



Designation: ~~D2303~~—13 D2303 – 20

Standard Test Methods for Liquid-Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials¹

This standard is issued under the fixed designation D2303; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope-Scope*

1.1 These test methods cover the evaluation of the relative tracking and erosion resistance of insulating solids using the liquid-contaminant, inclined-plane test.² The following test methods also can be used to evaluate the tracking resistance of materials: Test Method D2132 (contaminants: dust and fog) and Test Method D3638 (contaminant: conductive liquid drops).

1.2 Two tracking and one erosion test procedure are described:

1.2.1 A “variable voltage method” to evaluate resistance to tracking.

1.2.2 A “time-to-track method” to evaluate resistance to tracking.

1.2.3 A method for quantitative determination of erosion (Annex A1).

1.3 While a particular contaminant solution is specified, other concentrations of the same contaminant, or different contaminants are used to simulate different environmental or service conditions.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 Although this standard and IEC 60587-2007, “Test Methods for Evaluating Resistance to Tracking and Erosion for Electrical Insulating Materials Used Under Severe Ambient Conditions,” differ in approach or detail, data obtained using either are technically equivalent.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 89.

1.7 This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

¹ These test methods are under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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² K. N. Mathes, Chapter 4, “Surface Failure Measurements,” Chapter 4 of *Engineering Dielectrics, Vol. IIB, Dielectrics Volume IIB Electrical Properties of Solid Insulating Materials*; *Materials: Measurement Techniques*, R. Bartnikas, Editor, ASTM STP 926, ASTM, Philadelphia, ASTM International, 1987.

*A Summary of Changes section appears at the end of this standard

2. Referenced Documents

2.1 ASTM Standards:³

~~D374~~[D374/D374M](#) Test Methods for Thickness of Solid Electrical Insulation—(Metric) ~~D0374~~[D0374M](#)

[D1711](#) Terminology Relating to Electrical Insulation

[D2132](#) Test Method for Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials

[D3638](#) Test Method for Comparative Tracking Index of Electrical Insulating Materials

2.2 IEC Standards:Standard:

~~IEC 60587~~[60587-2007](#) Test Methods for Evaluating Resistance to Tracking and Erosion for Electrical Insulating Materials Used Under Severe Ambient Conditions

3. Terminology

3.1 Definitions:

3.1.1 *erosion, electrical, n*—the progressive wearing away of electrical insulation by the action of electrical discharges.

3.1.2 *erosion resistance, electrical, n*—the quantitative expression of the amount of electrical erosion under specific conditions.

3.1.3 *track, n*—a partially conducting path of localized deterioration on the surface of an insulating material.

3.1.4 *tracking, n*—the process that produces tracks as a result of the action of electric discharges on or close to the insulation surface.

3.1.5 *tracking, contamination, n*—tracking caused by scintillations that result from the increased surface conduction due to contamination.

3.1.6 *tracking resistance, n*—the quantitative expression of the voltage and the time required to develop a track under specified conditions.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *initial tracking voltage, n*—the applied voltage at which continuous tracking can be initiated in a specified time.

3.2.2 *time-to-track, n*—the time in which tracking proceeds a specified distance between the test electrodes at a specified voltage.

3.3 Other definitions pertinent to these test methods are given in Terminology [D1711](#).

4. Hazards

4.1 High Voltage:

4.1.1 Lethal voltages are a potential hazard during the performance of this test. It is essential that the test apparatus, and all associated equipment electrically connected to it, be properly designed and installed for safe operation.

4.1.2 Solidly ground all electrically conductive parts which it is possible for a person to contact during the test.

4.1.3 Provide means for use at the completion of any test to ground any parts which were at high voltage during the test or have the potential for acquiring an induced charge during the test or retaining a charge even after disconnection of the voltage source.

4.1.4 Thoroughly instruct all operators as to the correct procedures for performing tests safely.

4.1.5 When making high voltage tests, particularly in compressed gas or in oil, it is possible for the energy released at breakdown to be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury. If the potential for fire exists, have fire suppression equipment available.

5. Significance and Use

5.1 These test methods differentiate ~~among~~ solid electrical insulating materials on the basis of their resistance to the action of voltage stresses along the surface of the solid when wet with an ionizable, electrically conductive liquid contaminant.

