Designation: B667 – 97 (Reapproved 2014)

# Standard Practice for Construction and Use of a Probe for Measuring Electrical Contact Resistance[1]

This standard is issued under the fixed designation B667; 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.

## 1. Scope

1.1 This practice describes equipment and techniques for measuring electrical contact resistance with a probe and the presentation of results.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *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 become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet (MSDS) for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

B542 Terminology Relating to Electrical Contacts and Their Use

## 3. Terminology

3.1 *Definitions*—Many terms used in this practice are defined in Terminology B542.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *contact resistance, n*—the resistance to current flow between two touching bodies, consisting of constriction resistance and film resistance.

3.2.1.1 *Discussion*—Constriction resistance originates in the fact that mating surfaces touch in most cases at only their high spots, which are often called "asperities" or, more commonly, *a-spots*. The current flow lines are then forced to constrict as they funnel through these tiny areas. If oxide films or other insulating layers interfere with these metal-to-metal contacts, the contact resistance will be higher than when such layers are absent (see 4.4 for bulk resistance limitation).

3.2.2 *contact resistance probe, n*—an apparatus for determining electrical contact resistance characteristics of a metal surface. *Probe*, in this instance, should be distinguished from the classical tool whose function it is to touch or move an object.

## 4. Significance and Use

4.1 Electrical contact resistance is an important characteristic of the contact in certain components, such as connectors, switches, slip rings, and relays. Ordinarily, contact resistance is required to be low and stable for proper functioning of many devices or apparatus in which the component is used. It is more convenient to determine contact resistance with a probe than to incorporate the contact material into an actual component for the purpose of measurement. However, if the probe contact material is different from that employed in the component, the results obtained may not be applicable to the device.

4.2 Information on contact resistance is useful in materials development, in failure analysis studies, in the manufacturing and quality control of contact devices, and in research.

4.3 Contact resistance is not a unique single-valued property of a material. It is affected by the mechanical conditions of the contact, the geometry and roughness of contacting surfaces, surface cleanliness, and contact history, as well as by the material properties of hardness and conductivity of both contacting members. An objective of this practice is to define and control many of the known variables in such a way that valid comparisons of the contact properties of materials can be made.

4.4 In some techniques for measuring contact resistance it is not possible to eliminate bulk resistance, that is, the resistance of the metal pieces comprising the contact and the resistance of the wires and connections used to introduce the test current into the samples. In these cases, the measurement is actually of an overall resistance, which is often confused with contact resistance.

[1] This practice is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.11 on Electrical Contact Test Methods.

Current edition approved Oct. 1, 2014. Published October 2014. Originally approved in 1980. Last previous edition approved in 2009 as B667 – 97 (2009). DOI: 10.1520/B0667-97R14.

[2] 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.

## 5. General Description of a Probe

5.1 A probe generally includes the following:

5.1.1 Fixtures for holding specimens of varied size and shape and for attaching electrical leads to them.

5.1.2 A mechanism that applies a measurable load to the specimen that can be increased, decreased, or held constant.

5.1.3 A shock mounted table to prevent any indigenous vibrations from inadvertently altering the conditions at the contact interface.

5.1.4 A reference surface (the probe) that is pressed against the specimen and which is normally made of a noble metal. Noble metals such as pure gold are used because they are substantially free of oxide films and have the best likelihood of obtaining reproducible results.

5.1.5 A current source with current and voltage measuring instrumentation for determining contact resistance. Ordinarily, contact resistance is determined at dry circuit conditions[3] to avoid changes that may occur due to voltage breakdown or heating at the contact interface.

5.2 Additional electrical circuitry may be included to permit related measurements to be obtained, such as the voltage breakdown or the current versus voltage characteristics of film-covered surfaces.

5.3 Probes are also convenient for determining the dependence of contact resistance on sliding or *wipe* when a slide is incorporated in the specimen holder. This permits the probe to be moved small measurable distances after loading.

## 6. Design Aspects

6.1 The probe is mounted on one end of a pivoted beam, a cantilever, or a coil spring. Force is applied by dead weight, compression of the spring, bending of the cantilever, or electromagnetically.

6.2 Probe holders have been designed so that force may be applied to the contact and to an electronic load cell which is mounted between the probe contact and a micrometer spindle that can be advanced. An alternative design is to mount the specimen on the load cell and to advance the probe directly with the micrometer spindle. Load and contact resistance are the usual parameters measured and recorded simultaneously.

