



Designation: C16 – 03 (Reapproved 2018)

## Standard Test Method for Load Testing Refractory Shapes at High Temperatures<sup>1</sup>

This standard is issued under the fixed designation C16; 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.

### 1. Scope

1.1 This test method covers the determination of the resistance to deformation or shear of refractory shapes when subjected to a specified compressive load at a specified temperature for a specified time.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

### 2. Referenced Documents

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

C862 Practice for Preparing Refractory Concrete Specimens by Casting

E220 Test Method for Calibration of Thermocouples By Comparison Techniques

2.2 *ASTM Adjuncts:*<sup>3</sup>

Direct-Load Type Furnace (Oil or Gas Fired, or Electrically Fired); Lever-Load Type Furnace

### 3. Significance and Use

3.1 The ability of refractory shapes to withstand prescribed loads at elevated temperatures is a measure of the high-

temperature service potential of the material. By definition, refractory shapes must resist change due to high temperature, and the ability to withstand deformation or shape change when subjected to significant loading at elevated temperatures is clearly demonstrated when refractory shapes are subjected to this test method. The test method is normally run at a sufficiently high temperature to allow some liquids to form within the test brick or to cause weakening of the bonding system. The result is usually a decrease in sample dimension parallel to the applied load and increase in sample dimensions perpendicular to the loading direction. Occasionally, shear fracture can occur. Since the test provides easily measurable changes in dimensions, prescribed limits can be established, and the test method has been long used to determine refractory quality. The test method has often been used in the establishment of written specifications between producers and consumers.

3.2 This test method is not applicable for refractory materials that are unstable in an oxidizing atmosphere unless means are provided to protect the specimens.

### 4. Apparatus

4.1 The apparatus shall consist essentially of a furnace and a loading device. It may be constructed in accordance with Fig. 1 or Fig. 2 or their equivalent.<sup>4</sup>

4.1.1 The furnace shall be so constructed that the temperature is substantially uniform in all parts of the furnace. The temperature as measured at any point on the surface of the test specimens shall not differ by more than 10 °F (5.5 °C) during the holding period of the test or, on test to failure, above 2370 °F (1300 °C). To accomplish this, it may be necessary to install and adjust baffles within the furnace. A minimum of two burners shall be used. If difficulty is encountered in following the low-temperature portion of the schedule (particularly for silica brick), a dual-burner system is recommended, one to supply heat for low temperatures and another for the higher temperatures.

4.2 The temperature shall be measured either with calibrated platinum - platinum - rhodium thermocouples,<sup>5,6,7</sup> each

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee C08 on Refractories and is the direct responsibility of C08.01 on Strength.

