



Designation: D6120 – 97 (Reapproved 2017)<sup>ε1</sup>

# Standard Test Method for Electrical Resistivity of Anode and Cathode Carbon Material at Room Temperature<sup>1</sup>

This standard is issued under the fixed designation D6120; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>ε1</sup> NOTE—Units formatting was corrected editorially in February 2017.

## 1. Scope

1.1 This test method covers the determination of the electrical resistivity at room temperature of solid cylindrical specimens cored from commercial sized carbon anodes and cathodes. This test method also applies to samples from carbon blocks prepared in a laboratory.

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 establish appropriate safety and health practices and determine the applicability of regulatory limitation prior to use.* For specific warning information, see .

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

[C611 Test Method for Electrical Resistivity of Manufactured Carbon and Graphite Articles at Room Temperature](#)

[D5502 Test Method for Apparent Density by Physical Measurements of Manufactured Anode and Cathode Carbon Used by the Aluminum Industry](#)

## 3. Terminology

3.1 *Definitions:*

3.1.1 *electrical resistivity, n*—the electrical resistance offered by a material to the flow of current, times the cross-sectional area of current flow and per unit length of current

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.05 on Properties of Fuels, Petroleum Coke and Carbon Material.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

path, the reciprocal of conductivity. It is also known as resistivity, or specific resistance.<sup>3</sup>

## 4. Summary of Test Method

4.1 An electrical current is passed through a carbon cylinder and the voltage drop or electrical resistance is measured between two points along its length. The resistivity is calculated based on the voltage drop or electrical resistance, distance between the two points, and the cross-sectional area of the cylinder.

4.2 This test method are used to determine electrical resistivity for various carbon materials typically found in the aluminum industry. Electrical resistivity of other carbon artifacts such as graphite and specialty carbons is more appropriately determined by Test Method C611.

## 5. Significance and Use

5.1 The electrical resistivity of anode and cathode carbon material is important for efficient aluminum cell operation. It is a quality parameter that determines the suitability of an anode/cathode for operation in an aluminum cell.

5.2 The electrical resistivity may be selected as a requirement in a customer specification.

## 6. Apparatus

6.1 *Specimen Holder* (Fig. 1), a device for holding a specimen of 50 mm diameter and a minimum of 120 mm in length between two flat copper plates. One of the plates is swivel mounted to ensure good contact in case the ends of the specimen are not perfectly parallel. The plates shall be as large as the ends of the specimen and electrically insulated from each other.

6.1.1 *Voltage Drop Contact Points*—The contact points shall be conical or knife edge in shape and securely fastened to rigid insulating material with a minimum spacing of 50 mm and a maximum spacing of 80 % of the length of the specimen.

<sup>3</sup> Parker, Sybil P., Ed in Chief, *Dictionary of Scientific and Technical Terms*, McGraw Hill Book Co., Fourth Ed., 1989, p 615.

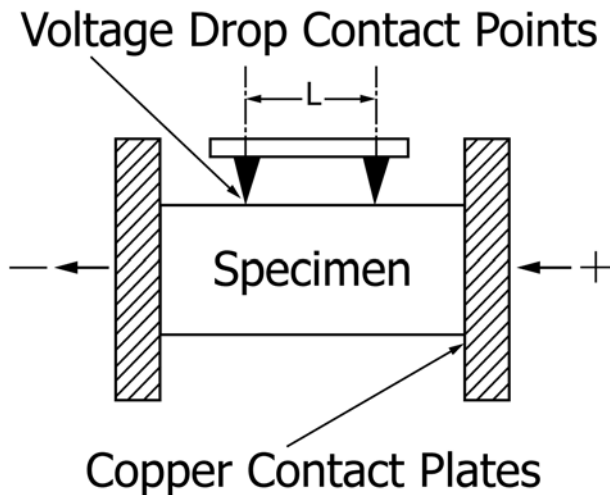


FIG. 1 Schematic of Specimen Holder

The distance (L) in millimetres (mm) between the center of the conical points or knife edges is used when calculating the electrical resistivity.

