



Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation¹

This standard is issued under the fixed designation D 495; 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 reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

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

1. Scope

1.1 This test method covers, in a preliminary fashion, the differentiation among similar materials with respect to their resistance to the action of a high-voltage, low-current arc close to the surface of insulation, intending to form a conducting path therein or in causing the material to become conducting due to the localized thermal and chemical decomposition and erosion.

1.2 The usefulness of this test method is very severely limited by many restrictions and qualifications, some of which are described in the following paragraphs and in Section 5. Generally, this test method should *not* be used in material specifications. Whenever possible, alternative test methods should be used, and their development is encouraged.

1.3 This test method will not, in general, permit conclusions to be drawn concerning the relative arc resistance rankings of materials that may be subjected to other types of arcs: for example, high voltage at high currents, and low voltage at low or high currents (promoted by surges or by conducting contaminants).

1.4 The test method is intended, because of its convenience and the short time required for testing, for preliminary screening of material, for detecting the effects of changes in formulation, and for quality control testing after correlation has been established with other types of simulated service arc tests and field experience. Because this test method is usually conducted under clean and dry laboratory conditions rarely encountered in practice, the prediction of a material's relative performance in typical applications and in varying "clean to dirty" environments may be substantially altered (Note 1). Caution is urged against drawing strong conclusions without corroborating support of simulated service tests and field testing. Rather, this test method is useful for preliminary evaluation of changes in structure and composition without the complicating influence of environmental conditions, especially dirt and moisture.

NOTE 1—By changing some of the circuit conditions described herein

¹ This test method is under the jurisdiction of ASTM Committee D-9 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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it has been found possible to rearrange markedly the order of arc resistance of a group of organic insulating materials consisting of vulcanized fiber and of molded phenolic and amino plastics, some containing organic, and some inorganic, filler.

1.5 While this test method uses dry, uncontaminated specimen surfaces, Test Method D 2132, Test Method D 2303, and Test Method D 3638 employ wet, contaminated specimen surfaces. Their use is recommended for engineering purposes and to assist in establishing some degree of significance to this test method for quality control purposes.²

1.6 This test method is not applicable to materials that do not produce conductive paths under the action of an electric arc, or that melt or form fluid residues that float conductive residues out of the active test area thereby preventing formation of a conductive path.

1.7 The values stated in inch-pound units are to be regarded as the standard.

1.8 *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 and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see 6.1.14, 6.1.19, Section 7, and 10.1.1.

2. Referenced Documents

2.1 ASTM Standards:

- D 1711 Terminology Relating to Electrical Insulation³
- D 2132 Test Method for Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials⁴
- D 2303 Test Method for Liquid-Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials⁴
- D 3638 Test Method for Comparative Tracking Index of Electrical Insulating Materials⁴
- D 6054 Practice for Conditioning Electrical Insulating Materials for Testing⁴

² Also helpful is Test Method D 2302 for Wet Tracking Resistance of Electrical Insulating Materials with Controlled Water-to-Metal Discharges. This test method was withdrawn and last appeared in the 1982 *Annual Book of ASTM Standards*, Part 39.

³ *Annual Book of ASTM Standards*, Vol 10.01.

⁴ *Annual Book of ASTM Standards*, Vol 10.02.

2.2 IEC Standard:

IEC 61621 Dry Solid Insulating Materials—Resistance Test To High-Voltage, Low-Current Arc Discharges⁵

NOTE 2—IEC 61621 is technically equivalent to D 495, and is directly based upon Test Method D 495. IEC 61621 describes only the tungsten electrodes, and does not include the stainless steel electrodes.

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in this test method, refer to Terminology D 1711.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *arc resistance, n*—the total elapsed time in seconds from the start of this test procedure until failure occurs (see Section 14).

3.2.2 *failure, n*—the end-point of the test procedure employed in this test method (see Section 14).

3.2.3 *normal orientation, n*—a test condition in which the electrodes are located on the upper surface of the specimen.

3.2.4 *inverted orientation, n*—a test condition in which the electrodes are located on the under surface of the specimen.

3.2.4.1 *Discussion*—Tests made with inverted orientation are more severe than tests made with normal orientation. Reduced data dispersion has been encountered when testing certain materials using inverted orientation. With other materials, increased data dispersion may be encountered, especially with materials that evolve considerable gas during test.

3.3 Abbreviations:

3.3.1 The stainless steel strip electrodes are referred to as s.s.s. electrodes.

4. Significance and Use

4.1 The high-voltage, low-current type of arc resistance test is intended to simulate only approximately such service conditions as exist in alternating current circuits operating at high voltage, but at currents limited to units and tens of milliamperes.

