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Standard Test Methods for Chemical Resistance and Physical Properties of Carbon Brick[1]

This standard is issued under the fixed designation C1106; 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 These test methods are intended for use as short-term tests for evaluating the physical properties of carbon brick and their chemical resistance at various temperatures in immersion service. These test methods provide a means of determining the following changes in the carbon brick specimen and the test media:

1.1.1 Weight, appearance, and compressive strength of the carbon brick specimen.

1.1.2 Appearance of the test media before, during, and after testing of the carbon brick specimen.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C904 Terminology Relating to Chemical-Resistant Nonmetallic Materials

E4 Practices for Force Verification of Testing Machines

3. Terminology

3.1 *Definitions*— For definitions of terms used in these test methods, see Terminology C904.

4. Significance and Use

4.1 The results obtained by these test methods should serve as a guide in, but not as the sole basis for, the selection of a chemical-resistant carbon brick for a particular application. No attempt has been made to incorporate into these test methods all the factors that may affect the performance of carbon brick when subjected to various actual service conditions.

5. Apparatus

5.1 *Equipment,* capable of weighing materials or specimens to ±0.01 g accuracy.

5.2 *Micrometer or Vernier Caliper* , having a range suitable for measuring brick specimens to within 0.001 in. (0.025 mm).

5.3 *Masonry Saw,* suitably equipped to permit wet cutting (water only) of carbon brick with a diamond edge blade.

5.4 *Constant-Temperature Oven or Liquid Bath,* capable of maintaining temperature within a range of ±4°F (±2°C).

5.5 *Testing Machine,* may be of any type of sufficient capacity that will provide the rates of loading prescribed. It shall have been documented to have an accuracy of ±1.0 %, or better, within 12 months of the time of use in accordance with Practices E4. The testing machine shall be equipped with two steel bearing blocks with hardened faces, one of which is a spherically seated block that will bear on the top bearing plate, and the other a plain rigid block that will support the bottom bearing plate. The diameter of the spherical bearing block shall be at least 75 % of the width of the specimen. The bearing faces shall not depart from a plane by more than 0.001 in. (0.025 mm) in any 6 in. (150 mm) diameter circle.

5.6 *Containers:*

5.6.1 *Wide-Mouthed Glass Jars,* of sufficient capacity, fitted with plastic or plastic-lined metal screw caps or other suitable sealed containers for low-temperature tests involving media of low viscosity.

5.6.2 *Erlenmeyer Flasks,* of sufficient capacity, each fitted with standard-taper joints and a reflux condenser attachment.

5.6.3 *Containers,* as described in 5.6.1 and 5.6.2, having an inert coating on their inner surfaces, or containers of a suitable inert material for use with media which attack glass.

[1] These test methods are under the jurisdiction of ASTM Committee C03 on Chemical-Resistant Nonmetallic Materials and are the direct responsibility on Subcommittee C03.01 on Mortars and Carbon Brick.

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[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.

5.7 *Hot Plate, Heating Mantel, or Pail Heater,* suitable for boiling water.

5.8 *Sander,* suitable for smoothing surfaces.

6. Test Specimens

6.1 The test specimens shall be wet cut using a masonry saw from representative full brick as received from the manufacturer.

6.1.1 All faces of the specimens shall be approximately plane and smooth. Adjacent faces must be normal to each other. If the faces are not suitably plane, smooth, and with adjacent faces normal to each other, the surfaces may be sanded, ground, or machined to specification. Exercise care that the frictional heat developed during such operations does not damage the specimens.

6.1.2 Specimens with scores, trademark indentations, chips, cracks, or other imperfections must be discarded.

6.1.3 The number of test specimens required is set forth in the respective test method.

7. Compressive Strength Test Method

7.1 *Test Specimens*—A minimum of six, 2 in. (50 mm) cube specimens shall be prepared in accordance with Section 6 of this standard.

NOTE 1—When cutting the full brick, the original depth orientation shall be noted on the cube specimens.

7.2 *Measurement of Specimens*—Measure to the nearest 0.001 in. (0.025 mm), the cross-section dimensions of those two opposite faces of the specimen that will be in contact with the upper and lower bearing blocks of the testing machine and thus perpendicular to the load axis. Record the dimensions for each respective specimen.

