Designation: C 704/C 704M – 09

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

This standard is issued under the fixed designation C 704/C 704M; 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, Practice C 861 and Practice C 865) and plastic refractories (see Practice C 1054).

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the 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]

C 134 Test Methods for Size, Dimensional Measurements, and Bulk Density of Refractory Brick and Insulating Firebrick

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

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

C 862 Practice for Preparing Refractory Concrete Specimens by Casting

C 865 Practice for Firing Refractory Concrete Specimens

C 1036 Specification for Flat Glass

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

2.2 *ASTM Adjuncts:*

Abrasion Tester (1 dwg)[3]

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. Interferences (Factors known to Affect Results)

5.1 During development, a ruggedness test was performed using 114 by 114 by 12.7 mm [4½ by 4½ by ½ in.] float glass plates conforming to Specification C 1036. Several factors were found to cause statistically significant effects on measured results.[4]

5.1.1 *Nozzle Tube Inside Diameter*—variation in the inside diameter of the flint glass nozzle tube statistically affected the abrasion values obtained on the glass plate. Ideal glass tube inside diameter is 4.8 mm. Glass tube lots purchased as 7 mm outside diameter tube with a nominal 1.1 mm wall thickness can have inside diameters ranging from 4.6 mm to 5.0 mm. For the ruggedness test, flint glass tube inside diameters of 4.7 mm and 4.9 mm were used. The statistically significant effect of this small tube inside diameter variation must be taken into consideration and all nozzle tube should be individually measured and chosen to conform to a specified 4.8 mm inside diameter.

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

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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.

[3] Detailed prints for the construction of the test chamber are available at a nominal cost from ASTM International Headquarters. Order Adjunct No. ADJC0704. An acceptable test chamber can be made from a weatherproof electrical switch box.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: **C08–1019** .

5.1.2 *Air Pressure*—variation in the test air pressure statistically affected the abrasion values obtained on the glass plate. Air pressure as specified in the test method is 448 kPa [65 psi] measured by a gauge capable to ± 6.9kPa [± 1 psi]. For the ruggedness test, air pressure was maintained at values of 441 kPa [64 psi] and 455 kPa [66 psi] by the use of a calibrated master series pressure gage. The statistically significant effect of this small air pressure variation must be taken into consideration and only calibrated gauges capable of maintaining 448 kPa [65 psi] air pressure be used. It is also recommended that air gauges be recalibrated at frequent intervals.

5.2 Factors which were found to be rugged during the test method evaluation were *(1)* particle size variation of the silicon carbide grain between sizings of grain composed of 25% 20mesh × 30mesh and 75% 30mesh × 50mesh silicon carbide to one composed of 15% 20mesh × 30mesh and 85% 30mesh × 50mesh silicon carbide sizing, *(2)* nozzle to sample distance varying between 200 mm [7⅞ in] to 206 mm [8⅛ in], *(3)* silicon carbide grit amount between 995 g and 1005 g, and *(4)* test operator.

6. Apparatus

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

6.1.1 *Blast Gun (Leitch Carco Gun Model LC-CG)*[5], modified for this equipment as shown in Fig. 3. Other sand blast gun models or types may affect test results.

6.1.2 *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 [4½ in.] long, 7 mm [0.276 in.] in outside diameter, with a measured 4.8 mm inside diameter, is used. This piece of glass tubing is held in place by a 70 mm [2¾ in.] long piece of stainless steel or copper tubing. The I.D. (inside diameter) of this tubing, which should be flared at one end to sit snugly inside a 9.53 mm [⅜ in.] tubing nut, should be 7.15 to 7.75 mm [9⁄32 to ⅝ in.]. The O.D. (outside diameter) should be 9.53 mm [⅜ in.]. This sleeve is glued or soldered in place 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 inserted in a 15.9 mm [⅝ in.] outside diameter, 6.4 mm [¼ in.] inside diameter rubber grommet of a thickness between 4.75 to 6.4 mm [3⁄16 to ¼ in.]. The glass tube is placed through the sleeve in the tubing nut, snugging the grommet within the nut.. The nut is attached to the gun. If there is an insufficient fit between the grommet, the tubing nut and the gun assembly, adequate vacuum draw (see 8.6) will be unattainable. The glass tube is then positioned at a distance of 2 mm [0.08 in.] from the air-generator nozzle. This is done by using 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 and inserting this rod into the glass tube. This will allow the operator to push the glass tubing up until the rod touches the nozzle, assuring a 2 mm [0.08 in.] gap between the nozzle and the glass tubing.