5.2 These test methods quantitatively evaluate, in a relative manner, the effects upon an insulating material resulting from the action of electrical discharges upon a material surface. The effects are similar to those that may occur in service under the influence of dirt combined with moisture condensed from the atmosphere.

5.2.1 In the field, the conditions resulting in electrical discharges occur sporadically. Degradation, often in the form of a conducting “track,” develops very slowly until it ultimately bridges the space between conductors thus causing complete electrical breakdown.

5.2.2 In these test methods, the conducting liquid contaminant is continuously supplied at an optimum rate to the surface of a test specimen in such a fashion that essentially continuous electrical discharge can be maintained.

5.2.3 By producing continuous surface discharge with controlled energy it is possible, within a few hours, to cause specimen failure which is similar to failure occurring under long-time exposure to the erratic conditions of service in the field.

5.2.4 The test conditions, which are standardized and accelerated, do not reproduce all of the conditions encountered in service. Use caution when making either direct or comparative service behavior inferences derived from the results of tracking tests.

5.3 The time-to-track a 1-in. (~~25-mm~~) (25 mm) distance at a specified voltage between electrodes separated 2 in. (50 mm) has also been found useful in categorizing insulating materials for indoor and protected outdoor applications, such as metal-clad switchgear.

5.4 The initial tracking voltage has been found useful for evaluating insulating materials to be used at high voltages or outdoors and unprotected, as well as for establishing (see ~~10.11.1~~) the test voltage for the time-to-track test.

5.5 In service many types of contamination cause tracking and erosion of different materials to different degrees. This test method recognizes the importance of such variability and suggests the use of special test solutions to meet specific service needs. For example, an ionic contaminant containing, in addition, a carbonaceous component such as sugar is substituted to cause tracking on very resistant materials like polymethylmethacrylate. Such contamination is considered representative of some severe industrial environments. In this case, the time-to-track technique is used, since time is required to decompose the contaminant solution and build up conducting residues on the sample surface.

5.6 Very track-resistant materials, such as polymethylmethacrylate, typically erodes rather than track under more usual contaminant conditions in service. The use of this method for measuring erosion is consequently important. For erosion studies, only tests as a function of time at constant voltage are useful.

6. Apparatus

6.1 A simple schematic diagram of the apparatus is given in Fig. 1 and consists of the following. Details are given in Annex A2.

6.1.1 A ~~60-Hz~~ 60 Hz power supply with an output voltage stabilized to $\pm 1\%$ which can be varied from 1 to at least 7.5 kV with a rated current of no less than 0.1 A for every test station to be used (that is, 0.5 A for five stations).

6.1.2 A means for applying a specified contaminant solution at a controlled rate to the specimen surface. A pneumatically actuated repeating pipet has been found useful for this purpose and is described in Annex A2. Peristaltic pumps have also been used (~~A2~~); (see Annex A2).

6.1.3 Stainless steel top and bottom electrodes as shown in Fig. 2.

NOTE 1—~~Stainless steel~~ Stainless steel type 302 is recommended.