7.3 *Temperature of Test*—Compression tests shall be performed at 73 ± 4°F (23 ± 2°C).

7.4 *Placing the Specimen:*

7.4.1 Orient the test cube under the load plate of the compression testing machine such that when the load is applied it will be in the direction of the original depth of the brick.

7.4.2 Center the test cube under the load plate of the compression testing machine to within 1⁄16 in. (2 mm) in any direction of true center such that the load is applied to the top or bottom face of the test specimen.

7.5 *Rate of Loading:*

7.5.1 Apply the load continuously and without shock. Test at a uniform rate of 3000 psi (20.7 MPa)/min.

7.5.2 Load the test specimen to failure and record the maximum load (*W*) indicated by the testing machine.

7.6 *Calculations:*

7.6.1 From the dimensions measured in 7.2 for each respective specimen, calculate the areas of the two specimen faces that were perpendicular to the load axis, and then calculate the average area (*A*) of the two.

7.6.2 Calculate the individual compressive strength (*C*) of each specimen as follows:

$$C = W/A \tag{1}$$

where:

C = compressive strength of the specimen, psi (MPa),
W = maximum load, lb (N), and
A = average of the areas of the upper and lower bearing surfaces of the test specimen, in.^{2} (mm^2).

7.6.3 Calculate the average compressive strength in accordance with Section 12.

7.7 *Report:*

7.7.1 Name of brick manufacturer.

7.7.2 Brand name of brick.

7.7.3 Manufacturer's lot number.

7.7.4 Full brick dimensions.

7.7.5 Any defects in the specimens.

7.7.6 Individual and average compressive strength values.

8. Water Absorption

8.1 *Test Specimens*—A minimum of four quarter-brick specimens shall be prepared in accordance with Section 6 of this standard. The four quarter-brick specimens shall be obtained by taking a representative carbon brick and first halving the brick shape lengthwise and then taking these two halves and cutting each of them lengthwise. Of the four respective test specimens prepared, each will have four original faces from the full brick shape before it was cut up and two faces will have been created by sawing the original brick into the four pieces.

8.2 *Preparing the Specimens*—Rinse the four specimens with a fine spray of distilled water. Place the test specimens in a constant-temperature oven set at 216 ± 4°F (102 ± 2°C) until they reach a constant weight. Allow the specimens to cool in a dessicator to 73 ± 4°F.

8.2.1 The constant dry weight of the respective test specimens shall be determined to the nearest 0.01 g after the specimens have cooled to 73 ± 4°F. Record the dry weight (W_D) of each specimen.

8.3 *Test Procedure:*

8.3.1 Place the test specimens in distilled water and boil for 2 h. During the boiling period, keep the specimens entirely covered with water and allow no contact with the heated sides or bottom of the container.

8.3.2 After the boiling period, remove the heat source and allow the specimens to cool to room temperature, 73 ± 4°F (23 ± 2°C). Be sure to keep the test specimens completely covered with water during this cooling down stage.

8.3.3 After cooling, remove and blot each specimen with a damp cotton cloth to remove all liquid droplets from the surface. Excessive blotting will introduce error by withdrawing liquid from the pores of the specimen.

8.3.4 Determine the saturated weight (W_S) of each specimen by weighing each to the nearest 0.01 g.

8.4 *Calculation:*

8.4.1 The water absorption is expressed as a percentage of the dry weight (W_D) of the specimen compared to the saturated weight (W_S) of the specimen calculated as follows:

$$\text{Water Absorption, \%} = \frac{(W_S - W_D)}{W_D} \times 100 \tag{2}$$

where:

W_S = saturated weight of specimen, and
W_D = dry weight of specimen.

8.4.2 Calculate the average water absorption in accordance with Section 12.

8.5 *Report:*
8.5.1 Name of brick manufacturer.
8.5.2 Brand name of brick.
8.5.3 Manufacturer's lot number.
8.5.4 Full brick dimensions.
8.5.5 Any defects in the specimens.
8.5.6 Percent water absorption for each specimen.
8.5.7 Average percent water absorption.