4.2 In order to distinguish more easily among materials that have low arc resistance, the early stages of this test method are mild, and the later stages are successively more severe. The arc occurs intermittently between two electrodes resting on the surface of the specimen, in normal or inverted orientation. The severity is increased in the early stages by successively decreasing to zero the interval between flashes of uniform duration, and in later stages by increasing the current.

4.3 Four general types of failure have been observed:

4.3.1 Many inorganic dielectrics become incandescent, whereupon they are capable of conducting the current. Upon cooling, however, they return to their earlier insulating condition.

4.3.2 Some organic compounds burst into flame without the formation of a visible conducting path in the substance.

4.3.3 Others are seen to fail by “tracking,” that is, a thin wiry line is formed between the electrodes.

4.3.4 The fourth type occurs by carbonization of the surface until sufficient carbon is present to carry the current.

4.4 Materials often fail within the first few seconds after a change in the severity stage. When comparing the arc resistance of materials, much more weight should be given to a few seconds that overlap two stages than to the same elapsed time within a stage. Thus, there is a much greater difference in arc resistance between 178 and 182 s than between 174 and 178 s.

NOTE 3—Some investigators have reported attempts to characterize the remaining insulating value of the damaged area after failure by allowing the specimen to cool to room temperature, without disturbance of the original position of the electrodes, and then either (1) measuring the insulation resistance between the electrodes or (2) determining the percentage of breakdown voltage remaining relative to that obtained on an undamaged area of the specimen. A recommended circuit arrangement and test procedure for carrying out the second of these two means of characterizing the remaining insulating value of the damaged area is described in Appendix X1. Still another, and obvious, method of re-evaluating the damaged area after failure is to repeat the arc resistance test after the specimen has cooled, with the electrodes undisturbed from their original positions. However, keep in mind that none of these methods will be universally applicable because of the severe physical damage to the test area in many instances.

5. Interferences

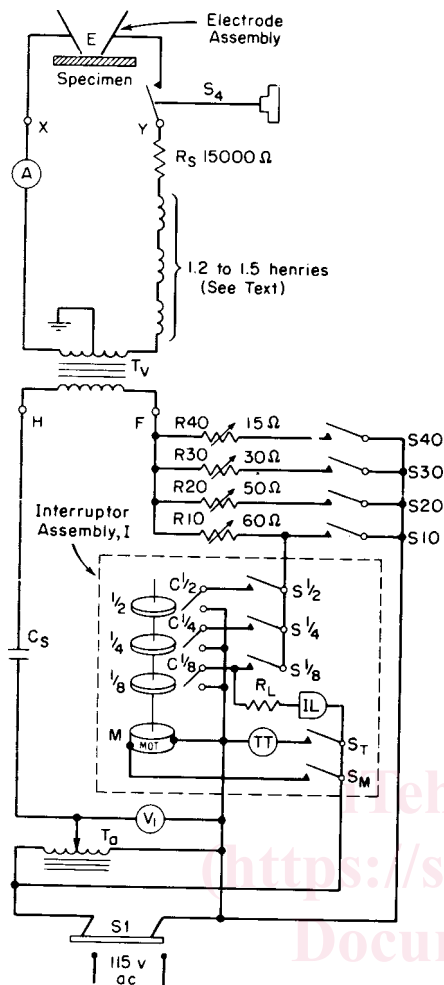
5.1 Changes in both the timing of the intermittent arc and the current, as well as other changes affecting the nature of the discharge, can affect the duration of a test of most specimens taken from a group of dissimilar materials. Any of these changes can drastically alter a material’s position in order of rank. Regardless of the conditions of anticipated use, do not use data obtained by this test method to infer that the materials examined occupy an unchanging quality relationship to each other.

5.2 This test method describes two electrode systems: stainless steel strip and tungsten rod. When testing materials with poor to moderate arc resistance (up to 180 s), use the stainless steel strip electrodes as the preferred technique. This technique decreases the variability often associated with the use of rod electrodes on materials having poor or moderate arc resistance. All of the factors that affect the disparate behavior of rod electrodes on such materials have not yet been fully reported. It is permissible to make additional tests with rod electrodes, so as to provide a basis for comparison with other data obtained with such electrodes. For values of arc resistance greater than 180 s, the use of the tungsten rod electrodes is recommended because the corners of the stainless steel strip electrodes erode appreciably under such conditions. Results obtained with the use of the tungsten rod electrode system may be different from those obtained with the use of the stainless steel strip electrode system.

