Designation: C 704 – 99

Standard Test Method for Abrasion Resistance of Refractory Materials at Room Temperature[1]

This standard is issued under the fixed designation C 704; 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 determination of relative abrasion resistance of refractory brick at room temperature. This test method can also be applied to castable refractories (see Metric Dimensions C 861 and Practice C 865) and plastic refractories (see Practice C 1054).

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information 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 134 Test Methods for Size, Dimensional Measurements, and Bulk Density of Refractory Brick and Insulating Firebrick[2]

C 179 Test Method for Drying and Firing Linear Change of Refractory Plastic and Ramming Mix Specimens[2]

C 861 Practice for Determining Metric Dimensions of Standard Series Refractory Brick and Shapes[2]

C 862 Practice for Preparing Refractory Concrete Specimens by Casting[2]

C 865 Practice for Firing Refractory Concrete Specimens[2]

C 1054 Practice for Pressing and Drying Refractory Plastic and Ramming Mix Specimens[2]

3. Summary of Test Method

3.1 This test method measures the volume of material in cubic centimetres abraded from a flat surface at a right angle to a nozzle through which 1000 g of size-graded silicon carbide grain is blasted by air at 448 kPa (65 psi).

4. Significance and Use

4.1 This test method measures the relative abrasion resistance of various refractory samples under standard conditions at room temperature.

4.2 The abrasion resistance of a refractory material provides an indication of its suitability for service in abrasion or erosive environments.

4.3 The results obtained by this test method could be different than those obtained in service because of the different conditions encountered.

5. Apparatus

5.1 *Abrasion Tester*, used for measuring the abrasion resistance of refractory specimens, consisting of the following (Fig. 1 and Fig. 2):

5.1.1 *Blast Gun*[3], modified for this equipment as shown in Fig. 3.

5.1.2 *Nozzle*—A piece of glass tubing is used to replace the steel nozzle supplied with the sand-blast gun to permit control of nozzle size through nozzle replacement after each determination. Flint-glass tubing, 115 mm (4½in.) long, 7 mm (¼in.) in outside diameter, with a nominal 1.1 mm (1⁄16in.) wall, is used. This piece of glass tubing is held in place by a 70 mm (2¾ in.) long piece of stainless steel tubing. The I.D. (inside diameter) of this tubing, which should be flared at one end to sit snugly inside a 9.53 mm (⅜in.) tubing nut, should be 7.15 mm (9⁄32in.). The O.D. (outside diameter) should be 9.53 mm (⅜ in.). This sleeve is glued in place along with a rubber grommet of proper size, inside the 9.53 mm (⅜ in.) tubing nut, and is used primarily to hold the glass tubing perpendicular to the test sample, assuring a proper vacuum within the gun. The end of the glass tube, through which the abrading media enters the nozzle in the venturi chamber, is placed at a distance of 2 mm (0.08 in.) from the air-generator nozzle. This is done by placing the glass tubing on a brass rod, 4.5 mm (0.175 in.) in diameter with a shoulder 7.9 mm (5⁄16 in.) in diameter, 117 mm (4.68 in.) from the tip. This will allow the operator to push the glass tubing up through the rubber grommet until the rod touches the nozzle, assuring a 2 mm (0.08 in.) gap between the nozzle and the glass tubing.

5.1.3 *Venturi*—The air-generator nozzle should have an inlet inside diameter of from 2.84 to 2.92 mm (0.112 to 0.115 in.) and an outlet inside diameter of from 2.36 to 2.44 mm

[1] This test method is under the jurisdiction of ASTM Committee C-8 on Refractories and is the direct responsibility of Subcommittee C08.03 on Physical Tests and Properties.

