IEC 61189-5-503

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INTERNATIONAL STANDARD

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Test methods for electrical materials, printed board and other interconnection structures and assemblies – Part 5-503: General test method for materials and assemblies – Conductive anodic filaments (CAF) testing of circuit boards

Méthodes d'essai pour les matériaux électriques, les cartes imprimées et autres structures d'interconnexion et ensembles – Partie 5-503: Méthode d'essai générale pour les matériaux et les assemblages – Essais des filaments anodiques conducteurs (CAF) des cartes à circuits

IEC 61189-5-503:2017-05(en-fr)

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Méthodes d'essai pour les matériaux électriques, les cartes imprimées et autres structures d'interconnexion et ensembles – Partie 5-503: Méthode d'essai générale pour les matériaux et les assemblages – Essais des filaments anodiques conducteurs (CAF) des cartes à circuits

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TEST METHODS FOR ELECTRICAL MATERIALS, PRINTED BOARD AND OTHER INTERCONNECTION STRUCTURES AND ASSEMBLIES –

Part 5-503: General test method for materials and assemblies – Conductive anodic filaments (CAF) testing of circuit boards

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International Standard IEC 61189-5-503 been prepared by IEC technical committee 91: Electronics assembly technology.

This bilingual version (2019-09) corresponds to the monolingual English version, published in 2017-05.

The text of this standard is based on the following documents:

FDIS	Report on voting
91/1433/FDIS	91/1443/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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The French version of this standard has not been voted upon.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61189 series, published under the general title *Test methods for electrical materials, printed boards and other interconnection structures and assemblies*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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TEST METHODS FOR ELECTRICAL MATERIALS, PRINTED BOARD AND OTHER INTERCONNECTION STRUCTURES AND ASSEMBLIES –

Part 5-503: General test method for materials and assemblies – Conductive anodic filaments (CAF) testing of circuit boards

1 Scope

This part of IEC 61189 specifies the conductive anodic filament (hereafter referred to as CAF) and specifies not only the steady-state temperature and humidity test, but also a temperature-humidity cyclic test and an unsaturated pressurized vapour test (HAST).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-1:2013, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-38, *Environmental testing – Part 2-38: Tests – Test Z/AD: Composite temperature/humidity cyclic test*

IEC 60068-2-66, *Environmental testing – Part 2: Test methods – Test Cx: Damp heat, steady state (unsaturated pressurized vapour)*

IEC 60068-2-67, *Environmental testing – Part 2: Tests – Test Cy: Damp heat, steady state, accelerated test primarily intended for components*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60194, *Printed board design, manufacture and assembly – Terms and definitions*

IPC-TM-650 No.2.6.14.1, *Electrochemical Migration Resistance Test [viewed 2017-01-31]. Available at: https://www.ipc.org/TM/2-6_2-6-14-1.pdf*

IPC-TM-650 No.2.6.25, *Conductive Anodic Filament (CAF) Resistance Test: X-Y Axis [viewed 2017-01-31]. Available at: https://www.ipc.org/4.0_Knowledge/4.1_Standards/test/2-6-25.pdf*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60194 and IEC 60068-1 as well as the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

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- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
electrochemical migration
degradation of insulation characteristics between conductors due to eletrochemical elution of ions in a humid environment when voltage is applied to conductors of a printed wiring board

Note 1 to entry: In addition, ionic impurities present in the insulations contribute to their degradation.

Note 2 to entry: Electrochemical migration may take the forms of dendrite (3.2) and CAF(3.3).

3.2
dendrite
metal migration

Note 1 to entry: Dendrite is visible in that it creates a branching and tree like structure on the surface, on the interface between layers, etc. of a printed wiring board.

3.3
CAF
conductive anodic filament
migration which occurs along the monofilament of reinforcing material such as glass cloth in an inner layer part of a printed wiring board

3.4
HAST
highly accelerated temperature and humidity stress test
stress test under unsaturated pressurized vapour test

Note 1 to entry: See IEC 60068-2-66.

3.5
automatic insulation resistance measurement
measurement to take continuous or predetermined periodic test data using an automatic measurement system without an operator

3.6
manual insulation resistance measurement
measurement to take predetermined periodic test data using measurement equipment by an operator

Note 1 to entry: Measurement can be done with or without taking out a specimen from the test chamber.

3.7
test voltage
voltage to apply on the specimen as a stress in the testing environment

3.8
measuring voltage
voltage to apply on the specimen in order to measure the insulation resistance

4 Testing condition

4.1 Standard condition

Measurement is performed under the standard atmospheric condition which is specified in Clause 4 of IEC 60068-1:2013.