6. Apparatus

6.1 The apparatus (see Fig. 1 for electrical circuit) is closely specified to maximize data reproducibility among different test sets. The arc obtained will be relatively quiet, rather than the crackly blue spark characteristic of a condenser discharge. Primary voltage control is made by a variable transformer rather than by a variable inductance because of its proved deleterious effect on the performance of the arc.

⁵ Available from American National Standards Institute, 11 W 42nd St., New York, NY 10036.



NOTE 1—Switches S_M to S_{40} are aligned in the sequence of their closing, from bottom to top, during a test.

FIG. 1 Arc-Resistance Test Circuit

6.1.1 *Transformer*,⁶ T_v —A self-regulating transformer (non-power factor corrected) with a rated primary potential of 115 V at 60 Hz ac, a rated secondary potential (on open circuit) of 15 000 V, and a rated secondary current (on short circuit) of 0.060 A.

6.1.2 *Variable Autotransformer*,⁷ T_a , An autotransformer rated at 7 A or more, and nominally adjustable up to 135 V.

6.1.3 *Voltmeter*, V_1 —An ac voltmeter, readable to 1 V in the range 90 to 130 V, is permanently connected across the output of the autotransformer to indicate the voltage supplied to the primary circuit.

NOTE 4—A constant primary voltage supply is recommended. Commercially available line voltage stabilizers that do not distort the voltage wave form are suitable.

⁶ Jefferson Electric Type 721-411 luminous tube transformers have been found to be satisfactory. Any other type or make meeting the requirements of 6.1.1 may be used if it can be demonstrated that equivalent data are obtained.

⁷ The Powerstat® (Superior Electric Co.) or the Variac® (GenRad Co.) with equal or greater current-carrying capacity than listed in 6.1.2 is satisfactory. Other makes of the same general construction will probably also be adequate.

6.1.4 *Milliammeter*, A —An ac milliammeter capable of reading from 10 to 40 mA with an error of not over $\pm 5\%$. Before use, to make certain of its readings, this meter should be calibrated in a test circuit containing no arc gap. Since this milliammeter is used only when setting up or making changes in the circuit, it may be shorted out by a by-pass switch when not in use.

TABLE 1 Sequence of 1-min Current Steps

Step	Current, mA	Time Cycle ^A	Total Time, s
1/8 10	10	1/4 s on, 1 3/4 s off	60
1/4 10	10	1/4 s on, 3/4 s off	120
1/2 10	10	1/4 s on, 1/4 s off	180
10	10	continuous	240
20	20	continuous	300
30	30	continuous	360
40	40	continuous	420

^A In the earlier steps an interrupted arc is used to obtain a less severe condition than the continuous arc; a current of less than 10 mA produces an unsteady (flaring) arc.

NOTE 5—Although provision has been made for the suppression of radio-frequency components of current in the arc, it may be desirable to check for their presence when the apparatus is first constructed. This is done by use of a suitable thermocouple-type r-f milliammeter temporarily inserted in series with the milliammeter.

6.1.5 *Current Control Resistors*, R_{10} , R_{20} , R_{30} , R_{40} —Four resistors are required in series with the primary of T_v but in parallel with each other. These resistors must be adjustable, to some extent, to permit exact settings of the currents during calibration. R_{10} is always in the circuit to provide a 10 mA current. Its value is approximately 60 Ω , with a current rating of at least 1 1/4 A. Closing switch S_{20} , to add R_{20} in parallel with R_{10} , will provide a 20 mA arc current. R_{20} is about 50 Ω with a current rating of at least 1 3/4 A. Similarly, R_{30} and R_{40} have values of about 30 Ω and 15 Ω respectively, with associated current ratings of 2 and 5 A. These resistors, when switched in, provide arc currents of 30 mA and 40 mA respectively.

6.1.6 *Suppressing Resistor*, R_3 —Rated at 15 000 Ω and at least 24 W. This resistor, along with the inductors in 6.1.7, is used to suppress parasitic high frequency in the arc circuit.

6.1.7 *Air Core Inductors*—Inductance totaling from 1.2 to 1.5 H is obtained from about 8 coils of No. 30 cotton- or enamel-covered wire. A single coil of this inductance is not satisfactory. Each coil consists of 3000 to 5000 turns of wire wound or insulating nonmetallic cores of about 1/2 in. (12.7 mm) diameter and 5/8 in. (15.9) inside length.⁸

6.1.8 *Interruptor*, I —This motor-driven device is used to give the required cycles for the three lower steps of the test by opening and closing the primary circuit according to the schedule in Table 1, with an accuracy of $\pm 1/120$ s or better. The interruptor can be a synchronous motor driving three appropriate sets of cams which actuate the contactor switches.