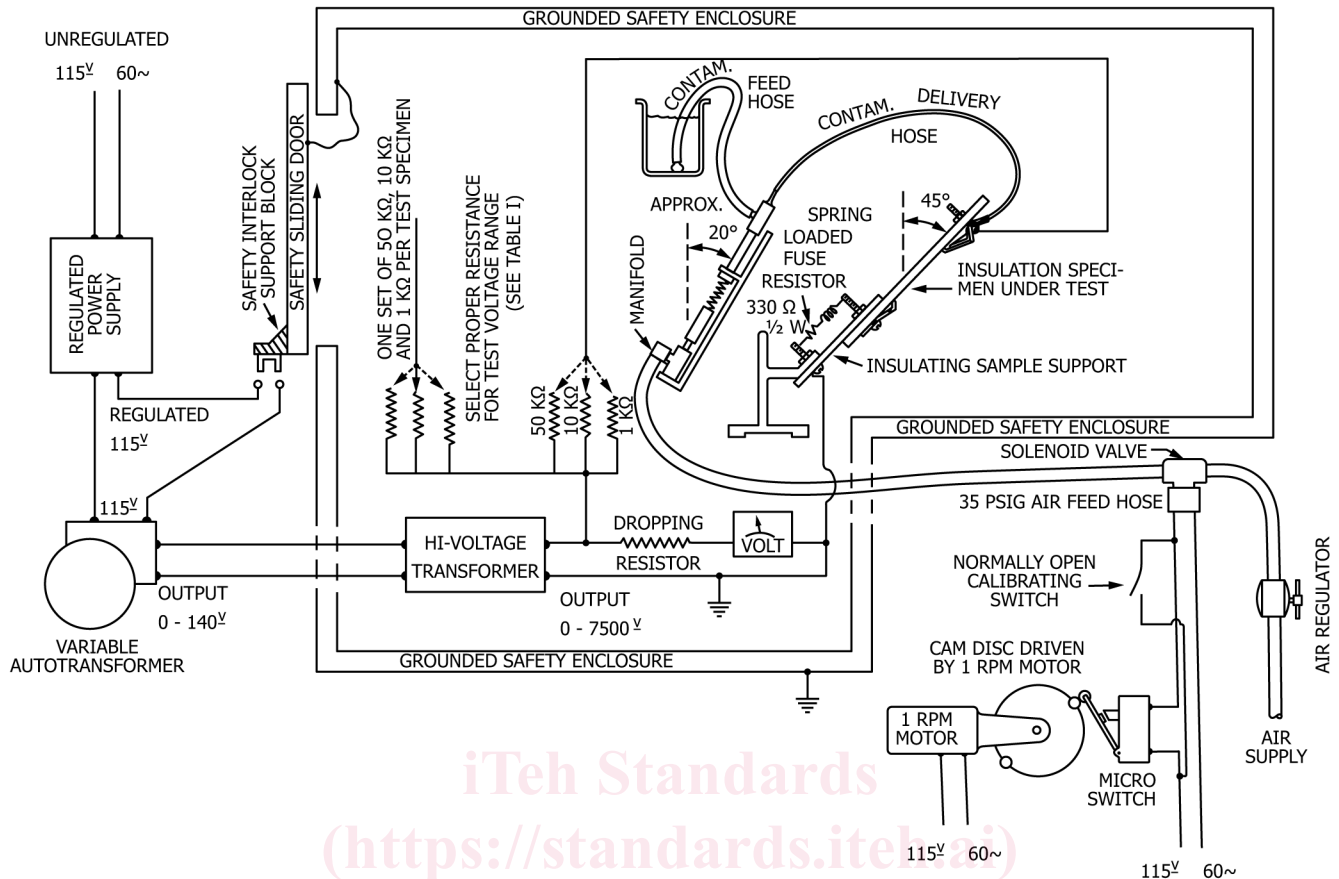


FIG. 1 Schematic Diagram of Apparatus

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6.1.4 A pad of filter paper cut as shown in Fig. 3a(a) and Fig. 3b(b) to fit under the top electrode and used to smooth out the flow of the contaminant solution.

6.1.5 A set of ballast resistors (50, 10, and 1 kΩ rated at 200 W each) to be connected as specified in series with each test specimen on the high-voltage side of the power supply. Somewhat lower resistances are being considered by the International Electrotechnical Commission (IEC/TC15).

6.1.6 A 330 Ω, 1/2 W, carbon resistor mounted with a simple tension spring and connected in series with the specimen and ground to act as an overload, high-voltage fuse.

NOTE 2—RC20 mil type carbon composition resistors are commercially available from several sources.

6.1.7 Structural parts and a grounded safety enclosure.

6.1.8 Clip to hold the hose and filter paper in place. Fig. 3a(a) and Fig. 3b(b) shows an example of a paper clip configuration that may be used. Other paper clip configurations may be used as long as they do not pinch the hose affecting the contaminant flow.