6.1.3 *Venturi*—The air-generator nozzle shall 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 [0.093 to 0.096 in.]. The air generator nozzle should be inspected for wear before any test series and replaced as necessary. The inside diameter of the venturi chamber should not exceed 10 mm [⅜ in.] and should be checked periodically for wear.

6.1.4 *Air Supply*—The air line pressure shall be maintained at the desired pressure at the gun through the use of a calibrated master series 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.

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

6.1.6 *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.

6.1.7 *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 specimen. Fig. 1 and Fig. 2 show the design of an acceptable chamber.[3]

6.1.7.1 *Dust Collector*—A dust-collecting cloth or paper 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 such as venting to the outside are acceptable as long as the chamber pressure is maintained at the desired level.

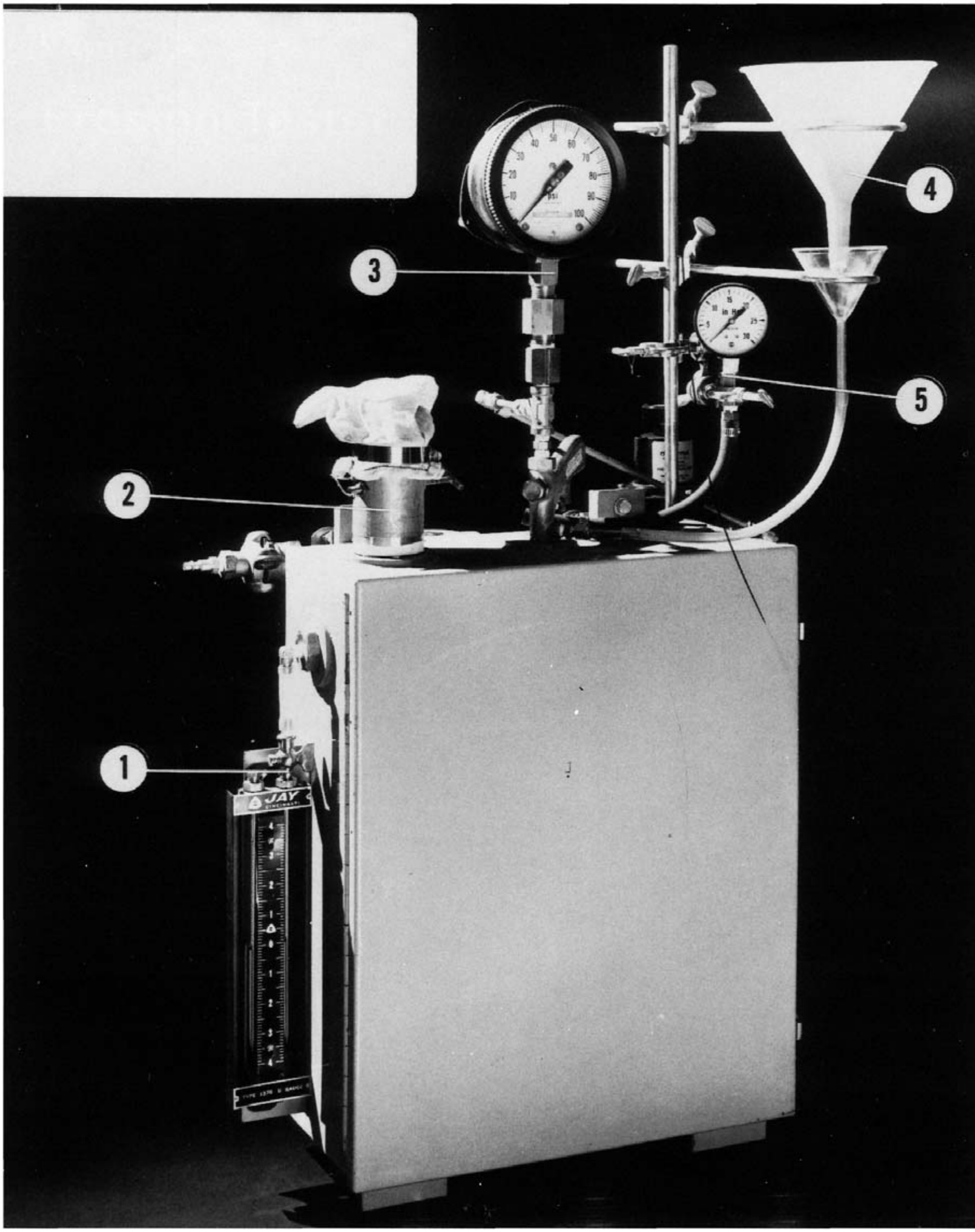
6.1.7.2 *Manometer*—During the test the chamber pressure shall be measured with a manometer (water, magnehelic or digital) having a scale such that 311 Pa [1¼ in.] of water may be readily measured. A 6-mm [¼-in.] inside diameter connector shall be mounted in the top of the chamber to permit manometer connection.