9. Flexural Strength

9.1 *Test Specimens*— A minimum of five test specimens shall be prepared by taking a minimum of three full, rectangular, straight brick which measure either 9 by 4½ by 3 in. (229 by 114 by 76 mm) or 9 by 4½ by 2½ in. (229 by 114 by 64 mm) and cutting them in half lengthwise to produce specimens measuring 9 by 2¼ by 3 in. (229 by 57 by 76 mm) or 9 by 2¼ by 2½ in. (229 by 57 by 64 mm), respectively.

9.2 *Test Procedure:*
9.2.1 Measure the respective depth of all specimens to the nearest 0.001 in. (0.025 mm) using a micrometer or a vernier caliper. Make two measurements near the middle of the specimen's length and average them. This average depth (*d*) will be used in the calculations.
9.2.1.1 Measure the respective width of all of the test specimens to the nearest 0.001 in. using a micrometer or a vernier caliper. Make two measurements near the middle of specimen's length and average them. This average width (*b*) will be used in the calculations.
9.2.2 The testing machine shall be set up to test the specimens in simple bending with two supports and the load being applied by means of a loading nose midway between the supports.
9.2.2.1 The loading nose and the supports shall have cylindrical surfaces. The radius of the nose and the supports shall be at least ¼ in. (6.4 mm).
9.2.2.2 The length of the loading nose and the supports shall be at least equal to the width of the test specimen.
9.2.2.3 The span between the supports shall be 1 ± 0.1 in. (25 ± 0.2 mm) less than the nominal length of the test specimens. The actual span between the supports (*I*) shall be measured and recorded for use in the calculations.
9.2.2.4 Ensure that the supports for the test specimen are free to rotate in the longitudinal and transverse directions of the test specimens, and adjust them so that they will exert no force in these directions.
9.2.3 Center the test specimen flatwise over the supports unless specified and reported otherwise (that is, apply the load in the direction of the depth of the unit) such that the load is applied to the top or bottom face of the test specimen.
9.2.4 Load the test specimens to failure, and record the maximum load (*W*).

9.3 *Rate of Loading:*
9.3.1 *Load Rate I*—Apply the load continuously and without shock. The rate of loading shall not exceed 2000 lbf (8896 N)/min.
9.3.2 *Load Rate II*—Set the crosshead speed of the machine not to exceed 0.05 in. (1.3 mm)/min when the machine is running without load.

9.4 *Calculations:*
9.4.1 The flexural strength (*S*) of each test specimen is calculated as follows:

$$S = 3WI/2bd^2 \quad (3)$$

where:

S = stress in specimen at midspan, lb/in.^{2} (kg/cm^2),
W = maximum load at failure indicated by the testing machine, lbf (N),
I = Distance between the supports, in. (mm),
b = average width of the test specimen, in. (mm), and
d = average depth of the test specimen, in. (mm).

9.4.2 Calculate the average flexural strength in accordance with Section 12.

9.5 *Report:*
9.5.1 Name of brick manufacturer.
9.5.2 Brand name of brick.
9.5.3 Manufacturer's lot number.
9.5.4 Full brick dimensions.
9.5.5 Any defects in the specimens.
9.5.6 Load rate used.
9.5.7 Flexural strength of each test specimen.
9.5.8 Average flexural strength.

10. Chemical Resistance

10.1 *Test Specimens:*
10.1.1 Test specimens shall be 2 in. (50 mm) cube specimens prepared in accordance with Section 6 of this standard.

10.2 The number of specimens required is dependent upon the number of test media to be employed, the number of different temperatures at which testing is performed, and the frequency of test intervals. The test specimens shall consist of sets of a minimum of three, 2 in. cubes for one medium at a single temperature and for each test interval. In addition, prepare other sets of at least three cubes, equivalent to the number of test temperatures, for the total test period. Calculate the total number of specimens required as follows:

$$N = n\,(M \times T \times I) + 6 \quad (4)$$

where:

N = number of specimens,
n = number of specimens for a single test,
M = number of media,
T = number of test temperatures, and
I = number of test intervals.

10.3 *Conditioning*—Rinse the test specimens with distilled water. Place the test specimens in a constant temperature oven set at 216 ± 4°F (102 ± 2°C) until they reach constant weight. Allow the specimens to cool in a desiccator to 73 ± 4°F.

10.3.1 After the conditioning period, the constant dry weight (W_C) of the respective test specimens shall be determined to the nearest 0.01 g. Record the dry weights.

