Designation: C 1100 – 88 (Reapproved 1998)

Standard Test Method for Ribbon Thermal Shock Testing of Refractory Materials[1]

This standard is issued under the fixed designation C 1100; 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 test method covers the procedure for determining the relative resistance of fired fireclay and high alumina refractories to thermal shock conditions resulting from specified heating and cooling cycles. The equipment specified is based on test units currently in use at several industrial laboratories.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

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:*

C 885 Test Method for Young's Modulus of Refractory Shapes by Sonic Resistance[2]

3. Significance and Use

3.1 The measurement or assessment of thermal shock damage of refractory materials is an important consideration in refractory selection for process vessels and furnaces.

3.2 This test method allows for a quantitative assessment of thermal shock damage based on either destructive or nondestructive test methods, or both.

4. Apparatus

4.1 *Burner Frame*—Sheet metal and angle iron provide support for the line burner, protective liner brick, and test samples. A cross section view of the unit is shown in Fig. 1. The unit is approximately 15 in. (0.38 m) wide, 69 in. (1.75 m) long, and 25 in. (0.64 m) high. Provision should be made to easily adjust the vertical burner-to-sample (hot face) distance, if needed. Wheels can be attached to the frame to permit easy relocation of the unit. Fig. 2 shows the material and dimension details needed for constructing the burner frame.

4.2 *Burner*—A segmented line burner (gas), with five 12 in. (0.305 m) connected sections is suggested. Burners of 300 000 to 900 000 BTU/h capacity are in use. Both center and end-fed burners are in use. Consideration should be given to the end-to-end temperature variation and control (±10°F (±5.5°C)) of whichever burner system is used. A typical burner system is shown in Fig. 3. An ignition device is needed to initiate firing for each of the heating cycles. A safety device is needed to shut off the gas in case of flame-out or other unexpected shutdown.

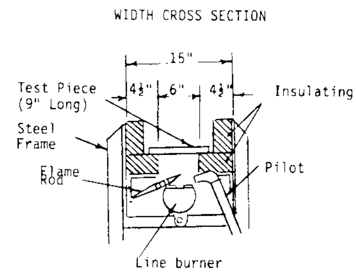

FIG. 1 Diagram Showing a Cross Section View of the Basic Components of the Ribbon Test Furnace

4.3 *Temperature Measurement*—Sample hot face temperature should be measured at the center and each end of the sample setting. The capability is needed to insert a protected (alumina (Al_2O_3) tube) thermocouple horizontally through the frame into a cut hot face slot in dummy brick positioned across the burner at each of the desired measurement sites.[3] The thermocouple bead should be positioned in the center (hottest zone) of the flame, within the groove in the dummy brick. During testing, a sharply defined flame should actually contact the hot face surface of the test brick (original face) creating a "red hot'' central band approximately 2 in. (50 mm) wide. Cold face thermocouples can be used if desired, to monitor the temperature gradient. An appropriate temperature-measuring or recording device, or both, should be attached to properly monitor the test conditions.

4.4 *Gas/Air Flow System*—The basic components for gas/air flow control, with the line burner, are shown in Fig. 3. Valves are needed to turn gas on and off at specified times during the cyclic operation. A gas regulator is used to maintain uniform flow. Blowers of from 75 to 150 ft^3/min (2.1 to 4.2 m^3/min) capacity are in use. The blower operates continuously

[1] This test method is under the jurisdiction of ASTM Committee C-8 on Refractories and is the direct responsibility of Subcommittee C08.02 on Thermal Stress Resistance.

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[2] *Annual Book of ASTM Standards*, Vol 15.01.

[3] Barna, G., "Ruggedness Evaluation of the Ribbon Test,'' Report to ASTM Subcommittee C08.02 (based on RRC test data), March 1982.

