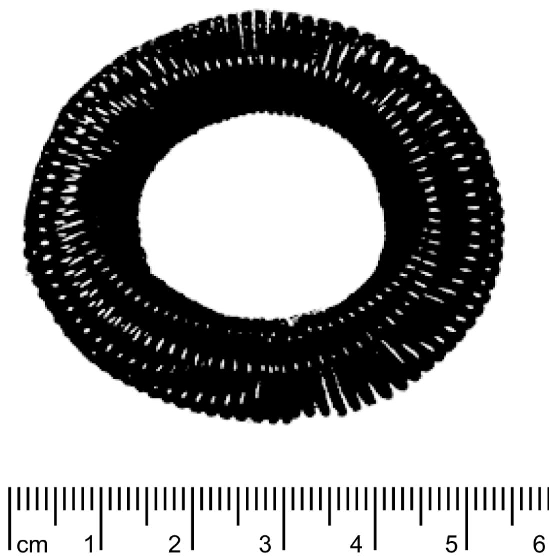

Figure 8—Helical spring electrode for in-service electrical testing of FRP tools (see 5.9.7 for the electrode specification)

The test instructions are as follows:

a) Suspend or support the tool in a horizontal position, using insulating material, approximately 1.2 m above the floor.
b) Orient the tool to the transformer to give the minimum leakage current at a fixed voltage. Maintain this reference location for all subsequent tests.
c) Wrap the spring electrodes around the tool. Spring contact should be maintained around the entire circumference of the tool.
d) Attach the test leads to the springs so that sharp edges extend inside the coiled area of the spring. The power lead of the test set should be routed directly to the nearest electrode. Coil excess lead in the center of the lead maintaining 0.60 m ground distance. Metal conductor spark plug wire may be used for the power lead. Use shielded cable for the ground lead. Attach the inner conductor of the shielded cable to the ground spring and to the ground return meter of the test set. Float the shield on the spring end, and attach the shield to the ground lug on the test set.
e) For fiberglass poles only, spray the test segment with distilled water to thoroughly wet its surface. A clean spray applicator adjusted to a fine mist is suitable for this purpose. Spray water uniformly on the pole until droplets just begin to drip from the bottom surface. Apply potential to the test segment immediately after wetting.
f) For wood poles, inspect them for dryness as they should be dry when tested.

g) Increase the voltage gradually at a rate of 3 kV/s to 75 kV across 30 cm for fiberglass and 50 kV across 30 cm for wood. Maintain this voltage for 1 min minimum. Read the maximum leakage current in the ground return meter.

If the current continues to rise after full voltage is reached, the test should be discontinued, and the pole should be cleaned or refinished and then retested. If the condition is not corrected, the pole should be removed from service.

5.9.5 Current measurements

Current measurement provides an objective evaluation of the specimen's insulating tool quality.

Typical current (leakage) values on new FRP poles using guarded electrodes and tested at 100 kV across 30 cm may be in the range of 5 μA to 28 μA depending on the diameter of the pole and other factors.

See ASTM F 711, 5.6.2, and Figure 6. This range of values can vary from laboratory to laboratory or from test to test within a given laboratory; therefore, historical data should be established by performing tests exactly the same way from day to day. The electrode's shapes, spacing, pole orientations, lead wires, instruments, etc., should not be varied.

If nonguarded electrodes are used, the current values may be appreciably higher by a factor of 10, 15, or more, depending on the voltage.

Sample current readings should be made when the specimen has clean, uncontaminated surfaces to establish historical data. These data should be used to establish a benchmark range for making a comparison between the in-service tool tested and the acceptance levels established for that particular diameter of pole and specific electrode configuration.

Changes in current may be cause for rejection. Significant changes in current values during a test are indications of any or all of the following conditions: contamination, moisture, specimen degradation, or instability of the test setup. If the test setup is not at fault, the tool should be cleaned, dried, refinished as recommended by the manufacturer, and retested.

If the current decreases when the voltage is maintained across the test specimen, it may be indicative of absorbed moisture drying out during the test. A reading that shows an increase may be indicative of incipient degradation of the specimen.

5.9.6 Wet and dry testing

Experience has shown that insulating tools with contaminated surfaces having failed electrically under humid, moist, or wet conditions may pass 100 kV across 30 cm after the tools have been dried.