6.3 A probe can be made by mounting a U-shaped free-standing gold wire to the micrometer spindle (see Fig. 1(b)). The load is measured after the probe is observed (preferably electrically) to first touch the specimen from a preliminary calibration (with a load cell) of micrometer advance versus load. In some cases, where very small (to tens of milligrams) forces are used, it may not be necessary to know the load precisely. In such cases, fine (for example, 50-µm diameter), straight, or U-shaped gold or platinum wires can be used as the probe.

6.4 The apparatus must be isolated from vibration to avoid damaging the surface film that may exist at the interface to be evaluated. The slightest movement can translate into extremely large stresses at the tops of small asperities. Likewise, bounce should be avoided when touching the probe to the specimen. Vibration may reveal itself as a noisy signal when contact resistance is continuously monitored electronically.

6.4.1 For sensitive surfaces, a preliminary run should be made on as-received (uncleaned) test specimens of the same surface material as the samples to be measured. If the vibration-induced fluctuations are greater than 10 %, additional antivibrational measures should be taken.

6.4.2 Wipe should not be introduced when contact resistance versus load characteristics are being measured, since as little as a few micrometers of lateral movement can drastically change the contact resistance of samples having films.

NOTE 1—Some variation of contact resistance with time under load has been found to occur for many materials.[4] It is therefore recommended that, for continuously monitored runs, the resistance at the final applied load should also be recorded after a fixed dwell time, usually 10 to 30 s.

6.5 The power supply shall be capable of delivering a pulse-free source under dry circuit conditions. To avoid errors that may arise due to contact potentials and thermal EMF's all d-c measurements should be taken with forward and reverse voltages and the results averaged. Measurements taken with low frequency a-c sources automatically compensate for this error.

## 7. Requirements of the Probe Contact

7.1 The probe is normally made with a pure gold surface, although other noble metals can be used. The probe should be smooth and have a large radius of curvature to minimize the possibility that it may damage the specimen surface. An exception to this latter recommendation are the wire probes that are generally designed for low normal loads (6.3).

7.1.1 One early probe design[5] that has seen much use is a 3.2-mm diameter solid gold rod having a hemispherical end. Such probes have been used extensively to loads of 10 N. They can be made by machining gold rods to finish dimensions, followed by burnishing with a glass microscope slide or other hard smooth surface, using care to maintain the radius of the end.

7.1.2 Other common probe types are solid gold rivets coined to a spherical end, with a radius of curvature of 1.6 mm, as well as balls or hemispheres of similar radius of curvature. Pure gold platings have also been used successfully on these spherical surfaces.

7.1.3 In special cases, materials other than noble metals and shapes other than spherical may be used. However, contact resistances obtained in these cases will usually be different from those obtained with spherical gold probes, especially if the specimen is film-covered.[6]

NOTE 2—In certain cases, it is of interest to use probes of metals similar

[3] See Test Methods B539, Measuring Contact Resistance of Electrical Connections (Static Contacts), in the *Annual Book of ASTM Standards*, Vol 03.04.

[4] Sproles, E. S. and Drozdowicz, M. H., "Development of an Automatic Contact Resistance Probe," *Proceedings of the 14th International Conference on Electric Contacts*, Paris, June 1988, pp. 195–199.

[5] For example, Antler, M., Auletta, L. V., and Conley, J., "An Automated Contact Resistance Probe," *Review Science Instruments* , Vol 34, 1963, p. 1317.

[6] See, for example, Antler, M., "Contact Resistance of Oxidized Metals: Dependence on the Mating Material," *IEEE Trans. on Components, Hybrids, and Manufacturing Technology*, Vol 10, pp. 420–424, 1987.