10.3.2 After the conditioning period, measure to the nearest 0.001 in. (0.025 mm), the cross-sectional dimensions of those two opposite faces of the specimen that will be in contact with the upper and lower bearing blocks of the testing machine and thus perpendicular to the load axis. Record the dimensions for each respective specimen.

10.4 *Test Procedure:*

10.4.1 Following the conditioning period, weigh all of the specimens to the nearest 0.01 g, and record the values. Prior to immersion, record a brief description of the color and surface appearance of the specimens and the color and clarity of the test medium. Place the weighed specimens to be immersed in a suitable container or containers taking care to prevent the faces from coming in contact with each other. The total number of specimens per container is not limited except by the ability of the container to hold the specimens, plus the required amount of test medium per specimen. Add approximately 150 mL of the test medium for each specimen, and place the closed container in a constant-temperature oven adjusted to the required temperature or in a suitably adjusted liquid bath. Examine the specimens after 1, 7, 14, 28, 56, and 84 days of immersion to determine the rate of attack.

NOTE 2—Other inspection periods may be employed, and the test may be terminated prior to or extended beyond 84 days if desired.

10.4.2 Clean the specimens by three quick rinses in running cold tap water and quick dry by blotting with a paper towel between each rinse. After the final blotting, allow the specimen to dry for 1 ½ h at 73 ± 4°F and weigh to the nearest 0.01 g. These weights shall be the weights of the specimens after immersion (W_I).

10.4.3 Note any indication of surface attack on the specimen, any discoloration of the test medium or specimen, the formation of any sediment in the container, and any change in pH of the test medium.

10.4.4 *Changing of Test Medium*—Discard and replace the test medium with fresh material after each inspection period. Replace media that are known to be unstable, for example, aqueous sodium hypochlorite, as often as necessary in order to maintain the original composition and concentration.

10.5 *Compressive Strength Determination of Specimens after Chemical Exposure:*

10.5.1 In accordance with subsections 7.2-7.6 of this standard, determine the compressive strength for six control specimens immediately following the conditioning period; for one set of specimens after each inspection period; and for each medium and each test temperature. The elapsed time between the removal of the specimens from the test medium and the compressive tests should be uniform for all specimens.

10.6 *Calculations:*

10.6.1 *Weight Change of Tested Specimens :*

10.6.1.1 Calculate in accordance with the following equation to the nearest 0.01 %, the percentage loss or gain in weight of the specimens during immersion for each examination period, taking the conditioned weight as 100 %.

$$\text{Weight Change, } \% = \frac{[W_I - W_C]}{W_C} \times 100 \qquad (5)$$

where:

W_C = conditioned weight of the specimen, g, and,
W_I = weight of specimen after immersion, g.

NOTE 3—A result showing a plus (+) sign shall indicate a gain in weight and a minus (–) sign shall indicate a loss in weight.

10.6.1.2 Construct a graph employing the average percentage of weight change of all the specimens at a given examination period after immersion in a particular test medium at a given temperature, plotting the percentage of weight change as the ordinate and the test period, in days, as the abscissa.

10.6.2 *Compressive Strength Change of Tested Specimens:*

10.6.2.1 Calculate to the nearest 0.01 %, the percentage loss or gain in compressive strength of the specimens during immersion for each examination period, taking the compressive strength after conditioning as 100 %.

$$\text{Compressive Strength Change, } \% = \frac{[S_2 - S_1]}{S_1} \times 100 \qquad (6)$$

where:

S_1 = average compressive strength, psi (MPa), of a set of specimens following the conditioning period. The compressive strength of each specimen in the set shall be the maximum applied load per cross-sectional area of the specimen, and
S_2 = average compressive strength, psi (MPa), of a set of specimens following the test period. The compressive strength of each specimen in the set shall be the maximum applied load per cross-sectional area of the specimen.

NOTE 4—A result showing a plus (+) sign will indicate a gain in compressive strength and a minus (–) sign will indicate a loss in strength.

10.6.2.2 Construct a graph employing the percentage change in the average compressive strength of the specimens broken at a given examination period after immersion in a particular test medium at a given temperature, plotting the percentage of change in compressive strength as the ordinate and the test period, in days, as the abscissa.