6.2 *Apparatus for Indirect Resistance Measurement*—(permits measurement of voltage and current needed for calculating electrical resistivity):

6.2.1 *dc Power Supply*—The power supply shall be capable of supplying a minimum dc current of 10 A at an electrical potential of up to 5 V. The line and load regulation shall be less than 0.1 % and background noise less than or equal to 0.1 %.

6.2.2 *dc Voltage Measuring Instrument*, high-impedance device capable of measuring a minimum of 5 V to 0.01 mV.

6.2.3 *dc Current Measuring Device*, a device capable of measuring a current of 10 A to 0.01 A.

6.3 *Apparatus for Direct Resistance Measurement:*

6.3.1 *Electrical Resistance Measuring Device*—A device capable of measuring electrical resistance directly to 0.01 mΩ such as a Kelvin bridge or a Micro-ohmmeter. These devices utilize 4-wire connections (current and voltage) and should not be confused with a volt-ohm-meter. The usual range measured is from approximately 0.1 mΩ to 10 mΩ.

6.4 *Micrometer (or equivalent)*, capable of measuring the dimensions of a specimen to 0.01 mm.

6.5 *Desiccator*, large enough to hold several test specimens (7.4), filled to capacity with a desiccant such as anhydrous calcium sulfate or equivalent.

6.6 *Core Drill*, equipped with a diamond abrasive and capable of producing a 50 mm core sample.

6.7 *Refractory Saw*, with a diamond blade.

## 7. Preparation of Test Specimen

NOTE 1—Specimens prepared for determination of density using Test Method D5502 are acceptable without further preparation.

7.1 Drill a core of 50 mm ( $\pm 1.0$  mm) diameter in the form of a right circular cylinder and use no lubricant having a boiling point above 100 °C.

7.2 Cut a specimen from this core with a minimum length of 120 mm.

7.3 Ascertain by visual inspection that all edges and faces of the specimen are free of chips or gouges. Ensure that the specimen is free of residue from the coring and sawing operations.

7.4 Dry the specimen for a minimum of 2 h at 100 °C; then allow it to cool to 22 °C  $\pm 5$  °C in a desiccator. Store the specimen in a desiccator until immediately prior to testing.

## 8. Procedure

8.1 Test at 22 °C  $\pm 5$  °C.

8.2 *Indirect Resistance Measurement:*

8.2.1 Mount the test specimen in the holder and tighten contact plates firmly to the ends of the specimen.

8.2.2 Apply voltage and adjust current to about 6 A  $\pm 3$  A.

8.2.3 Center the contact points longitudinally on top of this specimen and measure the voltage drop. Move the contact points around the circumference of the cylinder a distance equivalent to an arc length of the circumference subtended by a 45° angle. Make sure contacts are still longitudinally centered and take a voltage reading. Continue moving in the same direction around the circumference until a total of eight equally spaced voltage readings are recorded. (**Warning**—Passing a current through a test specimen for an extended period of time can increase the temperature and consequently lower the resistance of the specimen.)

8.3 *Direct Resistance Measurement:*

8.3.1 Mount the test specimen in the holder and tighten contact plates firmly to the ends of the specimen.

8.3.2 Center the contact points longitudinally on top of the specimen and measure the resistance. Move the contact points around the circumference of the cylinder a distance equivalent to an arc length of the circumference subtended by 45° angle. Make sure contacts are still longitudinally centered and take a resistance reading. Continue moving in the same direction around the circumference until a total of eight equally spaced resistance readings are recorded.

NOTE 2—The current in the specimen when using a direct reading electrical resistance measuring device (such as a Micro-ohmmeter) is lower than when using an indirect resistance measurement device (about 0.1 A versus 3 A to 9 A).