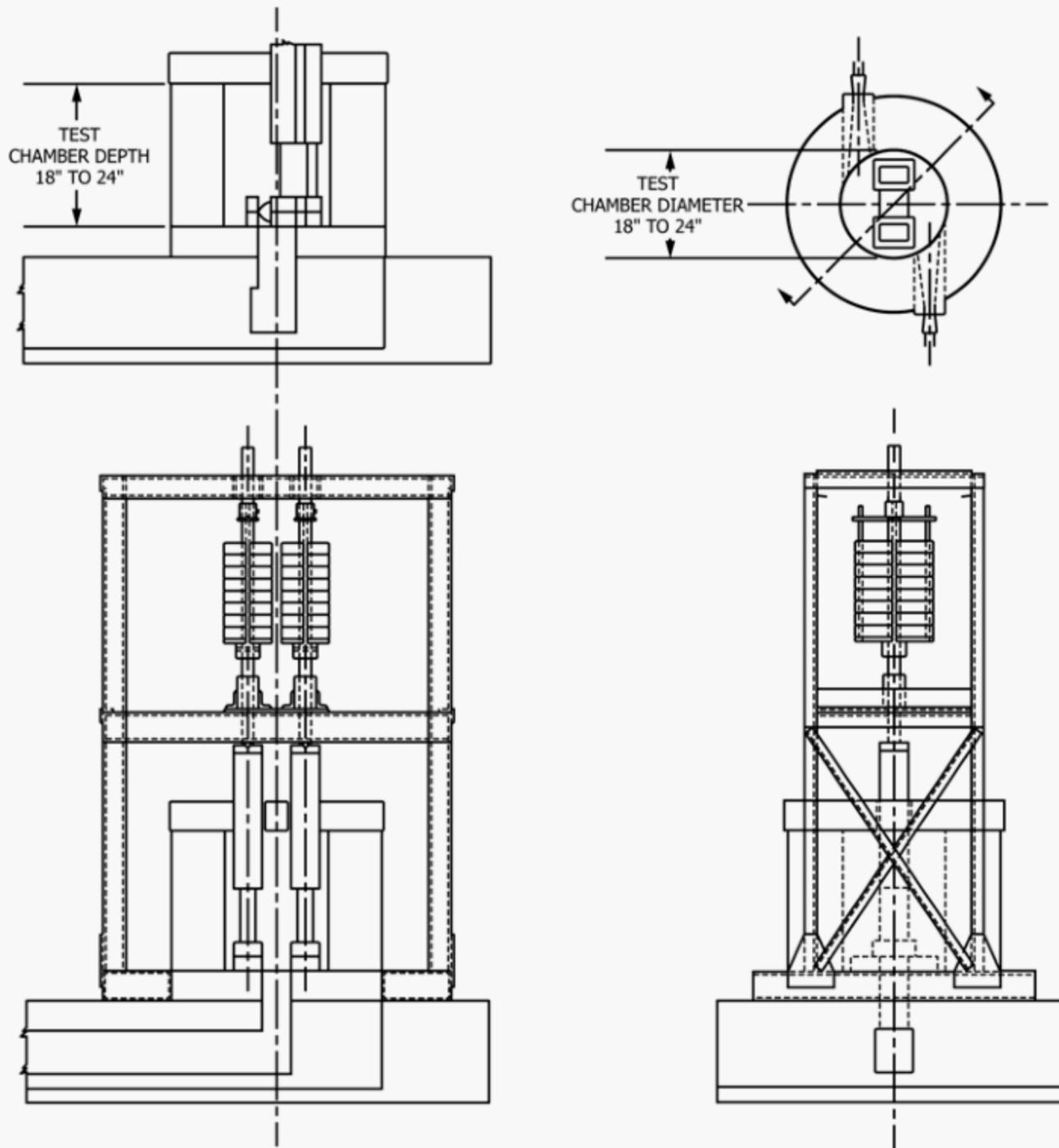
Current edition approved Feb. 1, 2018. Published February 2018. Originally approved in 1917. Last previous edition approved in 2012 as C16 – 03 (2012)<sup>ε2</sup>. DOI: 10.1520/C0016-03R18.

<sup>2</sup> 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.

<sup>3</sup> Available from ASTM International Headquarters. Order Adjunct No. ADJC0016-E-PDF. Original adjunct produced in 1969; digitized in 2017.

<sup>4</sup> Digital blueprints of detailed drawings of the furnaces shown in Figs. 1 and 2 are available from ASTM International. Request Adjunct No. ADJC0016-E-PDF.

<sup>5</sup> Test Method E220 specifies calibration procedures for thermocouples.



SI Equivalents	
in.	mm
18	460
24	610

NOTE 1—Dimensions are in inches.  
**FIG. 1 Direct-Load Type Test Furnace**

encased in a protection tube with the junction not more than 1 in. (25 mm) from the center of the side or edge of each specimen or with a calibrated pyrometer.<sup>5,6,7</sup> A recording form of temperature indicator is recommended. If the optical pyrometer is used, observations shall be made by sighting on the face of the specimens and in the same relative positions as those specified for the thermocouples.

**5. Test Specimen**

5.1 The test specimen shall consist of a minimum of two 9 by 4½ by 2½ or 3-in. (228 by 114 by 64 or 76-mm) straight

<sup>6</sup> The National Institutes of Standards and Technology, Gaithersburg, MD 20899, will, for a fee, furnish calibrations for radiation-type pyrometers and for thermocouples.

<sup>7</sup> All temperatures specified in this test conform to the International Practical Temperature Scale of 1968 (IPTS 1968) as described in *Metrologia*, Vol 5, No. 2, 1969, pp. 35–44.