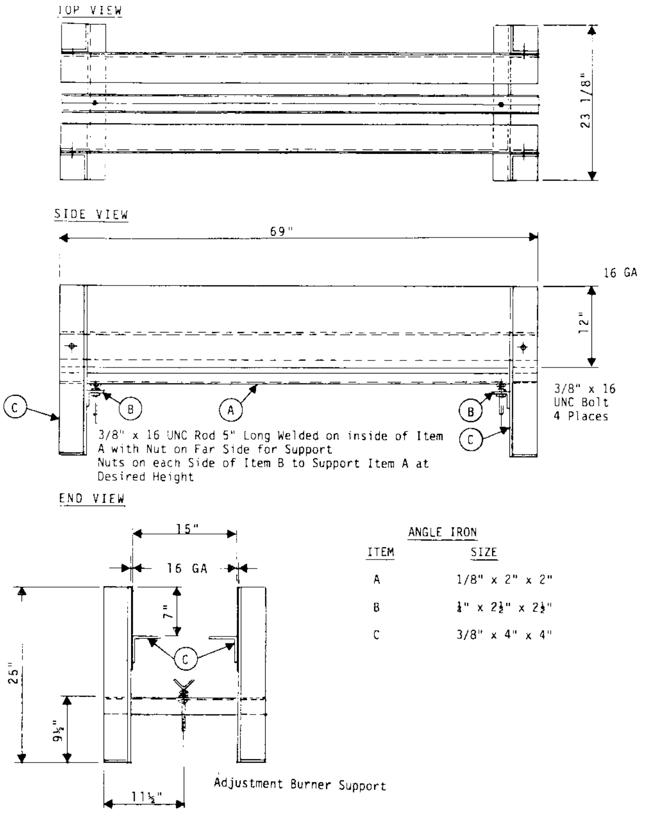


FIG. 2 Multiple (Top, Side, and End) Views Showing the Material and Dimension Details for a Ribbon Furnace Frame

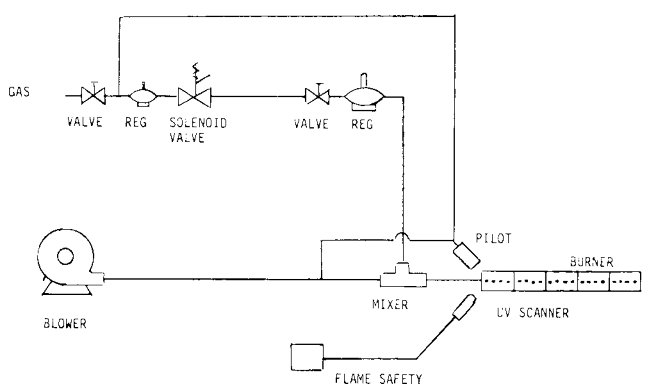


FIG. 3 Schematic of Ribbon Test Furnace Combustion Components

during the heating and cooling cycles of the test. If desired, automated cycling operation of this test can be provided.

4.5 *Sample Evaluation Equipment*—Degradation of samples, due to thermal shock exposure can be quantified by measured property changes (before and after test). The preferred, most statistically valid evaluation procedure[3] involves measurement of modulus of elasticity, in accordance with Test Method C 885 (sonic resonance technique). An alternative procedure, described in the literature[4], using ultrasonic velocity measurements, can provide calculated modulus of elasticity values. Modulus of rupture measurements can also be used for sample evaluation, providing another quantitative means of ranking the relative thermal shock resistance of fireclay and high alumina refractories.

4.6 *Sample Preparation*—A diamond saw should be used to obtain the appropriate sample geometry.

4.7 *Dryer*—Any samples that become wet during cutting, storage, or shipment, or combination thereof, should be dried overnight at 230°F (110°C), prior to thermal shock testing.

5. Test Specimens

5.1 Five samples of each of any brand or product type should be tested to permit generation of a representative average value. The sample size is discussed in this section.

5.2 Samples of various size and orientation have been used in various laboratories. The sizes have included 9 in. (228 mm) straights, splits, soaps, quarter brick, and bars, tester either flat, or on edge in cases where the thickness and width differ. The 9 in. (228 mm) sample length is maintained in all cases, but different widths and thicknesses have been used. To properly compare the thermal shock performance of different brands or product types, the samples should all be of the same size, tested in the same orientation and after the same cycling comparison, they should be exposed together in the same test. The hot face to cold face sample thickness is very important, as it (thermal gradient) controls the amount of damage the samples will incur. A sample with greater hot face to cold face thickness will show more damage than a thinner sample, with equal hot face exposure area. Materials that are more susceptible to thermal shock damage are more significantly affected by changes in the sample thickness.[5] A single sample size cannot be specified for evaluating all products, but general guidelines are presented to permit selection of the sample configuration that is appropriate for most comparative test purposes (see Fig. 4). It should be remembered that in order to compare the relative thermal shock resistance of two or more types of refractories, the same sample size and orientation must be used. For materials of poor thermal shock resistance (60 % Al_2O_3, or less) thinner samples should be used. The suggested sample size is a quarter brick cut from a 9 in. (228 mm) by 2½ in. (64 mm) by 1½in. (38 mm) cut from a 9 in. (228 mm) straight, to be tested flat (2½ in. (64 mm) hot face width. The cutting of samples from a 9 in. (228 mm) straight is shown in Fig. 5. Two samples can be taken from each brick, one of which can be used for modulus of rupture testing.