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It depends on a reference condition stated in 4.2 when an ambiguity is found for the judgment in the standard atmospheric condition or when it is required in particular.

It may be performed under other conditions than the standard atmospheric condition, when no doubt about the judgment subsits and when measuring in standard condition proves difficult, or when specified in particular specifications.

4.2 Judgment state

Reference condition is the standard atmospheric condition for measurement as stated in 4.2 of IEC 60068-1:2013.

5 Specimen

5.1 Outline of CAF test vehicle design

5.1.1 Evaluation design for the glass cloth direction

The in-line test combs are comprised of a series of alternate rows of via holes with a voltage applied across the comb. They represent the most common failure sites where CAF can occur: between via hole walls. The via holes are in line with one another and in alignment with the woven glass fibre reinforcement. The closest point between each via pair is the most likely point for CAF growth (example highlighted in Figure 1). The black spots represent the drilled hole, and the copper pads associated with the via holes are in orange.

The construction of staggered combs is similar to that of the in-line combs, however, the via pairs are arranged at 45°. This means that the most likely route for potential CAF growth is longer since the orientation of the glass fibres may only permit growth in the horizontal and vertical directions (as represented by the white ellipses in Figure 2).

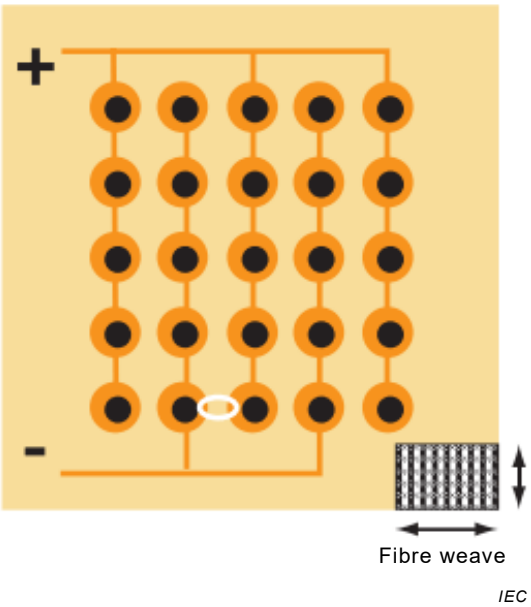

Figure 1 – Schematic of in-line test comb, with possible failure site

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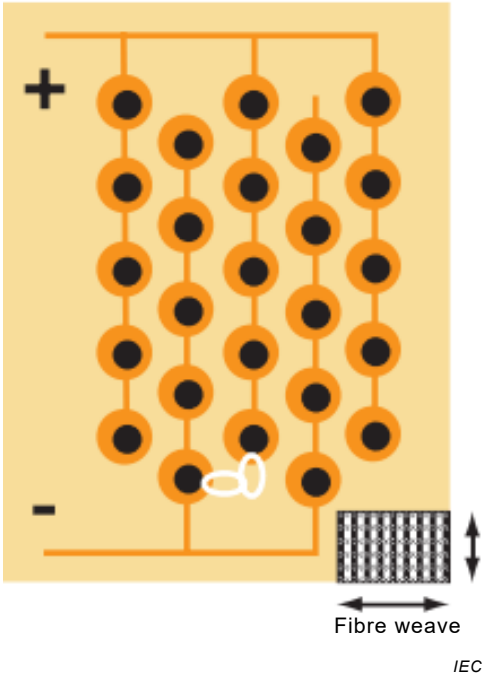

Figure 2 – Schematic of staggered test comb, with possible failure site

"Manhattan distance" is the shortest orthogonal distance along the X- and/or Y- axes lines between adjacent drilled hole features (corresponds to the orthogonal nature of the laminate material's woven glass fibre reinforcement (Figure 3).

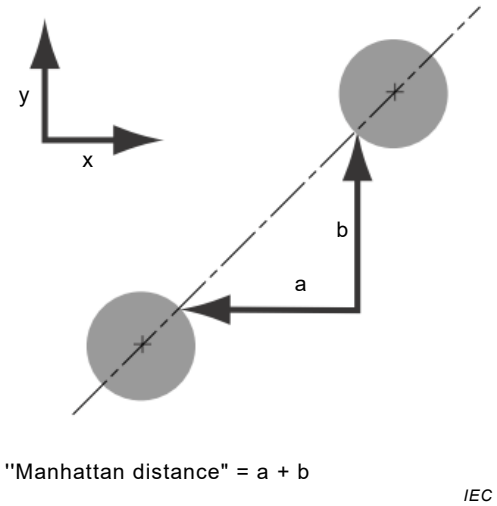

Figure 3 – Manhattan distance

5.1.2 Design between plated through hole (PTH)

a) Without inner layer pattern

Example design between PTH without inner layer pattern is shown in Figure 4, which is a schematic cross-section of a via pair.