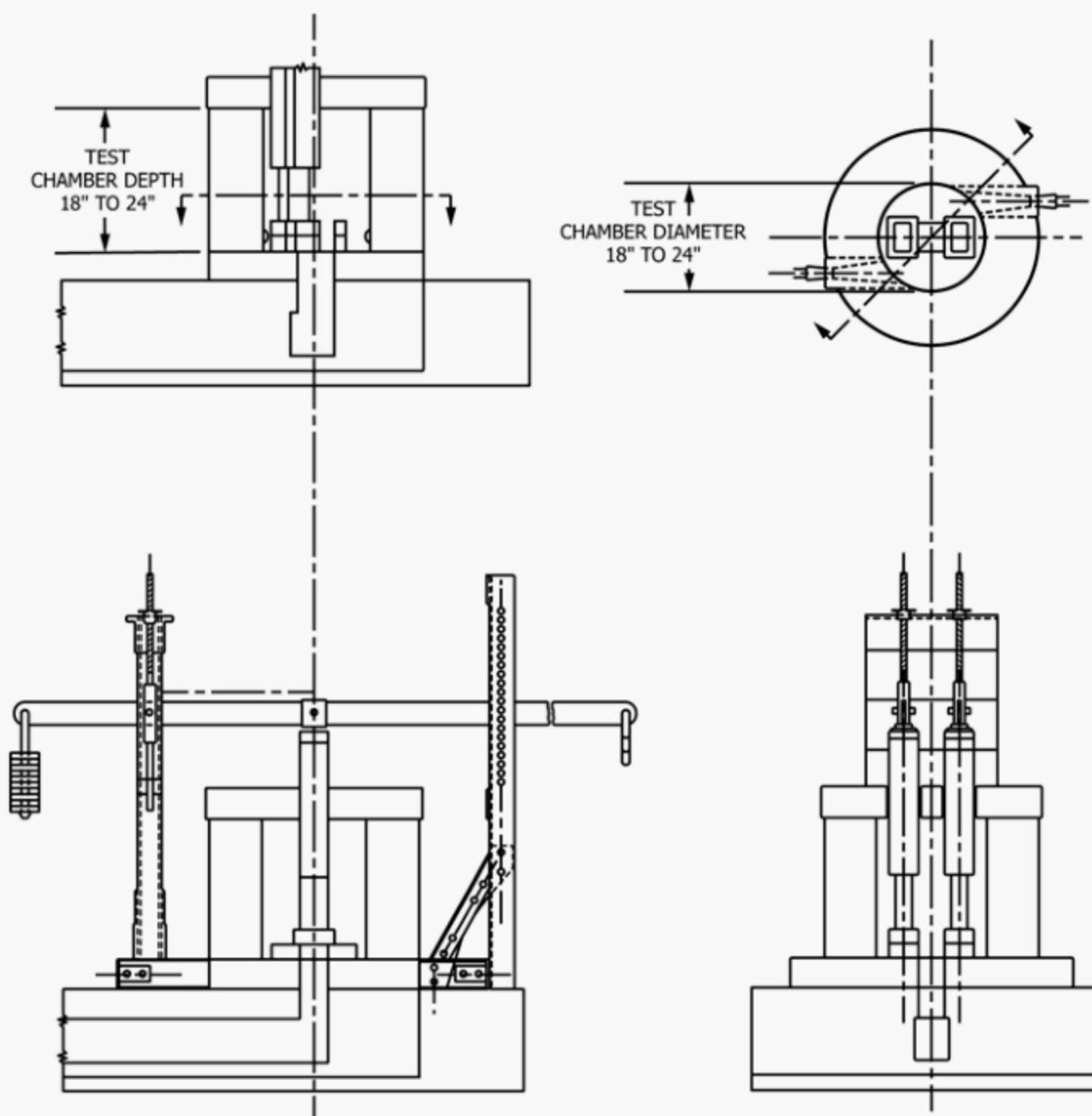
refractory brick, or specimens of this size cut from larger refractory shapes, utilizing as far as possible existing plane surfaces.