5.3 Wherever possible, a reference or material of known performance should be included in the test.

6. Procedure

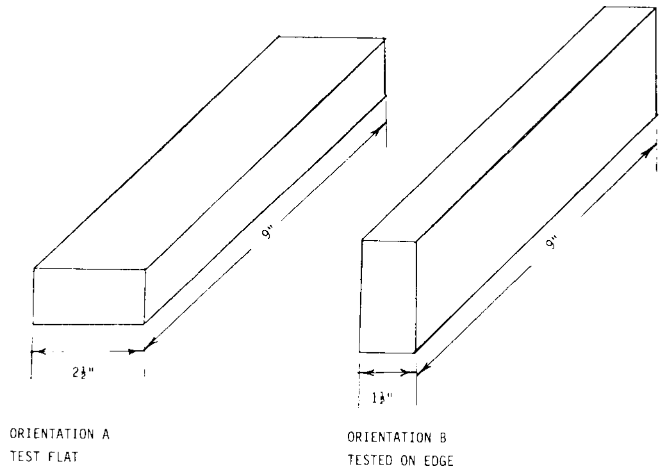
6.1 Determine and record the modulus of elasticity or sonic velocity for each test sample, prior to thermal shock exposure.

6.2 If MOR test results are also to be used to gage thermal shock resistance, test one sample cut from each brick.

6.3 Position the prepared test samples, arranged randomly in the proper orientation, across and 5 in. (127 mm) above the

[4] Semler, C. E., "Nondestructive Ultrasonic Evaluation of Refractories,'' *Interceram*, Vol 5, pp. 485–488, 1981.

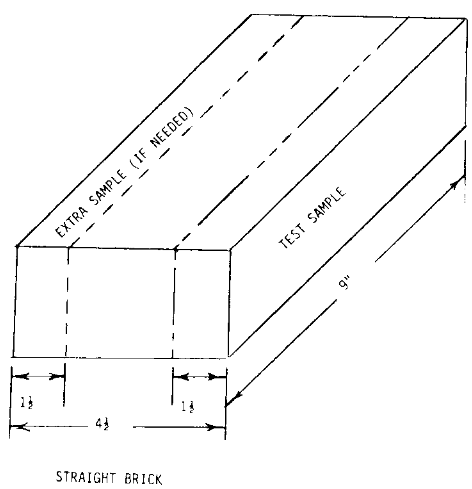
[5] Coppack, T. J., "A Method for Thermal Cycling Refractories and an Appraisal of its Effect by a Nondestructive Technique,'' *Journal of the British Ceramics Society*, Vol 80, No. 2, pp. 43–46, 1981.



NOTE 1—Orientation A (flat), with a hot face to cold face thickness of 1½ in. (38 mm) (hot face area, 2½ in. (64 mm) by 9 in. (228 mm) is suggested for refractories of poor thermal shock resistance (<60 % Al_2O_3), those of unknown thermal shock character, or a grouping of various types (±60 % Al_2O_3).

NOTE 2—Orientation B (edge), with a hot face to cold face thickness of 2½ in. (64 mm) (hot face area, 1½in. (38 mm) by 9 in.) (228 mm) is suggested for refractories of good thermal shock resistance (>60 % Al_2O_3).

FIG. 4 Diagram Illustrating the Two Recommended Orientations for Sample Exposure in the Ribbon Thermal Shock Test



NOTE 1—To be cut from a 9 in. (228 mm) straight brick for use in the ribbon thermal shock test. An extra sample can be obtained, if needed.

NOTE 2—Using modulus of elasticity (nondestructive) as the analysis method, the before- and after-shock values are obtained from the same sample.