6.1.9 *Timer*, TT —A stop watch or electric interval timer operating at 115 V ac, accurate to 1 s.

⁸ Coils may be obtained from Cutler-Hammer, Inc., Milwaukee, WI.

6.1.10 *Indicator Lamp, IL*—A 6 W, 115 V lamp with a 2000 Ω resistor, R_1 , in series. This lamp indicates the interrupting cycle being used and permits the operator to start the first cycle of each test in a uniform manner by closing $S_{1/8}$ just after the lamp is extinguished.

6.1.11 *Control Switches*—Toggle switches are convenient. All may be of the size rated at 3 A and 110 to 125 V ac, except S_1 and S_{40} , which require 10 A ratings.

6.1.12 *Safety Interlocking Contactor, C₅*—Rated at 10 A and 110 to 125 V ac, this interlocking contactor is installed so that raising the draft shield around the electrode assembly will open the contactor and thus remove high voltage from the electrodes.

6.1.13 *Interruptor Contactors, C_{1/8}, C_{1/4}, C_{1/2}*—Normally-open spring contactors, rated at 1 $\frac{1}{4}$ A (or better) and 125 V ac. These contactors are operated by the interrupted cams, thus closing and opening the primary circuit and providing the intermittent arc cycles listed in Table 1.⁹

6.1.14 *High Voltage Switch, S₄*—A single-pole, single-throw switch insulated for 15 000 V ac. This switch must be isolated from the operator by a suitable enclosure through which projects an insulating handle of sufficient length to ensure operator safety.

⁹ Microswitch contactors available from Micro Switch, a Division of Minneapolis Honeywell Regulator Co., Freeport, IL, have been found satisfactory.

6.1.15 *Wiring*—All wiring in the arc circuit must be of ignition wire rated at 15 kV or higher, and must be so disposed that it and any circuit components are not readily accessible when energized.

6.1.16 *Sharpening Jig for Tungsten Rod Electrodes*—A steel jig for securing the electrodes during sharpening to ensure finishing the pointed tips to the proper geometry (see Fig. 2).

6.1.17 *Stainless Steel Strip Electrodes*—Cut 0.006 in. (0.15 mm) thick stainless steel into $\frac{1}{2}$ by 1 in. (12.7 by 25.4 mm) strips. (The edges must be free of burrs.) Bend each strip slightly in the middle of the long dimension to form an angle of approximately 160° (see Fig. 3).

6.1.18 *Tungsten Rod Electrodes* (see 5.2 for restrictions)—Make the electrodes from $\frac{3}{32}$ in. (2.4 mm) diameter tungsten rod (tungsten welding rod has been found suitable) which is free of cracks, pits, or rough spots. Use rods about 1 $\frac{3}{4}$ in. (45 mm) long in the electrode assembly, or use shorter rod lengths fastened into a square shank (see Fig. 4) by swaging, brazing, or silver soldering, leaving an exposed length of about $\frac{3}{4}$ in. (19 mm). The shank ensures correct orientation of the electrode point after sharpening (see 9.2.2), although correct orientation of the simple rod electrode may be obtained by adjustment of the rod in the electrode assembly. In either type of rod electrode, grind the end of the rod at a 30° angle to the axis (see Fig. 4) to achieve a flat elliptical face. Exercise care in grinding to prevent cracking or chipping.