5.2 If necessary, the ends of the specimen shall be ground so that they are approximately perpendicular to the vertical axis.

5.3 The test specimen shall be measured before testing, four observations being made on each dimension (length, width, and thickness), at the center of the faces to within ±0.02 in. (0.5 mm). The average dimensions shall be recorded, and the cross section calculated.

**6. Setting the Test Specimen**

6.1 The test specimen, set on end, shall occupy a position in the furnace so that the center line of the applied load coincides with the vertical axis of the specimen as indicated in **Figs. 1 and 2** and shall rest on a block of some highly refractory



NOTE 1—Dimensions are in inches. See Fig. 1 for SI equivalents.

FIG. 2 Lever-Load Type Test Furnace

material, neutral to the specimen, having a minimum expansion or contraction (Note 1). There shall be placed between the specimen and the refractory blocks a thin layer of highly refractory material such as fused alumina, silica, or chrome ore, that has been ground to pass a No. 20 (850- $\mu$ m) ASTM sieve (equivalent to a 20-mesh Tyler Standard Series). At the top of the test specimen a block of similar highly refractory material should be placed, extending through the furnace top to receive the load.

NOTE 1—Recommended designs for the furnace and loading device are shown in Figs. 1 and 2. Inside dimensions may vary between those shown on these drawings. The dimensions of the framework will be determined by the selection made on inside dimensions, thickness of refractory wall, etc. The framework for either the direct loading or lever type are shown in sufficient detail so detailed drawings for furnace construction can easily be made. The use of a flue system with either design is optional.

NOTE 2—Gross errors that may more than double the deformation will result if the specimen is not set perpendicular to the base of the support or if the load is applied eccentrically.

## 7. Procedure

7.1 *Loading*—Calculate the gross load to be applied throughout the test from the average cross section of the original specimen as determined in 5.3. Apply a load of 25 psi (172 kPa) before heating is started. When testing specimens

that are likely to fail by shear, make provisions so that the loading mechanism cannot drop more than 1/2 in. (13 mm) when failure occurs.

7.2 *Heating*—The rate of heating shall be in accordance with the requirements prescribed in Table 1. The temperature shall not vary more than  $\pm 20$  °F (11 °C) from the specified temperature.

7.3 *Furnace Atmosphere*—Above a temperature of 1470 °F (800 °C), the furnace atmosphere shall contain a minimum of 0.5 % oxygen with 0 % combustibles. Take the atmosphere sample from the furnace chamber proper, preferably as near the test specimen as possible.

### 7.4 Completion of Test and Report:

7.4.1 Include in the report the designation of the specimens tested (manufacturer, brand, description, etc.). Note, if applicable, specimen preparation procedures, character of the faces (cut, ground, as-pressed, as-cast, etc.), and pretreatments (curing, firing, coking, etc.).

7.4.2 When a shear test is completed by failure of the specimens, report the temperature of shear. At the expiration of a test that does not involve shearing of the specimens, allow the furnace to cool by radiation to 1830 °F (1000 °C) or lower before the load is removed and the specimens are examined.

**TABLE 1 Time-Temperature Schedules for Heating the Test Furnace**

NOTE 1—All temperatures shall be maintained within  $\pm 20$  °F (11 °C) during the heat-up schedule and  $\pm 10$  °F (5.5 °C) during the holding period.