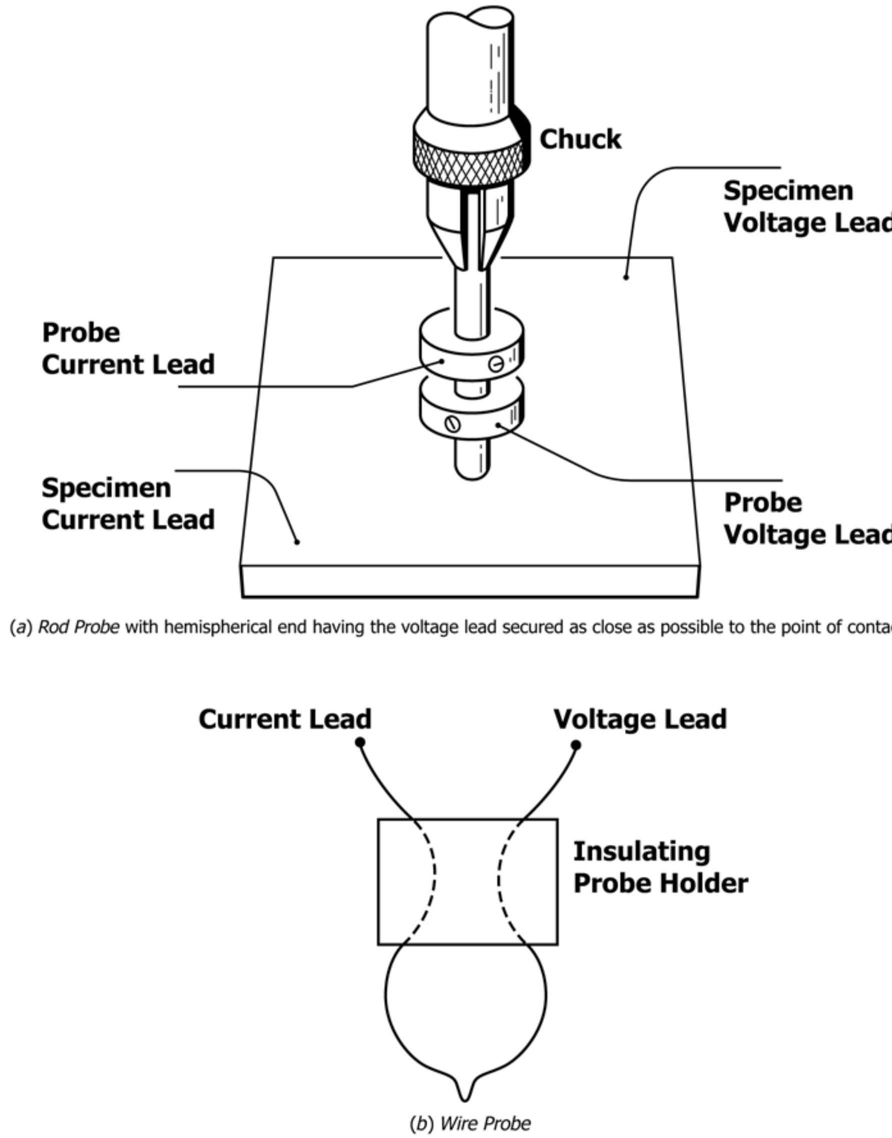


**FIG. 1 Arrangement of Current and Voltage Leads to Probe and to Specimen (Typical)**

or identical to metals or platings of the test specimen. Probing with similar metals is a procedure of particular practical interest.

7.2 When rods are used as probes, a newly fixtured probe contact should be loaded and unloaded ten times against a hard, clean, smooth surface such as an optical flat to obtain an equilibrium shape, an end that is slightly flattened, before using it to measure contact resistance. The force used should be the maximum that will be employed in subsequent use of the probe.

7.3 Alternatively, the chuck holding the rod, rivet, or ball may be mounted in a stable position 10 to 15° from the perpendicular. By this or similar means, a repositioning step for each contact resistance measurement will provide a fresh area on the probe (without preconditioning against the optical flat).

7.4 Fig. 1 illustrates different *4-wire* methods for fastening current and voltage leads to the probe and specimen that minimize (Fig. 1(a)) or eliminate (Fig. 1(b)) their bulk resistance contributions to the measured value.

7.5 Transfer of nonmetallic film from the sample to the probe may occur. Therefore, if fresh areas on the probe are not used in accordance with 7.3, the tip may have to be wiped clean frequently, for example, with lens tissue that has been moistened with isopropyl alcohol or other appropriate solvent. Pressurized propellents, such as fluorocarbons or propane, should be avoided as they may chill the sample and introduce contaminations of their own. Other cleaning techniques can also be used.[4]

7.5.1 Metallic transfer to the gold probe surface has been observed when soft metals, such as tin and tin-lead alloys, are examined. This occurrence may affect the results of subsequent probings. In these cases, an organic solvent will not be adequate for cleaning the probe tip. Other cleaning procedures are required, or else the probe tip should be renewed or the probe area changed, if possible.