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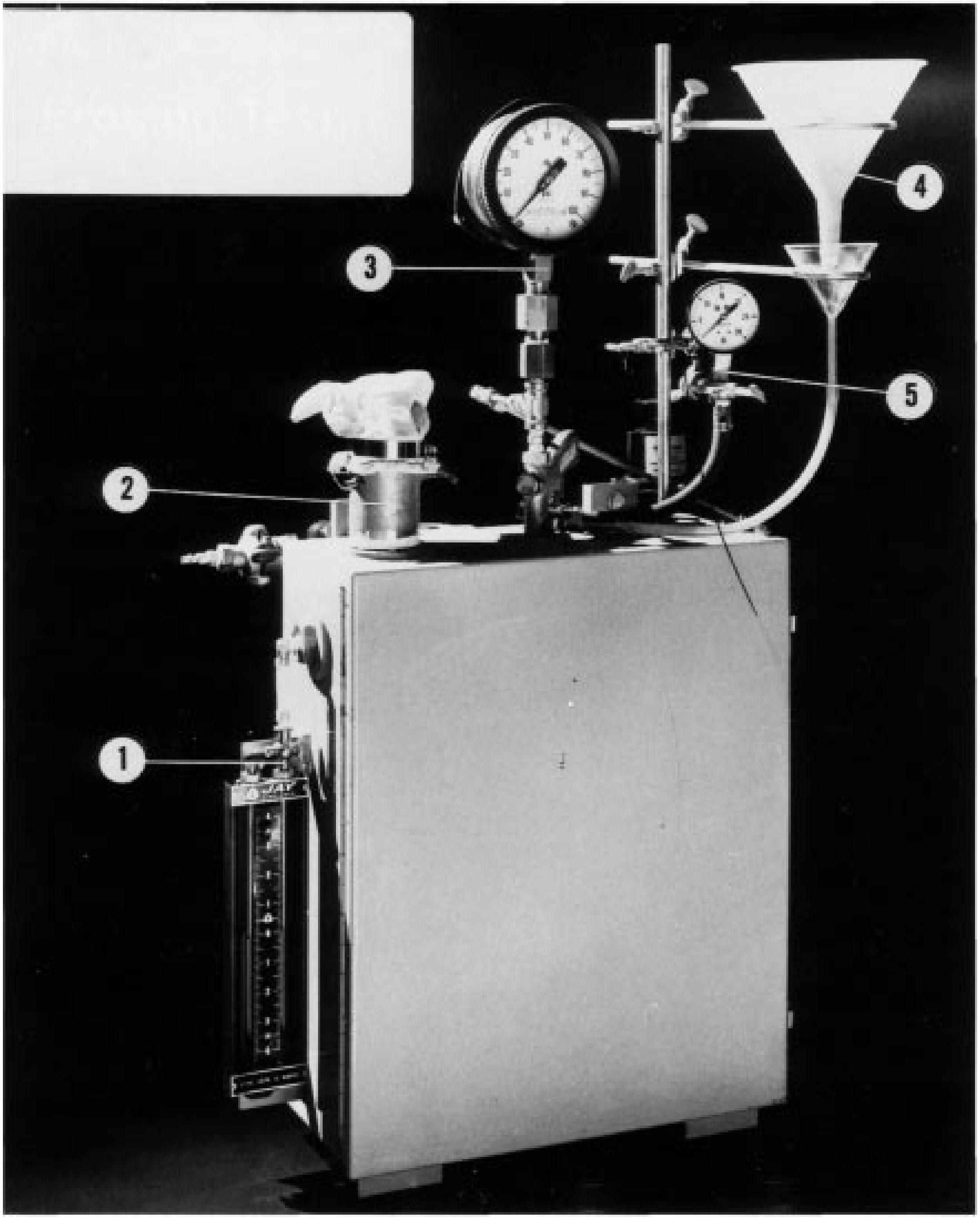
[2] *Annual Book of ASTM Standards*, Vol 15.01.

[3] The sand blast gun shown in Fig. 3, available from Leitch and Company, 971 Howard St., San Francisco, CA, has been found suitable for use in this test method.