7. Sampling

7.1 Refer to applicable materials specifications for sampling instructions.

8. Test Specimens

8.1 Specimens with a flat surface measuring approximately 2 × 5 in. (50 × 125 mm) as shown in Fig. 4. Measure the thickness

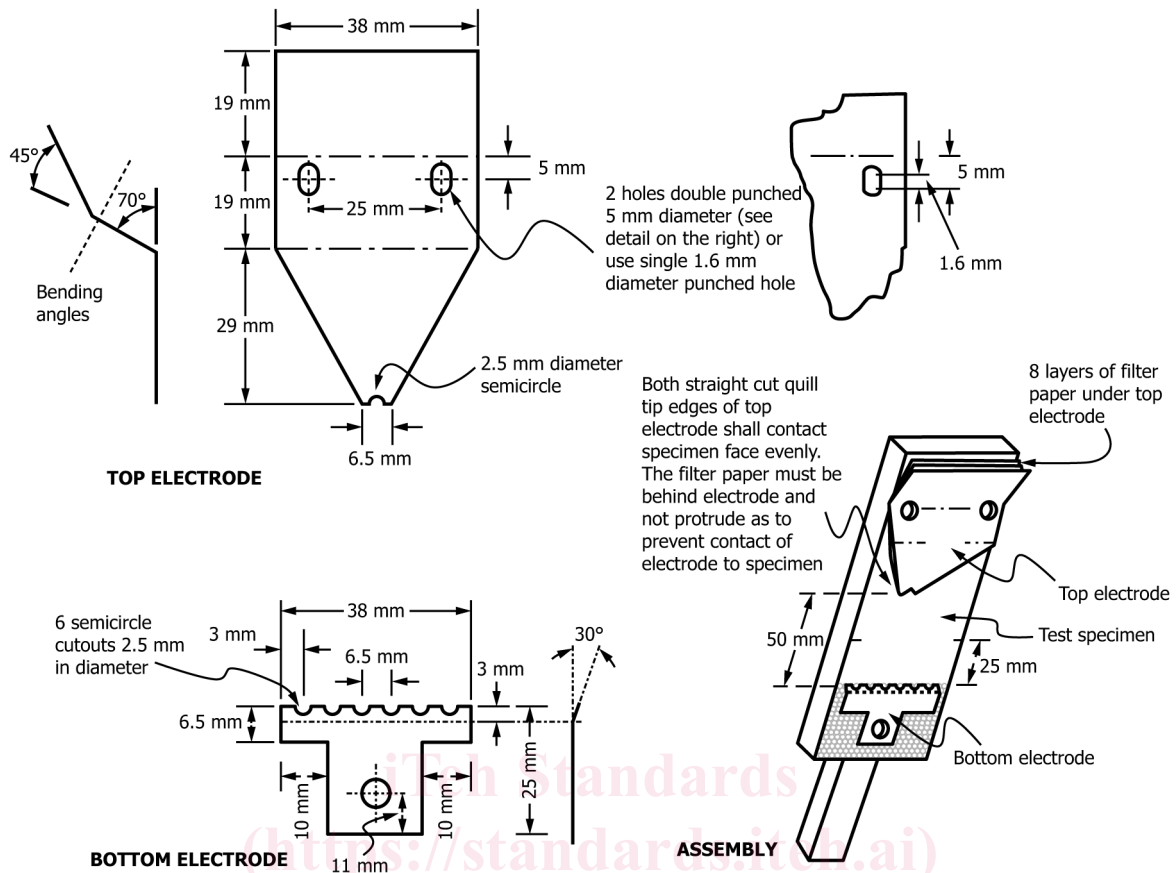


FIG. 2 Top and Bottom Electrodes

in accordance with Test Methods [D374/D374M](#) if there is no standard for a particular material. Specimens must be thick enough that tracking does not penetrate completely through the specimen during the test.

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8.1.1 Thin specimens shall be mounted on the apparatus as individual layers (that is, samples shall not be stacked).

8.1.2 Thin specimens shall be secured by mounting them on a support plaque made from an inert nonconductive material. **Fig. 3a(a)** shows an example of a mounting support plaque made out of PTFE (polytetrafluoroethylene) at an approximate thickness of 6 mm.

8.1.3 Care shall be exercised with thin specimens to ensure contaminant does not flow on the back of the specimen. This can lead to inconclusive results.