10.6.2.3 The compressive strength in pounds-force per square inch (or pascals) should be shown for the initial specimen (100 % value) and for the final specimen. These values should be noted parenthetically near the plot of each value.

10.6.3 *Volume Change of Tested Specimens :*

10.6.3.1 Calculate to the nearest 0.01 % the percentage loss or gain in volume of the specimens during immersion for each examination period taking the volume after conditioning as 100 %.

$$\text{Volume Change, \%} = \frac{[V2 - V1] \times 100}{V1} \quad (7)$$

where:

V1 = cubic volume, in.^{3} (cm^3), of a set of specimens following the conditioning period. The volume of each specimen in the set shall be determined by taking two measurements in height, width, and depth of each specimen, averaging the two values and using the average to calculate the volume, and

V2 = average volume, in. ^{3} (cm^3), of a set of specimens following the test period. The volume of each specimen in the set shall be determined by taking two measurements in height, width, and depth of each specimen, averaging the two values and using the average to calculate the volume.

NOTE 5—A positive sign (+) will indicate an increase in volume and a negative sign (–) will indicate a loss in volume.

10.6.3.2 Construct a graph employing the percentage change in the average volume of the specimens at a given examination period after immersion in a particular test medium at a given temperature, plotting the percentage change in volume as the ordinate and the elapsed time, in days, as the abscissa.

10.7 *Report:*

10.7.1 Name of brick manufacturer.

10.7.2 Brand name of brick.

10.7.3 Manufacturer's lot number.

10.7.4 Full brick dimensions.

10.7.5 Any defects in the specimens.

10.7.6 Test conditions—test medium, frequency of change of test medium, temperature, etc.

10.7.7 Color and surface appearance of specimens before testing.

10.7.8 Total duration of the test and the examination periods, in days. For each examination period the following data are required:

10.7.8.1 Average percentage of weight change of the specimens,

10.7.8.2 Appearance of the specimens before, during, and after immersion testing (surface cracks, delaminations, etching, pitting, softening, etc.),

10.7.8.3 Appearance of the test medium (discoloration, sediment, etc.),

10.7.8.4 Average percent change in the compressive strength of the specimens,

10.7.8.5 Graph showing percent weight change plotted against the test periods,

10.7.8.6 Graph showing percent change in compressive strength plotted against the test period, and

10.7.8.7 Percent volume change of the specimens.

11. Interpretation of Results

11.1 *Weight Change*— Because of the nature of certain brick, the rate of weight change with time is of more significance than the actual value at any time. A plot of the test results will indicate whether a particular brick will approach constant weight in time or will continue to change in weight as the test progresses.

11.2 *Appearance of Specimen*—Visual inspection of the exposed specimen for surface cracks, delaminations, etching, pitting, softening, etc. is very important in cases where initial weight changes are high.

11.3 *Appearance of Test Medium*—Discoloration of the test medium and the formation of sediment are significant factors. An initial discoloration, coupled with a high weight loss, may indicate extraction of soluble components. Continuation of the test with fresh medium will indicate whether or not the attack is progressive.

11.4 *Change in Compressive Strength* —The same considerations hold true as mentioned in 11.1 and therefore, the rate of change in compressive strength is the important characteristic to be determined.

11.5 *Percent Volume Change*—The rate of change in volume is of more significance than the actual value at a particular time. However, if expansion becomes severe, the brick may swell sufficiently to reach a "critical volume" at which point stress relief will occur and appear as cracking. Conversely, too much volume loss may leave a specimen too severely eroded/corroded to allow for meaningful measurements. If either event occurs, it must be recorded and graphed. A regression analysis of the test results will indicate whether a particular brick will approach constant volume in time, or whether it will continue to change in volume. Constructing an overlay of the volume change curve, strength change curve, and weight change curve will reveal information about mass loss/gain and the effect on physical properties. Comparison of the volume change and absorption curves is also often revealing.

12. Precision and Bias

12.1 If any value(s) differs from the mean by more than 15 %, the value farthest from the mean shall be rejected and the mean recalculated. If any value(s) still differs from the new mean by more than 15 %, the farthest value should again be rejected and the mean recalculated. If any value(s) remains 15 % from the mean, the test should be rerun.

13. Keywords

13.1 alkali resistant; block; brick; carbon brick; chemical-resistant; conductive; fluoride resistant; tile