NOTE The gap is taken from the edge of the copper. Copper thickness on the hole wall is approximately 50 µm per side.

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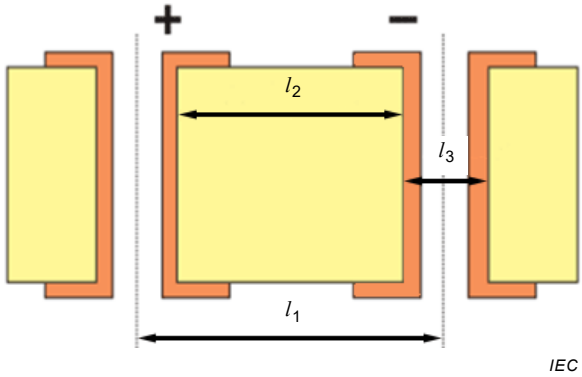

Key

l_1 via pitch

l_2 via to via distance

l_3 via diameter

Figure 4 – Schematic section of via pair with bias

b) With inner layer pattern

There are two designs. One is the design of inner layer via pads and layers as shown in Figure 5. The other is the design of no inner layer via pads and layer patterns as shown in Figure 6.

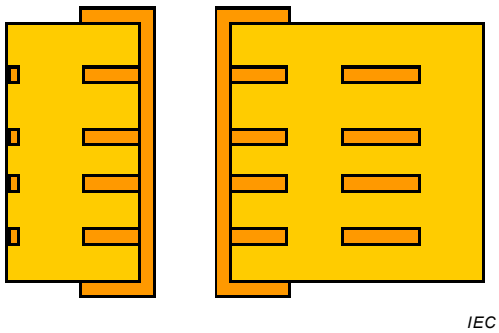

Figure 5 – Example of inner layer via pads and layer patterns

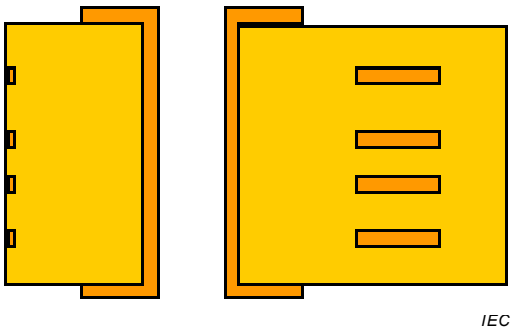

Figure 6 – Example of no inner layer via pads and layer patterns

5.2 CAF test board

5.2.1 Example A

This design is based on 5.1. Evaluation of insulation between through-holes is made using the lattice-like pattern of through-holes as illustrated in Figure 7. The diameter of holes is kept

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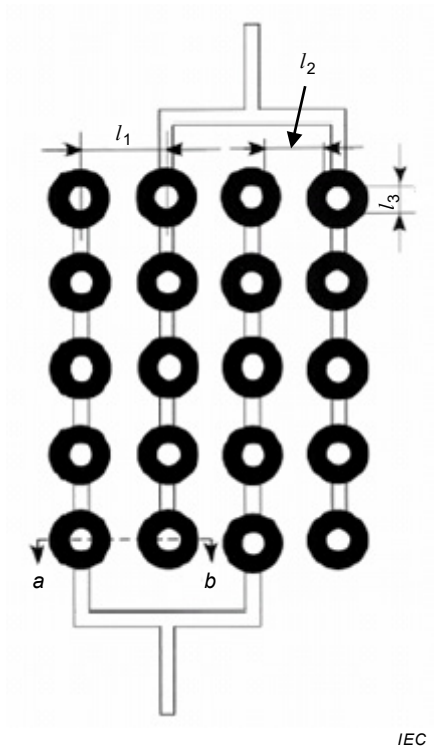
constant. Dimensions of the holes are specified in Table 1. There should be more than five holes on a line in the pattern. The number depends on an agreement between the user and supplier concerned.



Key

l_1 via pitch

l_2 via to Via distance

l_3 via diameter

a and b cross-section

Figure 7 – Insulation evaluation pattern for through-holes and via holes

Table 1 – Dimension of insulation evaluation pattern for through-holes

Via diameter (l_3) (µm)	300					
Via to via distance (l_2) (µm)	150	200	250	300	350	400
Via pitch (l_1) (µm)	450	500	550	600	650	700
Pattern arrangement	n holes × 4 rows (n: ≥ 5)					

5.2.2 Example B

The IPC-9253 and IPC-9254 have 10 layers, and dimensions are approximately 125 mm × 175 mm. Test board designs for evaluating CAF resistance shall have varying drilled hole wall to drilled hole wall distances for plated holes. These distances can range from as low as 0,15 mm separation for alternate laminate materials expected to have very high CAF resistance and minimal copper wicking out from the plated-through hole (PTH), to as high as 0,89 mm separation for evaluating press-fit connector applications. The drilled hole size, rather than the finished hole size, is specified in the chart on the bare board fabrication drawing to ensure consistent spacing.