8.4 *Measuring Specimen Diameter:*

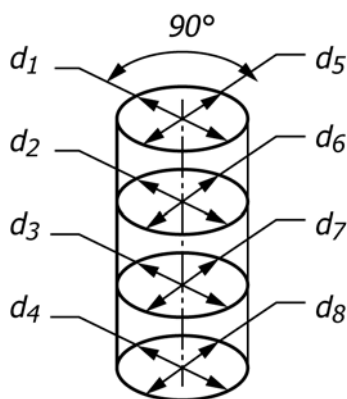
8.4.1 Make two sets of four diameter measurements in millimetres using a micrometer or similar instrument. For the first set record the diameter at both ends and at two equidistant intermediate points along the same plane cutting through the axis. Rotate the plane 90° and record an equivalent set of four readings (Fig. 2).

8.4.2 Determine the quadratic mean diameter using Eq 1.

$$d = \sqrt{\frac{8}{\frac{1}{d_1^2} + \frac{1}{d_2^2} + \dots + \frac{1}{d_8^2}}} \quad (1)$$

where:

$d$  = quadratic mean diameter, mm, and  
 $d_1, d_2, \dots, d_8$  = individual diameter measurements, mm.



**FIG. 2 Measurement of Specimen Diameter**

## 9. Calculation of Resistivity

9.1 Average the eight voltage readings from 8.2.3 or the eight resistance readings from 8.3.2.

9.2 Calculate the cross-sectional area using Eq 2:

$$A = \frac{\pi \times d^2}{4} \quad (2)$$

where:

$A$  = cross-sectional area, mm<sup>2</sup>,

$\pi$  = 3.1416, and

$d$  = quadratic mean diameter, mm (8.4.2).

9.3 If the indirect resistance measurement method (8.2) was used, calculate electrical resistivity using Eq 3:

$$ER = \frac{V \times A}{I \times L} \quad (3)$$

where:

$ER$  = electrical resistivity,  $\mu\Omega\cdot m$ ,

$V$  = average voltage drop, mV (9.1),

$A$  = cross-sectional area, mm<sup>2</sup> (9.2),

$L$  = distance between contact points, mm (6.1.1), and

$I$  = magnitude of electrical current, A (8.2.2).

9.4 If the direct resistance measurement method (8.3) was used, calculate electrical resistivity using Eq 4:

$$ER = \frac{A}{L} \times R \quad (4)$$

where:

$ER$  = electrical resistivity,  $\mu\Omega\cdot m$ ,

$A$  = cross-sectional area, mm<sup>2</sup> (9.2),

$L$  = distance between contact points, mm (6.1.1), and

$R$  = average electrical resistance, milliohms (9.1).

## 10. Report

10.1 Report the following information:

10.1.1 Electrical resistivity to 0.1  $\mu\Omega\cdot m$ .

## 11. Precision and Bias

11.1 The criteria in 11.1.1 and 11.1.2 shall be used for judging the acceptability of results (95 % probability) obtained using a current between 0.1 A and 9 A and in the electrical resistivity range from 12  $\mu\Omega\cdot m$  to 80  $\mu\Omega\cdot m$ . Based upon a round robin testing program<sup>4</sup> using duplicate measurement of 12 samples at 8 laboratories, the following equations represent the expected behavior for these tests.

11.1.1 *Repeatability*—The difference between successive results obtained by the same operator with the same apparatus under constant operating conditions on identical test material would, in the long run, exceed the following values only in one case in twenty.

$$\text{Repeatability} = 0.1780 \times \sqrt{x} \quad (5)$$

where  $x$  = average of the successive results in  $\mu\Omega\cdot m$ .

11.1.2 *Reproducibility*—The difference between single and independent results obtained by different operators working in different laboratories on identical test material would, in the long run, exceed the following values only in one case in twenty.

$$\text{Reproducibility} = 0.6535 \times \sqrt{x} \quad (6)$$

where  $x$  = average of the two results in  $\mu\Omega\cdot m$ .

11.2 *Bias*—Bias of this test method for measuring electrical resistivity has not been determined because, currently, all methods are based on electrical resistance measured within the parameters given in this test method.

## 12. Keywords

12.1 anode; cathode; cathode carbon; conductivity; electrical resistivity; resistivity

<sup>4</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1414. Contact ASTM Customer Service at service@astm.org.

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