8.2 Prepare separate specimens representative of different surfaces affected by anisotropy, morphology, texture, surface treatments, pull direction, fill direction, etc. Identify the different surfaces to be tested, such as mold face, press face, textured side, machine direction, cross-machine direction, warp or fill direction, etc. Prepare two sets of specimens of materials with noticeable directional characteristics, with the predominant directional characteristic in line with the electrodes for one set and at right angles to the other set. Identify the specimen direction such as machine direction, cross-machine direction, warp or fill direction (for woven textile reinforced products). (See **Fig. 5**.)

8.3 *Preparation of Specimens*—Clean the specimen face with a suitable solvent and rinse with distilled water. ~~water~~ (see **Note 3**). For specimens to be used in the time-to-track method, do not mechanically destroy, that is, sand, abrade, and so forth, the natural surface finish of the specimen unless otherwise specified. However, with the variable-voltage method, the surface of the test specimens shall be lightly but completely sanded under flowing tap water with 400A-grit wet silicon carbide paper and rinsed with distilled water. Such sanding removes gloss and contaminants to provide a surface that is wet more easily and rapidly by the contaminant. Loss of gloss and slight erosion of the surface usually occurs in service, particularly outdoors. Generously cover the specimen area under the bottom electrode with conductive silver paint (see **Note 4**) and add the 1-in. (25-mm) (25 mm) tracking

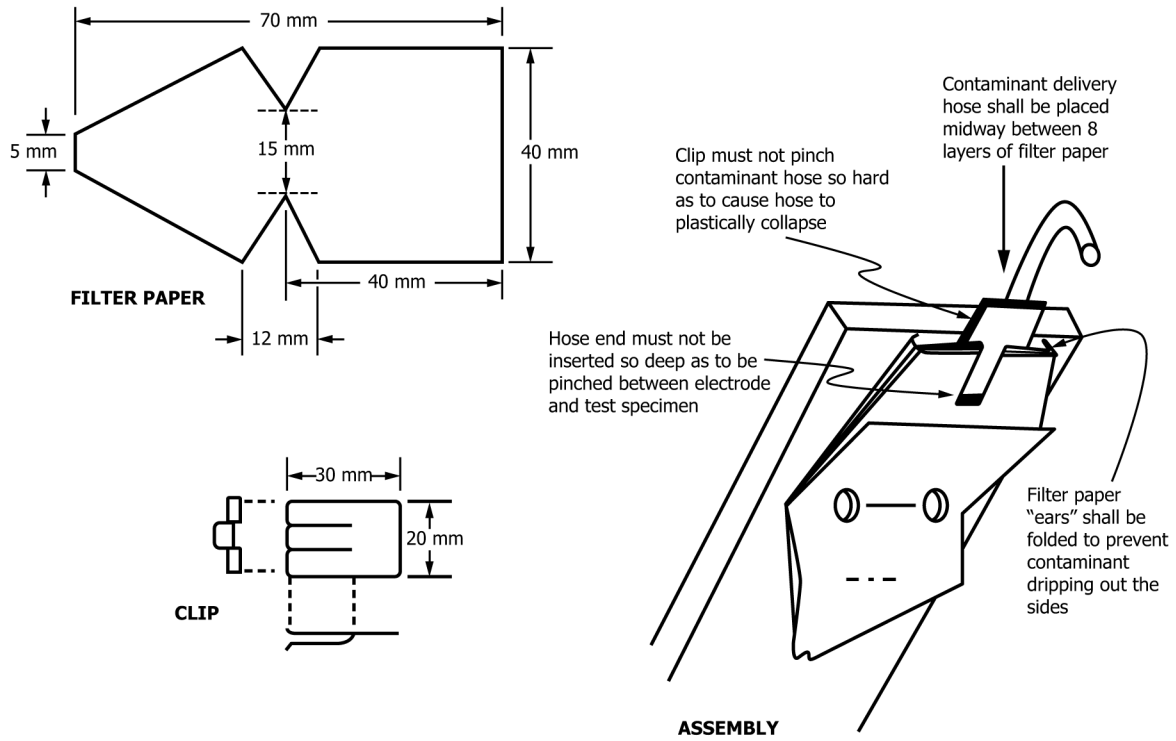


FIG. 3 (a) Filter Paper, Clip, and Method of Fastening



FIG. 3 (b) Nonconductive Mounting Support Plaque Made Out of PTFE, Approximately 6 mm Thick

reference marks as shown in Fig. 5. For all tests, other than the time-to-track test, soak the test specimens prepared as above for 24 to 48 h in the specified contaminant solution before test.