Elapsed Time from Start of Heating		Schedule 1, 2370 °F Hold		Schedule 2, 2460 °F Hold		Schedule 3, 2640 °F Hold		Schedule 4, Silica Brick, Test to Failure		Schedule 5, Test to Failure		Schedule 6, 2900 °F Hold		Schedule 7, 3000 °F Hold	
h	min	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
1	0	930	500	930	500	1040	560	245	120	1330	720	1330	720	1330	720
	15	1105	595	1150	620	1255	680	310	155	1490	810	1490	810	1490	810
	30	1265	685	1330	720	1470	800	380	195	1650	900	1650	900	1650	900
	45	1420	770	1500	815	1650	900	450	230	1780	970	1780	970	1780	970
2	0	1560	850	1650	900	1815	990	535	280	1910	1045	1910	1045	1910	1045
	15	1690	920	1795	980	1960	1070	630	330	2005	1095	2005	1095	2005	1095
	30	1815	990	1915	1045	2085	1140	775	415	2100	1150	2100	1150	2100	1150
	45	1920	1050	2010	1100	2190	1200	1025	550	2180	1195	2180	1195	2180	1195
3	0	2010	1100	2100	1150	2280	1250	1275	690	2260	1240	2260	1240	2260	1240
	15	2095	1145	2185	1195	2355	1290	1525	830	2315	1270	2315	1270	2315	1270
	30	2165	1185	2255	1235	2425	1330	1750	955	2370	1300	2370	1300	2370	1300
	45	2230	1220	2320	1270	2500	1370	1990	1090	2415	1325	2415	1325	2415	1325
4	0	2280	1250	2370	1300	2550	1400	2200	1205	2460	1350	2460	1350	2460	1350
	15	2325	1275	2425	1330	2605	1430	2400	1315	Continue at 180 °F (100 °C)/h to failure	2505	1375	2505	1375	
	30	2370	1300	2460	1350	2640	1450	2550	1400		2550	1400	2550	1400	
	45	Hold for 90 min		Hold for 90 min		Hold for 90 min		2660	1460	2595	1425	2595	1425		
5	0	...		...		...		2700	1480	...		2640	1450	2640	1450
	15							Continue at 100 °F (55 °C)/h to failure				2685	1475	2685	1475
	30											2730	1500	2730	1500
	45											2775	1525	2775	1525
6	0	...		...		...		...		...		2820	1550	2820	1550
	15											2865	1575	2865	1575
	30											2900	1595	2910	1600
	45											Hold for 90 min		2955	1625
7	0	...		...		...		...		...				3000	1650
	15														
	30														
Total time	45	6 h		6 h		6 h		8 h to 3000 °F (1650 °C)		8 h to 3180 °F (1750 °C)		8 h		Hold for 90 min 8½ h	

**TABLE 2 Critical Differences**

Number of Observations in Average	Critical Difference as Percent of Grand Average	
	Within One Laboratory	Between Laboratories
1	79.6	96.5
2	56.3	78.4
4	39.8	67.6
6	32.5	63.6
8	28.1	61.5
10	25.2	60.2
100	8.0	55.2

After cooling the test specimens to room temperature, re-measure them for length in accordance with 5.3. Calculate and report the average percent deformation, based on the original length, as the average value of the two specimens.

NOTE 3—It is recommended that a photograph be made of the specimens before and after testing to provide useful information.

## 8. Precision and Bias

### 8.1 Interlaboratory Test Data:

8.1.1 Results of a round-robin test between six laboratories running two replicates each of a lot of super-duty fireclay brick

and a lot of 70 % Al<sub>2</sub>O<sub>3</sub> brick (*N* = 24) using Schedule 3 were evaluated to develop precision and bias statements.

8.1.2 Using 95 % confidence limits, the differences and interactions between laboratories were found to be not significant. The interaction sum of squares was pooled with the residual error to calculate the within-laboratory variance:

Grand mean = 3.19 % subsidence.

Standard deviation within laboratories =  $\pm 0.915$  %.

Standard deviation between laboratories =  $\pm 0.629$  %.

Coefficient of variation within laboratories =  $\pm 28.7$  %.

Coefficient of variation between laboratories =  $\pm 19.7$  %.

## 8.2 Precision:

8.2.1 Critical differences were calculated from the coefficients of variation to normalize for the variation in means for the two brick types ( $\bar{x} = 5.43$  % subsidence for super-duty brick and 0.939 % subsidence for 70 %  $\text{Al}_2\text{O}_3$  brick). Thus, for the 95 % confidence level and  $t = 1.96$ , the critical differences are as specified in **Table 2**.

8.2.2 The user is cautioned that other test temperatures, test schedules, and specimens of different compositions may yield greater or less precision than given above.

8.3 *Bias*—No justifiable statement on bias is possible since the true value of hot compressive load deformation cannot be established.

## 9. Keywords

9.1 compressive load; deformation resistance; high temperature; refractory brick; refractory shapes

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