FIG. 2 Grinding and Polishing Block with Tungsten Rod Electrode in Place

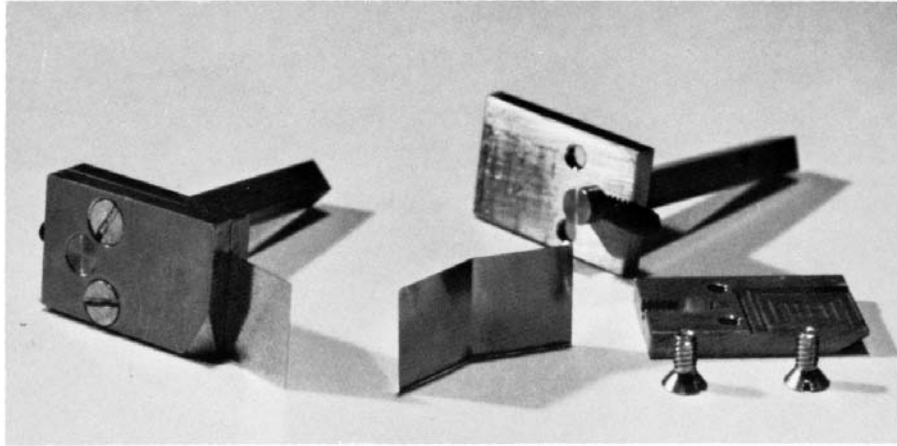


FIG. 3 Strip Electrodes and Holders

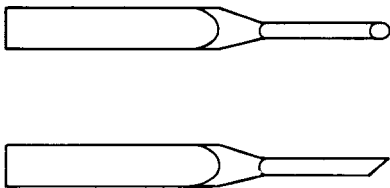


FIG. 4 Top and Side Views of Tungsten Rod Electrode

6.1.19 *Electrode Assemblies*—These assemblies provide a means of holding the electrodes and specimen and of applying the arc to the top surface of the specimen. Construct each assembly, whether for stainless steel strip electrodes or for tungsten rod electrodes, so that the top surface of each specimen is at the same level height. Provide ample air space below the specimen, especially in the region directly below the test area. Adjust each electrode so that it rests independently with a force of 50 ± 5 g on the top of the specimen. Provide a transparent shield around the assembly to protect the specimen from air drafts, and allow venting of combustion products in cases where specimens give off toxic smoke or gases during the test. Protect the operator from inadvertent contact with the electrodes, and provide a clear view of the arc from a position slightly above the plane of the specimen.

6.1.19.1 *Stainless Steel Strip Electrode Assembly* (see Fig. 3, Fig. 5, Fig. 6, and Fig. 7)—Place two stainless steel strip electrodes on the top of the specimen surface with the corners down and spaced 0.250 ± 0.003 in. (6.35 ± 0.08 mm) apart, and at angles of 45° to a line joining the corners. Either use an electrode holder such as the one in Fig. 3, Fig. 6, and Fig. 7, or use the rod electrode assembly with the rods separated and resting on the stainless steel strip electrodes.

6.1.19.2 *Tungsten Rod Electrode Assembly* (see Fig. 4 and Fig. 8)—Position the electrodes so that they lie in the same vertical plane and are both inclined 35° from the horizontal (thus inclined 110° between their axes). Check to see that the minor axes of the elliptical tip surfaces are horizontal, and space the tips 0.250 ± 0.003 in. (6.35 ± 0.08 mm) apart. The proper orientation will automatically be obtained if the following factors are controlled: (a) axis of tungsten rod is perpendicular to the axis of the support rod, (b) support rods are

gripped in the pivot blocks in a position such that the axis of each electrode is inclined at 35° when the support rods are horizontal, (c) electrodes are mounted in square shanks and sharpened in a correctly made jig, and (d) the spacing between electrode tips is adjusted with the support rods in a horizontal position. If electrodes are not mounted in square shanks, obtain proper orientation by adjusting and rotating the electrodes after they are inserted in the appropriate electrode assembly.

7. Safety Precautions

7.1 *Lethal voltages may be present during this test. It is essential that the test apparatus, and all associated equipment that may be electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts that any person might come in contact with 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; may have acquired an induced charge during the test; may retain a charge even after disconnection of the voltage source. Thoroughly instruct all operators in the proper way to conduct tests safely. When making high voltage tests, particularly in compressed gas or in oil, the energy released at breakdown may 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.*

8. Specimens and Number of Tests

8.1 For standard comparison of materials, test at least five specimens 0.125 ± 0.010 in. (3.17 ± 0.25 mm) in thickness. Make each test on a flat surface of the specimen, with each test area not closer than $\frac{1}{4}$ in. (6.4 mm) to the specimen edge nor closer than $\frac{1}{2}$ in. (12.7 mm) to a previously tested area. Test thin materials by first clamping them together tightly to form a specimen as close as possible to the recommended thickness.

8.2 When testing molded parts, apply the arc to a location deemed most significant. Make all comparison tests of parts in similar locations.