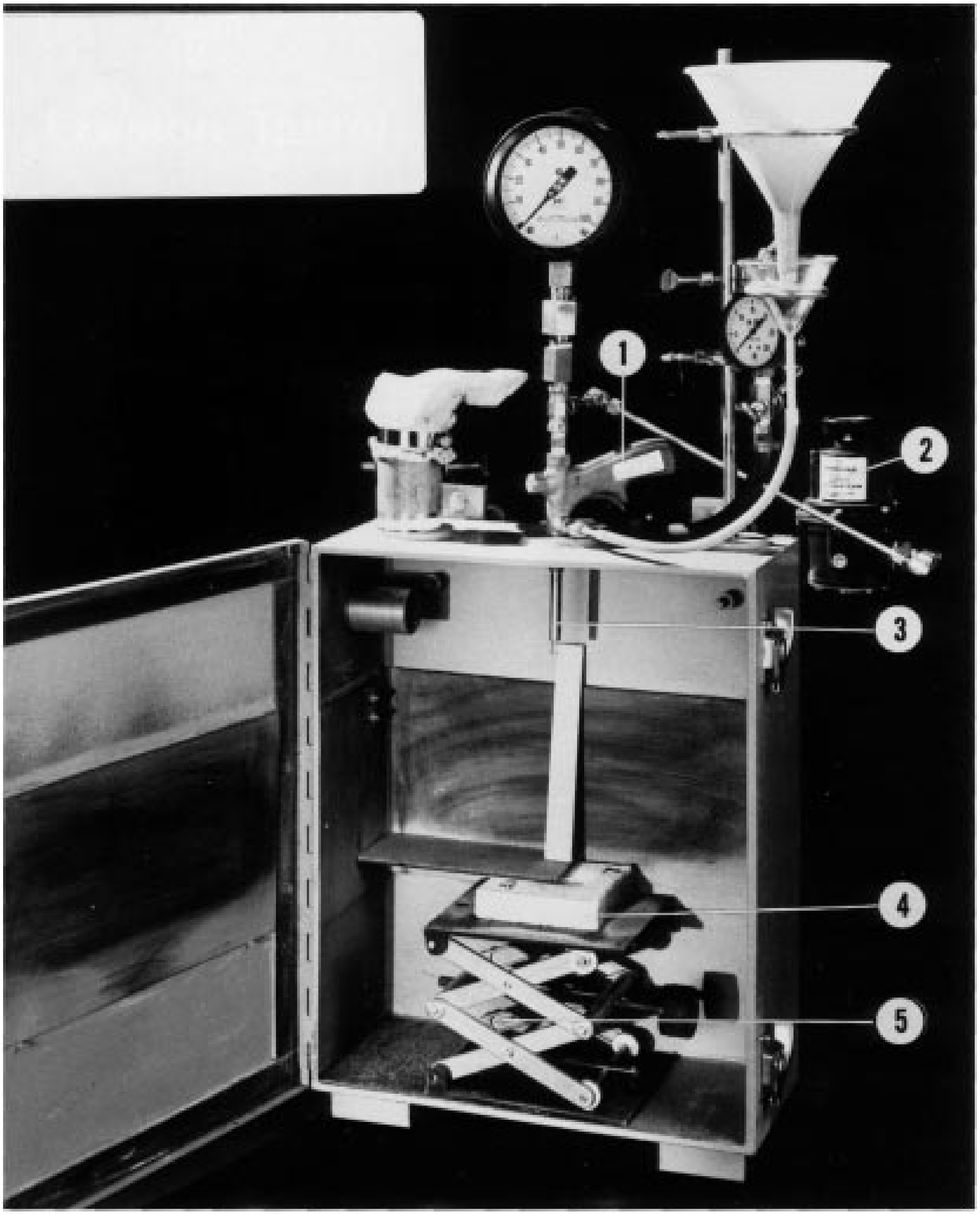
NOTE 1—Identified by number in this figure are: (1) cabinet pressure manometer, (2) dust collector vent, (3) test pressure gage, (4) grit feed tunnel, and (5) vacuum gage.

FIG. 1 Abrasion Tester

(0.093 to 0.096 in.). The surface of the air-generator nozzle within the venturi chamber of the gun is protected from the abrading media with a 9.4 mm (3⁄8 in.) long piece of vinyl tubing 4.7 mm (3⁄16 in.) inside diameter with a 1.5 mm (1⁄16 in.) wall thickness. The inside diameter of the venturi chamber should not exceed 10 mm (3⁄8 in.) and should be checked periodically for wear.

5.1.4 *Air Supply*—The air line pressure shall be maintained at the desired pressure at the gun through the use of a standard suppressed range air gage indicating 6.9 kPa (±1 psi) mounted as close to the gun as possible. Only clean dry air should be used.

5.1.5 *Abrading Media*—No. 36 grit silicon carbide having a screen analysis as shown in Table 1.