It is the surface conditions of the tool that determine the performance under wet conditions. A glossy stick may allow water to bead on the surface whereas a dull surface may allow the water to spread in a sheeting action. Fairly dirty tools that retain surface gloss may show an increase in leakage current, but may sustain 100 kV across 30 cm with an acceptable leakage level. Conversely, fairly clean tools with a dull surface that has been wetted may fail at a low applied voltage. Tests on tools under wet conditions, therefore, verify whether the surface condition of the tool is satisfactory.

Only fiberglass tools should be tested under wet conditions.

5.9.7 Electrode design

5.9.7.1 General

Guarded electrodes are required to measure the high-potential leakage current through and along the surface of the test specimen.

Manufacturers use guarded electrodes in design testing of FRP poles without end fittings. See ASTM F 711.

When testing FRP poles with end fittings or operating rods, special electrodes should be designed to slide over the end fittings, or the electrodes should be a clam shell design.

Nonguarded electrodes are not recommended. However, if they are used, they should have a rounded edge contour to reduce the streamers that can occur before sparkover. Such streamers can cause ionic bombardment and cause electrons to rupture the chemical bonds of the stick material leading to degradation of the organic materials of the specimen being tested.

One type of contoured electrode used for in-service testing is a spring toroid that can be formed from 12.7 mm outside diameter (minimum) springs wound from 1.02 mm (18 gauge) stainless steel wire. These should be made with the inside diameter of the toroid slightly less than the pole diameters tested. Such springs are flexible enough to expand and roll over most end fittings. The 12.7 mm outside diameter of the spring gives a rounded contour to reduce the streamers (see Figure 8).

Another type of electrode system, which is less contoured than the one described above, is made using conductor straps or collars, which are easily wrapped around the specimen. Metal rings secured to the ends of the straps serve both to help hold the straps securely in place and as a point to attach the test electrodes.

The cables connecting the electrodes to the instruments should be shielded.

5.9.7.2 Electrode spacing

The spacing of electrodes is determined by the purpose of the test and the voltage chosen. For in-service testing of FRP materials, the voltage should be 75 kV across 30 cm of the pole. Wood poles should be tested at 50 kV across 30 cm spacing. Close spacing of electrodes allows inspection of more minute sections for quality control and thus avoids the averaging effects of wider electrode spacing. For example, 75 kV across 30 cm spacing or an equivalent potential difference such as 37.5 kV across 15 cm spacing has proved to be satisfactory. Testing may also be performed over a greater distance provided the applied voltage and distance are proportionally increased.

For larger or smaller distances, the relationship may be nonlinear.

Spacing distance of adjacent spring toroids should be measured between the centerlines of the springs.

5.9.7.3 Rack testing

Rack testing is the procedure of placing poles or tools on an insulating lattice structure where line and ground electrodes are attached alternately to the metal supports at a distance of 30 cm (1 ft) along the length of the tool.

This type of testing is intended primarily for high-volume acceptance testing of new poles in the manufacturing process (see Figure 9).