8.3 Dust, moisture, or finger marks can affect the time required to track. If affected, clean specimens or parts with a

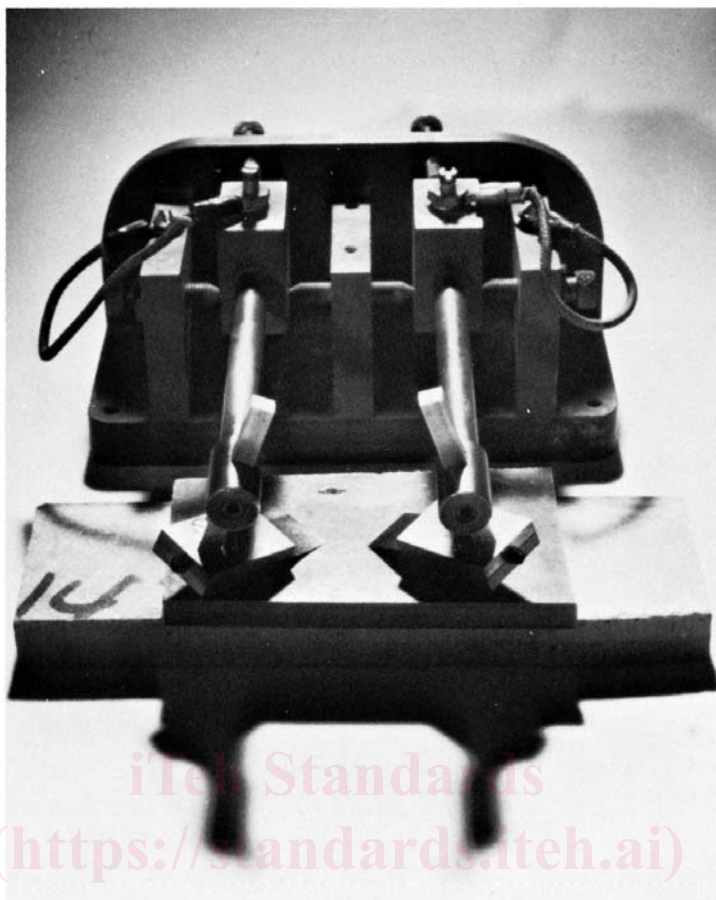


FIG. 5 Strip Electrodes in Place

cloth containing water or other suitable solvent before conditioning. Wipe such specimens with a dry cloth immediately before testing.

NOTE 6—If the purpose of the test is to ascertain the effect of contamination, these instructions may be disregarded. However, state the nature and quantity of contaminant present (if known) in the report.

9. Cleaning and Sharpening Electrodes

9.1 *Stainless Steel Electrodes*—Use two new corners of the stainless steel strip electrodes for each test. Replace electrodes after four tests. Other than inspecting the electrode corners to be sure that they are free of burrs, no cleaning or sharpening is required.

9.2 *Tungsten Rod Electrodes:*

9.2.1 If excessive accumulations of products of decomposition occur, clean the rod electrodes gently with laboratory tissues. The application of a continuous 40 mA arc for approximately 1 min (without a specimen in place) often proves to be the most effective technique of cleaning the electrodes.

9.2.2 Sharpen the tungsten rod electrodes when examination of the tip edge shows that it has been rounded to a diameter of 0.030 in. (0.08 mm), or when burrs or rough edges are observable at 15 \times magnification. First, polish the rod surface by rotating it on its axis using successive grades of emery paper (from No. 1 to 000) held between the fingers. Then mount the

electrode in the sharpening jig (see Fig. 2) with its elliptical face flush with the surface of the jig. Hold the surface against a rotating polishing disk or rub against a stationary machinist's flat, using No. 1 to No. 000 emery or emery paper to make successive cuts. The resulting elliptical face should be a highly polished surface inclined at $30 \pm 1^\circ$ to the axis of the electrode. The electrodes are considered properly sharpened and polished when no burrs or rough edges are observable at 15 \times magnification.

10. Calibration

10.1 With the circuit connected as shown in Fig. 1, calibrate the test apparatus for correct voltage and current as follows:

10.1.1 In making these calibrations, the operator necessarily comes into contact with the high voltage wiring of the secondary circuit. It is therefore imperative that the circuit be de-energized by opening S_1 before each change in connection is made.

10.1.2 *Open Circuit Operating Voltage*—Attach an electrostatic voltmeter across the secondary of T_v . With S_4 open and S_{10} and S_1 closed, initially adjust the autotransformer, T_a , to provide an open circuit operating voltage of 12 500 V.

10.1.3 *Adjustment of Secondary Current*—With the correctly spaced electrodes resting on a lava or ceramic block and with the draft shield closed, close switches S_1 , S_4 , and S_{10} . Adjust R_{10} to give the required current of 10 mA as indicated