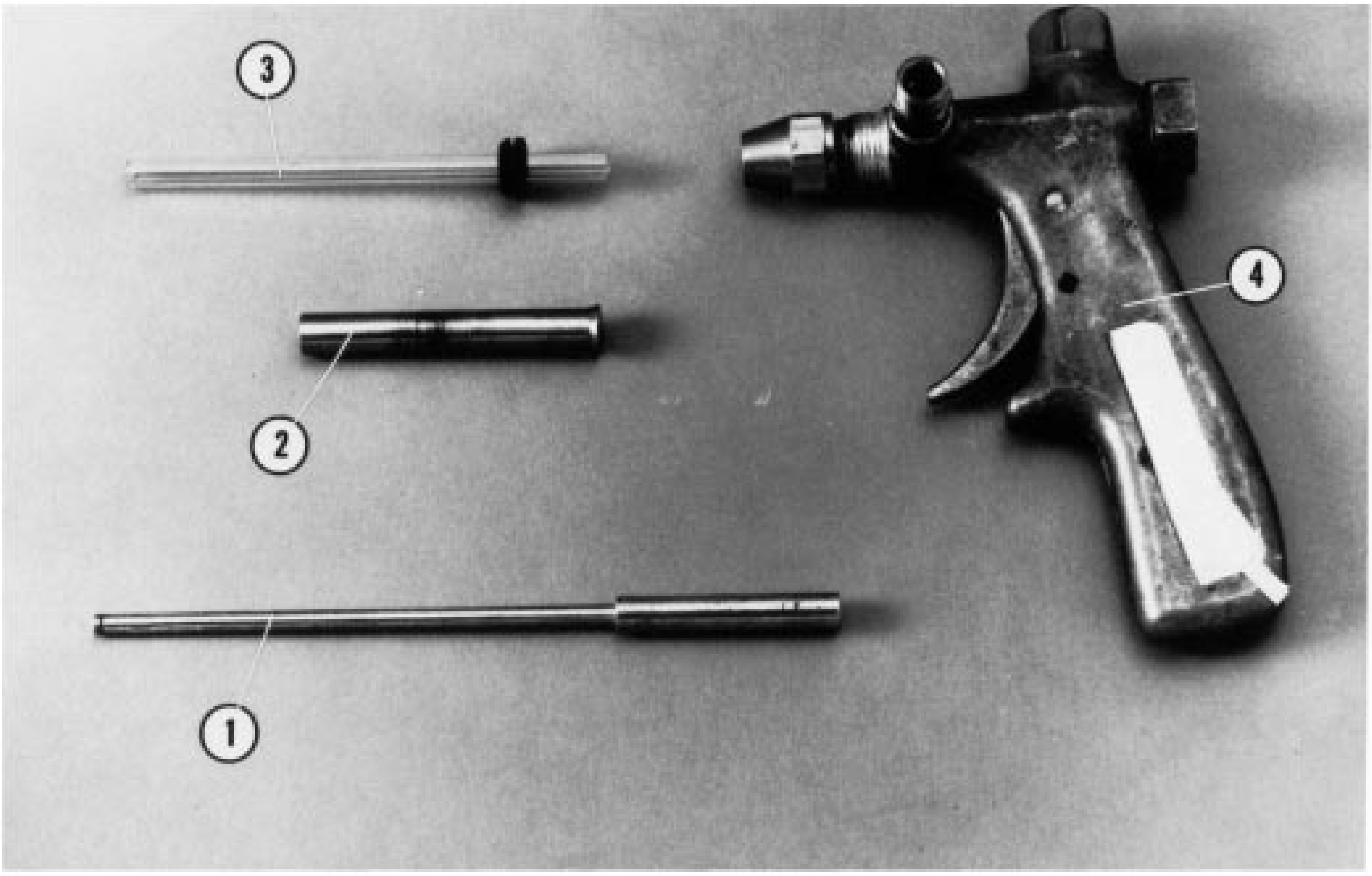


NOTE 1—Identified by number in this figure are: (1) sand blast gun, (2) air pressure regulator, (3) glass tube and metal stabilizing sleeve, (4) test sample, and (5) adjustable platform.