NOTE 3—The solvent should not soften or otherwise damage the test specimen. Isopropyl alcohol has been found suitable for many materials.

NOTE 4—Conductive silver paint is commercially available from several sources.

8.4 Prepare five specimens for each determination.

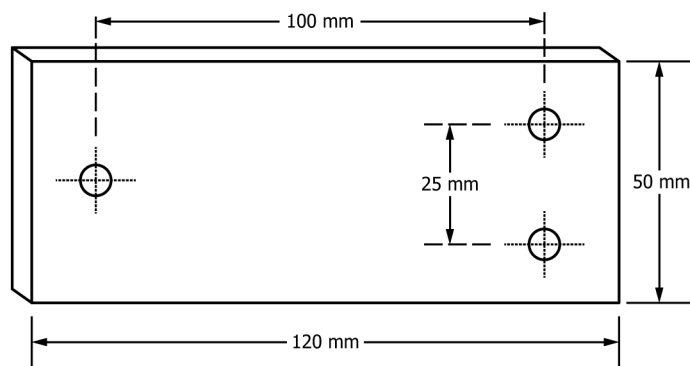


FIG. 4 Test Specimen

9. Procedure

9.1 Lethal voltages are a potential hazard during the performance of this test. It is essential that the test apparatus, and all associated equipment electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts which it is possible for a person to contact during the test. Provide means for use at the completion of any test to ground any parts which were at high voltage during the test or have the potential for acquiring an induced charge during the test or retaining a charge even after disconnection of the voltage source. Thoroughly instruct all operators as to the correct procedures for performing tests safely. When making high voltage tests, particularly in compressed gas or in oil, it is possible for the energy released at breakdown to be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury. If the potential for fire exists, have fire suppression equipment available.

8.1.1 Also see Fig. 1.

9.2 Mount and fuse the specimen with the flat test surface on the underside at an angle of 45° from the horizontal as shown in Fig. 1. Insert the contaminant delivery hose midway between eight thicknesses of the filter paper as shown in Fig. 3a(a) and Fig. 3b(b) and fold back the filter paper “ear” to prevent contaminant from squirting out the sides.

9.3 At the start of each test date, replace all residual liquid in the contaminant supply beaker with fresh contaminant. Cover all beakers to minimize dust and dirt as well as evaporation. Unless otherwise specified, use 0.1 % (by weight) ammonium chloride (reagent grade) and 0.02 % (by weight) nonionic wetting agent (see Note 5) in distilled water. This contaminant solution must have a resistivity between $385 \pm 15 \Omega \cdot \text{cm}$ – $15 \Omega \cdot \text{cm}$ when measured at $23 \pm 1^\circ\text{C}$.

NOTE 5—Octylphenol ethylene oxide condensate has been found satisfactory. It should be added to a small portion of the water and thoroughly mixed before being added to the larger bulk.

9.4 Adjust the contaminant flow and calibrate as described in Annex A1 to give the flow rate for the voltage to be specified in Table 1.

9.5 After calibration, the start-up procedure differs depending on whether the test specimen is a carry-over from a previous test, or an entirely new specimen.

9.5.1 For a specimen that has never been subjected to voltages and contaminant (that is, new specimen), start the contaminant injection into the filter paper, allowing the fresh contaminant to wet the filter paper thoroughly and replace the old liquid in the tubes and syringes and to flow as a steady stream (Note 26) (not intermittent bursts) across the test specimen face between electrodes. The contaminant must flow from the quill hole in the bottom of the top electrode and shall not squirt out of the sides or top of the filter paper during the pressure stroke of the pipet. Adjust the specimens so that the contaminant runs down as nearly as possible the center line of the specimen. Avoid drafts on equipment that might cause undue cooling of the specimens or of the water vapor from evaporation of the contaminant. Close the safety gate and apply the appropriate test voltage tabulated in Table 1.