FIG. 5 Diagram Illustrating the Position of the Quarter Brick Test Sample(s)

gas burner, with a recommended ¼ in. (6.4 mm) gap between each sample (see Note 1). Use an original surface and not a cut one on the hot face. Initiate the thermal cycling; the desired hot face temperature (typically from 1500 to 2000°F (815.6 to 1093°C)) should be reached within five min. The total heating cycle time from flame ignition is 15 min. At the conclusion of the heating cycle, shut off the gas and leave on the blower air to provide rapid cooling of the samples' hot face for 15 min. Each thermal shock cycle is 30 min duration, of which 15 min is heating and 15 min is cooling. Exposure to five thermal shock cycles (150 min total) has proven adequate to delineate the relative thermal shock resistance of fireclay and high alumina refractories. After the fifth thermal shock cycle, air-cool the samples. After cooling to room temperature, determine the modulus of elasticity or sonic velocity or MOR, or combination thereof, for each sample, to permit calculation of the damage incurred (property change).

6.4 Using the before- and after-shock modulus of elasticity, sonic velocity or MOR values, or combination thereof, for each sample, calculate the percent change, either as percent retained or percent decrease in these properties. The comparison of the thermal shock performance should only be based on comparison of data for the same sample size, that have been tested in the sample orientation under the same conditions. Generally, the higher the percent SV, MOE, or MOR retained on the lower the percent SV, MOL, or MOR decrease, the better the product will perform in a thermal cycling environment compared to materials of the same class. In most cases, percent SV, MOE, or MOR change should be adequate to rate refractory thermal shock resistance. There are instances where evaluation of the actual before- and after-shock SV, MOE, or MOR values (instead of percents) may provide a more meaningful interpretation of results.

NOTE 1—If desired, gap sizes may be increased, decreased, or eliminated. However, it is not possible to accurately compare results between tests run with varying gap sizes. As with the review of any test data, common sense must be an integral part of the evaluation.

7. Report

7.1 Report the following information for each brand or product:

7.1.1 Brand name or product type, or both,

7.1.2 Sample dimension, orientation, distance to the burner and gap width,

7.1.3 Test temperature, number of cycles, and cycle characteristics (heating time, in minutes and cooling time, in minutes),

7.1.4 Individual sonic velocity, modulus of elasticity values, or MOR, or combination thereof, before shock,

7.1.5 Average sonic velocity, modulus of elasticity value or MOR, or combination thereof, before shock,

7.1.6 Individual sonic velocity, modulus of elasticity values and MOR, after shock,

7.1.7 Average sonic velocity, modulus of elasticity value and MOR, after shock, and

7.1.8 Calculated percent sonic velocity, modulus of elasticity, and MOR retained or lost for both individual and average results, before- and after-shock.

8. Precision and Bias [6]

8.1 The results of an interlaboratory study conducted from 1986 to 1987 were evaluated to develop precision and bias statements.

8.2 In the interlaboratory study three types of brick were tested. These were superduty fireclay brick, 70 % alumina

[6] Supporting data are available from ASTM Headquarters. Request RR:C-8-1009.

brick, and 90 % alumina brick. Five samples of each brick were tested at six laboratories. Thermal shock damage was assessed as a percent of sonic velocity and modulus of rupture lost after thermal shocking the brick at 1800°F (980°C).

8.3 *Precision*—The results of this interlaboratory study are shown in Table 1 and Table 2. The precision was found to vary with the type of material tested. Coefficients of variation between laboratories of all materials tested were quite large as were the repeatability and reproducibility intervals. In review of the data obtained in this study by Subcommittee C08.02, it was noted that test method variation in MOR and sonic velocity measurements may have contributed to the large variations obtained. Both MOR and sonic velocity testing are being reviewed by Subcommittee C08.01. Plans have been made to run the interlaboratory study again after this test method has been reviewed and revised.

TABLE 1 Relative Precision

Brick Type	% MOR Loss	Coefficient of Variation		Repeatability Interval, % of Average	Reproducibility Interval, % of Average
		Within Labs %	Between Labs %		
Superduty fireclay	43.2	19.0	22.4	53.8	83.1
70 % Alumina	26.9	46.7	52.0	132.1	197.6
90 % Alumina	42.5	27.4	67.0	77.4	204.6

TABLE 2 Relative Precision

Same	% Sonic Velocity Lost	Same		Same	Same
Superduty fireclay	13.6	10.2	55.2	28.7	158.8
70 % Alumina	7.9	17.4	42.0	49.1	128.3
90 % Alumina	5.3	33.0	102.3	93.2	303.8

8.4 *Bias*—No just final statement of bias is possible because its true effect of thermal shock on a refractory material cannot be established.

9. Keywords

9.1 refractories; ribbon thermal shock; thermal shock