FIG. 2 Abrasion Tester

5.1.6 *Feeding Mechanism*—Two acceptable mechanisms for feeding the abrading media are shown in Fig. 4. The feed funnel must contain a suitable orifice to obtain a flow time of 450 ± 15 s while delivering 1000 g of abrading media into the gun supply funnel. Metal, glass, or plastic orifices can be used to regulate the flow. There must be an air gap between the orifice and the gun supply funnel to allow secondary air to enter with the abrading media.

5.1.7 *Test Chamber*, consisting of a tightly sealed closure with a door to permit ready access for mounting and removing the test specimens. A 13-mm (½-in.) hole shall be cut in the top of the test chamber to permit the vertical mounting of the blast gun such that the downward stream of abrading media will travel 203 mm (8 in.) from the glass nozzle tip to the test



NOTE 1—Identified by number in this figure are: (1) glass tube adjustment rod, (2) metal stabilizing sleeve, (3) glass tube with grommet, and (4) sand blast gun.

FIG. 3 Modified Blast Gun Breakdown

TABLE 1 Screen Analysis for Abrading Media

ASTM Standard Sieve No.	Opening, µm	Retained, %
20	850	trace
30	600	20± 2
50	300	80± 3
70	212	2 max
Pass No. 70		trace

specimen. Fig. 1 and Fig. 2 show the design of an acceptable chamber.[4]

5.1.7.1 *Dust Collector*—A standard dust-collecting cloth bag of adequate capacity may be used on the 52 mm (2¹⁄₁₆-in.) exhaust port of the chamber. This port is equipped with a butterfly valve to regulate the pressure in the chamber during the test. Alternate dust handling systems are acceptable as long as the chamber pressure is maintained at the desired level.

5.1.7.2 *Manometer*—During the test the chamber pressure shall be measured with a water manometer having a scale such that 311 Pa (1¼ in.) of water may be readily measured. A 6 mm (¼-in.) inside diameter pet cock shall be mounted in the top of the chamber to permit manometer connection.

5.2 *Balance*, capable of weighing the sample to an accuracy of ±0.1 g, used for weighing the abrading media and test specimens. Typically a 2000 g to 3000 g capacity balance is required.

6. Test Specimens

6.1 Test specimens shall be cut from refractory brick or shapes, or molded from monolithic refractory materials and measure from 100 by 100 by 25 mm (4 by 4 by 1 in.) to 114 by 114 by 65 or 76 mm (4½ by 4½ by 2½ or 3 in.). Only the most abrasion resistant materials can be 25 mm (1 in.) thick since the test is invalid if a hole is eroded completely through the specimen.