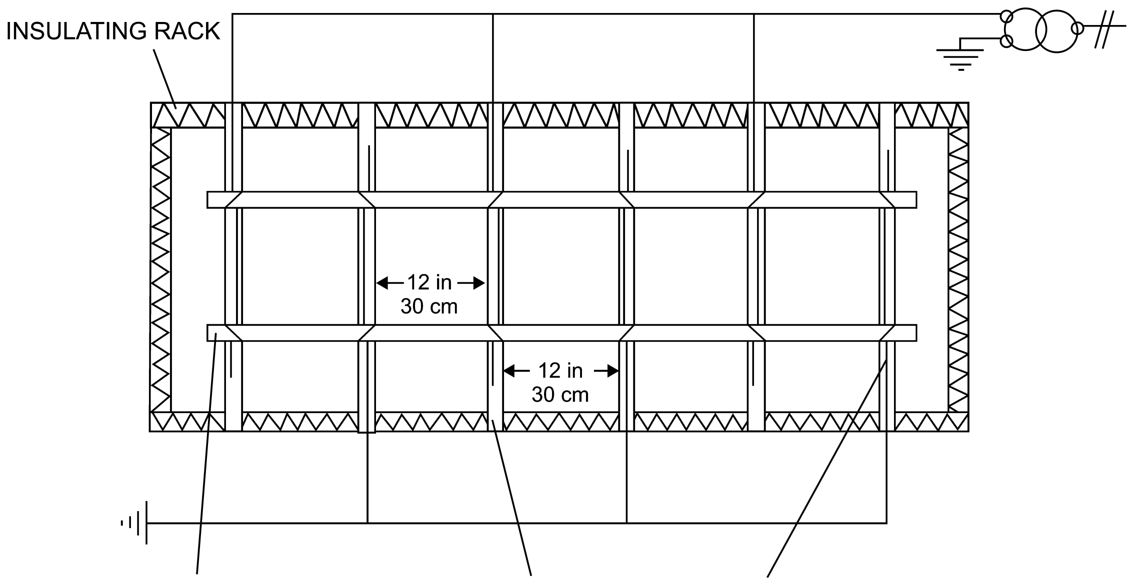

Figure 9—Typical rack for testing FRP tools

The electrodes, which are impractical to shield, should be of a shape to minimize corona streamers. Typical electrodes are beaded chain, machined clamps, stranded wire, helical springs, or flat braid up to 6.35 cm (2.5 in) wide.

Racks may also be used for in-service testing provided that certain disadvantages are recognized. For instance, assembled tools having metal end fittings, handles, or hooks might shorten some of the 30 cm (1 ft) spacing on the rack and thus not allow the voltage to be raised to the appropriate level without premature sparkover. Also it is inconvenient to monitor the current unless a meter is placed in each ground lead. Therefore, the rack is primarily used for testing new FRP poles where 100 kV is impressed across each 30 cm (1 ft) for 5 min and for observing any puncture, surface tracking, or heating (see 29 CFR 1926.957(b) [B11] and 29 CFR 1910.269(j)(1) [B10]). Since new poles have an inherent high gloss, only dry electrical testing is required.

5.9.8 Test voltage supply for high-potential testing

Either ac or dc may be used. Direct current testing is less sensitive to slight changes in the geometry of the test equipment. Also, dc equipment is much lighter, compact, and portable enough to perform insulating tool testing at many different locations. It is a good practice to test equipment to be used on ac lines with ac and equipment to be used on dc lines with dc.

The required test voltage for acceptance testing by users is that which will give a voltage gradient great enough for evaluation of material, but not so great that it leads to material degradation from corona or streamer discharges.

The power supply voltage parameters are dependent on factors such as electrode design and the distance over which the tests are conducted. The required test voltage capacity for in-service testing is that which will give an average voltage gradient of 75 kV across 30 cm of FRP specimen being tested or 50 kV across 30 cm of wood specimen being tested.

The 75 kV across 30 cm and 50 kV across 30 cm parameters are for in-service tests. New poles are tested by the manufacturer at 100 kV across 30 cm and 75 kV across 30 cm, respectively (see 29 CFR 1926.951(D) [B11]. The lower recommended test voltage for wood recognizes that wood tools are more susceptible to cumulative damage by repeated overvoltage tests than FRP tools. However, this lower test voltage does not compromise tool integrity or safety under proper use.

5.9.9 Orientation of equipment and test specimen

The high voltage should be applied to the end of the test specimen nearest to the power supply. The orientation of the high-voltage bus and test specimen should be such that nearby ground planes do not introduce significant capacitive effects.

To reduce the effects of stray currents on the specimen and on the meter indication, the specimen tested, especially on ac circuits, should be parallel to the high-voltage lead or bus, and the high-voltage connection (bus) should be kept as short as possible.

Other factors to be considered are the following:

a) Leads, bushings, and instruments should be shielded to minimize stray currents to any nearby ground planes.
b) Meters or other current-indicating devices should be incorporated to give quantitative data for material evaluation.
c) The power supply should have an adjustable interrupting device (circuit breaker) to protect against leakage currents significantly greater than the highest acceptance level for a given specimen and against damage to the power supply.
d) Interlocks and grounding features should be included for operator protection.

5.9.10 AC power loss (watts loss) test method

5.9.10.1 General

The power loss method is employed to determine the electrical condition of FRP and wood materials using the loss or dissipation of energy in the material compared to a reference based on a new or good condition value.

5.9.10.2 Test equipment

At a minimum, the test set should be capable of applying 2500 V; however, the preferred test voltage is 10 kV or greater. Provision for the measurement of power loss or the leakage (resistive) component, I_R, of the total specimen current is required. If desired, the average alternating voltage resistance of the specimen can be calculated as follows:

$$W = (V_T \times I_R) / R \qquad (63)$$

where

R is the resistance, in ohms
I_R is the resistive (loss) component of the specimen current, in amperes
W is the power, in watts
V_T is the test voltage, in volts

Measurement sensitivity should be sufficient to distinguish between 10^{10} (10 000M) Ω and 10^{11} (100 000M) Ω resistance.