Internal layer thieving may be added to plane layers around the perimeter. Test boards should be manufactured so that the machine/grain direction of the woven fibre reinforcement is

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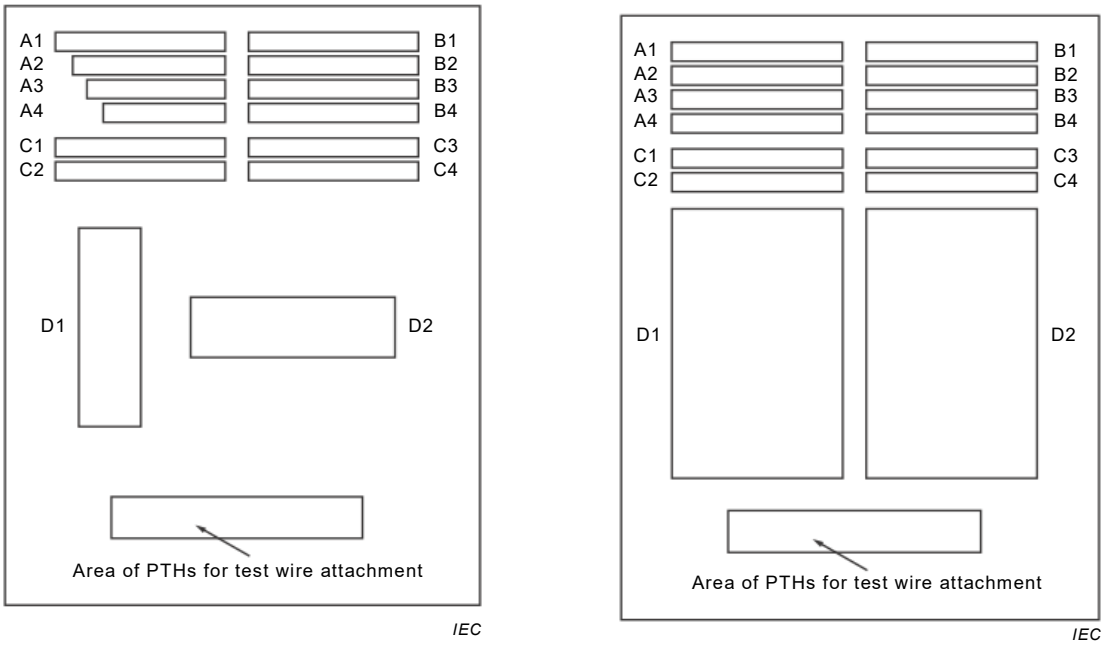
perpendicular to the rows of same-net daisy chain vias for A1 to A4 (machine/grain direction tends to fail first).

Test board designs shall have sufficient minimum spacings on outer layers to ensure that surface insulation resistance failures do not occur. Layouts of the IPC-9253 and IPC-9254 test board structures (CAF test boards) are shown in Figure 8. The test board design rules are listed in Table 2 and Table 3.



a) IPC-9253 **b) IPC-9254**

Figure 8 – Layouts of the two versions of the CAF test boards

Table 2 – Test structures A1 through A4 design rules

	A1	A2	A3	A4
Outer layer pad size	0,86 mm (0,033 9 in)	0,81 mm (0,031 9 in)	0,75 mm (0,029 5 in)	0,69 mm (0,027 2 in)
Inner layer pad size	0,86 mm (0,033 9 in)	0,81 mm (0,031 9 in)	0,75 mm (0,029 5 in)	0,69 mm (0,027 2 in)
Drilled hole size	0,74 mm (0,029 1 in)	0,63 mm (0,024 8 in)	0,51 mm (0,020 1 in)	0,37 mm (0,025 6 in)
Via edge to via edge (shortest distance)	0,27 mm (0,010 6 in)	0,38 mm (0,015 0 in)	0,51 mm(0,020 1 in)	0,65 mm (0,025 6 in)
Via edge to via edge (Manhattan distance)	0,27 mm (0,010 6 in)	0,38 mm (0,015 0 in)	0,51 mm (0,020 1 in)	0,65 mm (0,025 6 in)
On IPC-9254 only, bias applied between:	J1, J5	J2, J5	J3, J5	J4, J5