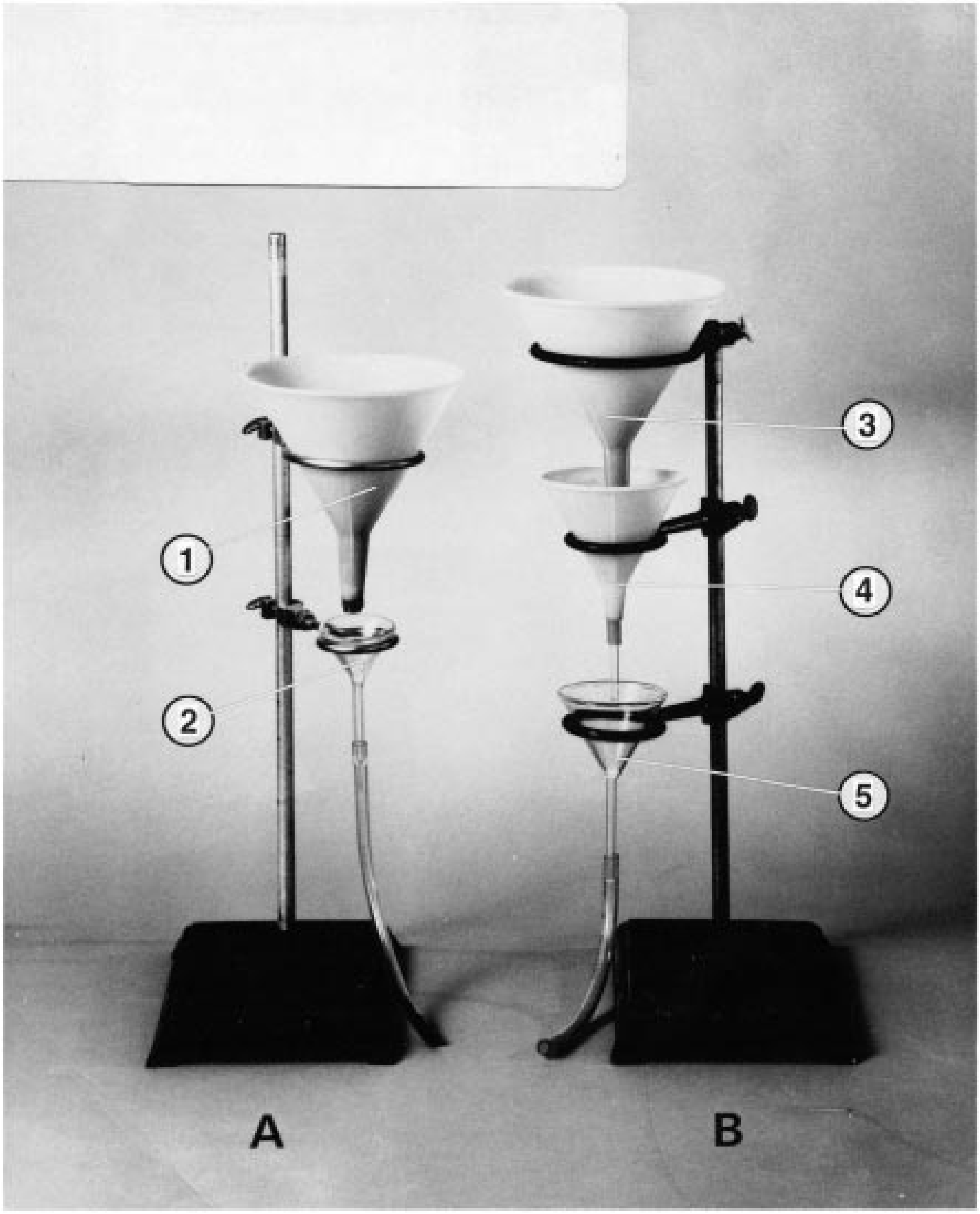
6.2 Castable refractories shall be molded in accordance with Practice C 862 and fired to anticipated service temperatures in accordance with Practice C 865.

6.3 Plastic refractories shall be molded and fired to anticipated service temperature in accordance with Test Method C 179 (see the sections on apparatus and test specimens).

7. Procedure

7.1 Dry the test specimens to a constant weight at 105 to 110°C (220 to 230°F) before testing.

[4] Detailed prints for the construction of the test chamber are available at a nominal cost from ASTM Headquarters. Request ADJC0704. An acceptable test chamber can be made from a weatherproof electrical switch box such as a Wiegmann B 20167 continuous hinge box.



NOTE 1—Identified by number in this figure are: (1) main supply funnel with metering insert, (2) gun supply funnel, (3) main supply funnel, (4) metering funnel, and (5) gun supply funnel.

FIG. 4 Feeding Mechanisms

7.2 Weigh the specimens to the nearest 0.1 g. Determine the volume of the specimens by measurement of length, width, and thickness to the nearest 0.5 mm (1⁄50 in.) in accordance with the apparatus section of Test Methods C 134.

7.3 Place the nominal 114 by 114 mm (4½ by 4½in.) face of the test specimens at a 90° angle to the glass nozzle with the unbranded surface to be abraded 203 mm (8 in.) from the tip of the glass nozzle. With monolithic refractory specimens, the surface (that is, top troweled face or bottom mold face) that most accurately reflects the actual field situation should be the test surface.

7.4 Turn on the air pressure and regulate it to 448 kPa (65 psi). Check the air pressure before and after the abrading media is run through the system.

7.5 Measure the cabinet pressure using the water manometer and maintain the pressure in the chamber at 311 Pa (1¼ in.) of water by means of the butterfly valve in the exhaust vent.