NOTE 3—With the solid gold rod probe, cleanliness is verified by determining the contact resistance of a reference smooth noble metal specimen, such as a freshly abraded solid gold flat, and comparing the contact resistance with known values of resistance. These determinations are best made at smaller loads than are used in the measurements of the materials themselves. It is a good practice to periodically check the repeatability, or ability of the probe to give similar contact resistances, by probing a reference specimen having a thin, compact film. This provides an excellent check of the integrity of the probe tip and the mechanical and electrical functioning of the instrument. Some examples of film-covered *references* are given in Appendix X1. In working with film-covered standards to check measurement consistency, it is necessary to determine contact resistance repeatedly, for example, by probing the standard ten or more times, and to compare the median values and their spread at several loads.

7.5.2 It is good practice to remove contaminants from the surface of the test specimen prior to testing, unless the existence of the contaminant(s) is pertinent to the test. Examples of the latter would arise in the measurement of field-exposed surfaces or in investigations of the contact properties of lubricant- or inhibitor-covered samples.

## 8. Presentation of Results

8.1 Contact resistance values vary at different locations on the specimen surface, except with uniformly clean, film-free metals. Therefore, many contact resistance determinations should be made at different places on the surface and statistical methods used to present the results. It is common practice to describe contact resistance by any of the following methods:

8.1.1 *Contact Resistance-Load Characteristic Curves Plotted on Logarithmic Coordinates with Medians and Extreme Values or Standard Deviations Indicated at Various Loads*—Each point on such a curve should represent at least six measurements, although ten or more determinations are preferred. This method is especially useful for clean metals or metals having a uniform insulating film.

8.1.2 *Frequency of Failure Versus Load,* that is, the percent of measurements at given loads which exceed a defined resistance criterion. This method is preferred for go-no-go resistance studies.

8.1.3 *At a Given Load, Contact Resistance Probability Distribution Plots or Cumulative Percent Plots, with Logarithmic Coordinates for Contact Resistance Values*—This method is particularly appropriate for field-exposed contact plating with pore corrosion products and related heterogeneous distribution of insulting contaminants.

8.2 Inspection of the samples is often helpful in determining the cause and significance of unusual contact resistance distributions.

## 9. Report

9.1 In reporting the results of probing tests, describe the method used in full detail, including the following:

9.1.1 Probe metal, particularly the surface material, if plated.

9.1.2 The shape and dimension of the probe.

9.1.3 If applicable, the load used to precondition the probe tip (see 7.2).

9.1.4 The normal load(s) at which the contact resistance are being reported. This is required even when resistance versus load measurements are recorded continuously.

9.1.5 Resistance measurement circuitry (a-c or d-c). If d-c is used, the resistance values should be averages of the values obtained from forward and reverse voltages (see 6.5).

9.1.6 Sample description, particularly surface material, if plated, including underplate.

9.1.7 Number of points probed on the sample surface, and the distribution of these points if known.

## 10. Keywords

10.1 contact resistance; electrical contact; gold probe; reliability; resistance probe; wire probe

# APPENDIX

**(Nonmandatory Information)**

## X1. EXAMPLES OF FILM-COVERED REFERENCED SPECIMENS

X1.1 *Film Covered Reference Specimens*, for assuring the repeatability of measurements with solid gold rod probes, where the same point on the probe is used for more than one area on the test specimen.

X1.1.1 Polished copper coupons, plated with 5 to 20 µm of 65 % Sn 35 % Ni alloy electrodeposit, then aged in air for 2000 h to develop a passive oxide film having a limiting thickness,[7] has been used for this purpose because of its chemical stability and ruggedness as a standard.

X1.1.2 Polished metals such as copper or nickel aged in clean dry air may also be suitable standards, provided that appropriate care is taken to protect such samples from possible changes due to environmental exposure and from handling during use.

[7] Antler, M., "Contact Resistance of Tin-Nickel Alloy Electrodeposits," *Journal Electrochemical Society*, Vol 125, No. 3, 1978, pp. 420–423.