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Table 3 – Test structures B1 through B4 design rules

	B1	B2	B3	B4
Outer layer pad size	0,94 mm (0,037 0 in)	0,89 mm (0,035 0 in)	0,84 mm (0,033 0 in)	0,75 mm (0,030 0 in)
Inner layer pad size	0,94 mm (0,037 0 in)	0,89 mm (0,035 0 in)	0,84 mm (0,033 1 in)	0,75 mm (0,029 5 in)
Drilled hole size	0,81 mm (0,031 9 in)	0,71 mm (0,028 0 in)	0,57 mm (0,022 4 in)	0,46 mm (0,018 1 in)
Via edge to via edge (shortest distance)	0,26 mm (0,010 2 in)	0,37 mm (0,014 6 in)	0,51 mm(0,020 1 in)	0,62 mm (0,024 4 in)
Via edge to via edge (Manhattan Distance)	0,37 mm (0,014 6 in)	0,52 mm (0,020 5 in)	0,72 mm (0,028 3 in)	0,88 mm (0,034 6 in)
On IPC-9254 only, bias applied between:	J7, J11	J8, J11	J9, J11	J10, J11

5.3 Number of specimens

Number of specimens, test boards or coupons required in a test depends on the purpose of the test, for example for prototypes or for mass produced products. For CAF testing of circuit boards for mass production, a minimum quantity of 25 is needed for statistical reliability analysis. More than 25 specimens may be needed for a test lot in order to provide at least as many opportunities-for-failure as a single production board (see IPC-9691B).

6 Equipment/Apparatus or material

6.1 Environmental test chamber

a) A clean test chamber capable of producing and recording an environment of 65 °C ± 2 °C or 85 °C ± 2 °C at 87 °C ± 2 % RH, and that is equipped with cable access to facilitate measurement cables to be attached to the specimens under test.

b) The temperature and humidity in the chamber can be continuously supplied and not reused, and independently controlled to prevent condensation.

c) Humidification water in the chamber can be continuously supplied and not reused.

d) The condensation water does not drop from the wall and the ceiling in the chamber.

e) Impurities and the residual substances of the previous test shall be removed so as to not affect the test.

f) The chamber should be made of the materials which do not have any influence on the specimen and humidification water.

6.2 Measuring equipment

A high resistance meter equivalent to that described in ASTM D257, with a range up to 10^{12} Ω and capable of yielding an accuracy of ±5 % at 10^{10} Ω with a DC applied voltage of 100 V ± 2 V, or an ammeter capable of reading 10^{-10} A and capable of yielding an accuracy of ±5 % in combination with 100 V ± 2 V DC power supply. The values of resistors used shall be verified by reference resistors traceable to known industry or national standards.

6.3 Power supply

A power supply capable of producing a standing bias potential of 5 V DC up to 100 V DC with a ±2 % tolerance, and current supply capacity of at least 1 A.

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6.4 Current limiting resistors

Tight control of the total current limiting resistance value is critical for this test method. 1 MΩ resistor in series shall be used for each current path. Insert the current limiting resistors in series with the terminating leads going to each test pattern. Note that some test equipment has current limiting resistors built into the testing systems. For the purposes of this standard test, excluding the current limiting resistor and for each CAF test circuit, the total series resistance of the measuring equipment and wires shall not be more than 200 Ω. A lower total resistance value will increase potential for damage to the test board when a CAF failure occurs. A higher total current limiting resistance value for each test net removes test conditions further from actual field conditions and is not recommended.

6.5 Connecting wire

Use PTFE- or PFE-insulated copper wires and solder the copper wire directly to the board to connect test points for each test board to the measurement apparatus.

6.6 Other dedicated fixtures

Hard-wiring is the default connection method. Other dedicated fixtures may be used, provided that the fixture does not change the resistance by more than 0,1 decade compared to a comparable hard-wired system when measured at the test conditions. These fixtures should be checked for their resistance values frequently. The colour of the leads connected to plus and minus electrodes of the measuring equipment should be changed. Usually red is used for the cable connected to the plus terminal and black to the minus terminal.

7 Resistance measurement method

7.1 Manual insulation resistance measurement method

The resistance measuring unit can measure the resistance range of 10^6 Ω to 10^{12} Ω. Figure 9 illustrates an example of a manual measuring system in the chamber, using an insulation resistance meter. This measuring system has a built-in power source, can select the test voltage and the measuring voltage arbitrary, and is capable of resistance measurement of up to 10^{13} Ω using double shielded cables and a shielded test chamber.

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