7.6 After the air pressure to the gun and the chamber pressure have been adjusted, disconnect the media line to the gun and place a 30 in. of mercury vacuum gauge in position. If the vacuum gauge does not show a minimum of 15 in. of mercury, check the position of the glass tubing or the condition of the air-generator nozzle. After obtaining the proper vacuum pressure, reconnect the feed tube and recheck the cabinet pressure before placing 1000 ± 5 g of dry abrading media in the reserve funnel. The feed funnel to the gun must not fill completely or flood with material. The feed mechanism when connected with the test apparatus must deliver the abrading media in the specified time of 450 ± 15 s.

7.7 Use the silicon carbide abrading media no more than 5 times before discarding. Remove the material retained on No. 20 (850-µm) and passing No. 50 (300-µm) sieves after each run.

7.8 Remove the refractory specimens from the test chamber, blow off the dust, and weigh to the nearest 0.1 g.

8. Calculation and Report

8.1 From the weight and volume, calculate the bulk density of the specimens in grams per cubic centimetre.

8.2 Calculate the amount of refractory lost by each specimen by abrasion in cubic centimetres, A, as follows:

$$A = [(M_1 - M_2)/B] = M / B$$

where:

B = bulk density, grams per cubic centimetre,
M_1 = weight of specimen before testing, g,
M_2 = weight of specimen after testing, g, and
M = weight loss of specimen, g.

8.3 Report the average of the individual results as the abrasion loss for that sample.

8.4 Record and report the time required for 1000 g of abrading media to flow through the gun.

8.5 Report which surface was abraded.

9. Precision and Bias

9.1 *Interlaboratory Test Data*—An interlaboratory study was completed among eight laboratories in 1999. Five different types of refractories were tested for abrasion resistance by each laboratory. The five types of refractories were a high-alumina brick, a silica brick, an abrasion-resistant castable, a super-duty fire brick, and a conventional high-cement castable. All samples were 4.5 by 4.5 in. in cross section. Additionally, both castables were fired to 1500°C. Prior to testing, bulk density and sonic velocity were measured on all samples to ensure uniformity. Samples were then randomly selected for distribution to the participating laboratories.

9.2 *Precision*—Table 2 contains the precision statistics for the abrasion resistance results.

9.2.1 *Repeatability*—The maximum permissible difference due to test error between two test results obtained by one operator on the same material using the same test equipment is given by the repeatability interval (r) and the relative repeatability interval (%r). The 95 % repeatability intervals are given in Table 2. Two test results that do not differ by more than the repeatability interval will be considered to be from the same population; conversely, two test results that do differ by more than the repeatability interval will be considered to be from different populations.

9.2.2 *Reproducibility*—The maximum permissible difference due to test error between two test results obtained by two operators in different laboratories on the same material using the same test equipment is given by the reproducibility interval (R) and the relative reproducibility interval (%R). The 95 % reproducibility intervals are given in Table 2. Two test results that do not differ by more than the reproducibility interval will be considered to be from the same population; conversely, two test results that do differ by more than the reproducibility interval will be considered to be from different populations.

9.3 *Bias*—No justifiable statement can be made on the bias of the test method for measuring the abrasion resistance of refractories because the value of the volume loss can be defined only in terms of a test method.

10. Keywords

10.1 abrasion resistance; blasted by air; castable refractories; flat surface; monolithic refractory materials; refractory brick or shape; room temperature

TABLE 2 Precision Statistics for Abrasion Resistance

Material	Average Volume Loss, cm^3	Standard Deviation Within Laboratories, *Sr*	Standard Deviation Between Laboratories, *SR*	Repeatability Interval, *r*	Reproducibility Interval, *R*	Coefficient of Variation Within Laboratories, *Vr*	Coefficient of Variation Between Laboratories, *VR*	Relative Repeatability, %*r*	Relative Reproducibility, %*R*
High-alumina brick	4.19	0.39	0.71	1.08	1.98	9.22	16.85	25.80	47.19
Silica brick	22.17	2.64	4.62	7.40	12.95	11.91	20.86	33.36	58.41
Abrasion-resistant castable	8.36	0.87	1.89	2.42	5.29	10.35	22.59	28.99	63.24
Super-duty firebrick	25.48	4.25	7.81	11.90	21.86	16.68	30.64	46.70	85.80
Conventional high-cement castable	10.89	2.12	3.02	5.94	8.45	19.48	27.71	54.54	77.59