6.2 *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.

7. Test Specimens

7.1 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

[5] The sole source of supply of the apparatus known to the committee at this time is Leitch & Company, 106 Abram Court, San Leandro, CA 64577. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.



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.

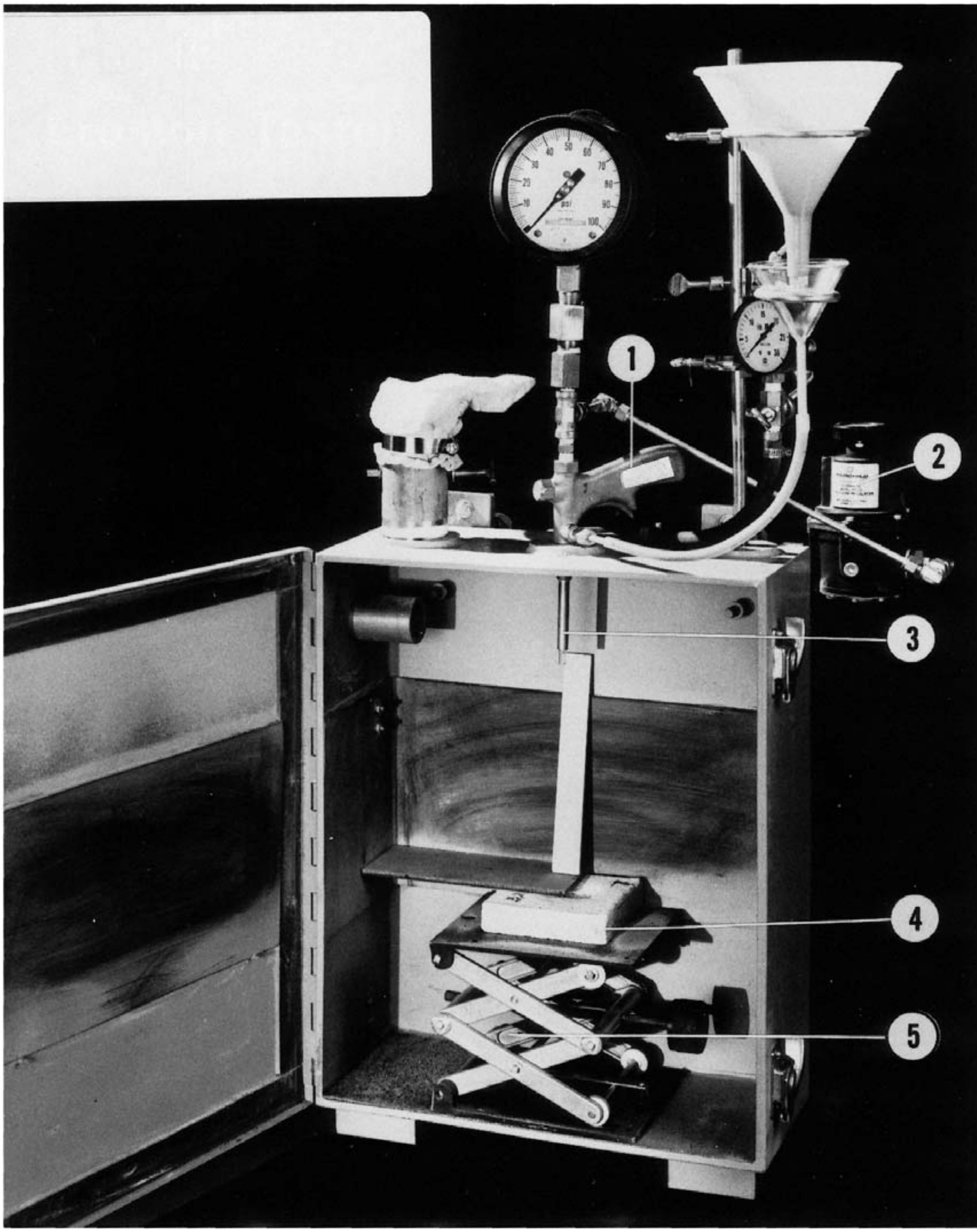
FIG. 1 Abrasion Tester

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.

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

7.3 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).

7.4 Calibration check specimens shall be 100 by 100 by 12.7 mm [4 by 4 by ½ in.] to 114 by 114 by 12.7 mm [4½ by 4½ by ½ in.] heavy float glass plates to Specification C 1036



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.

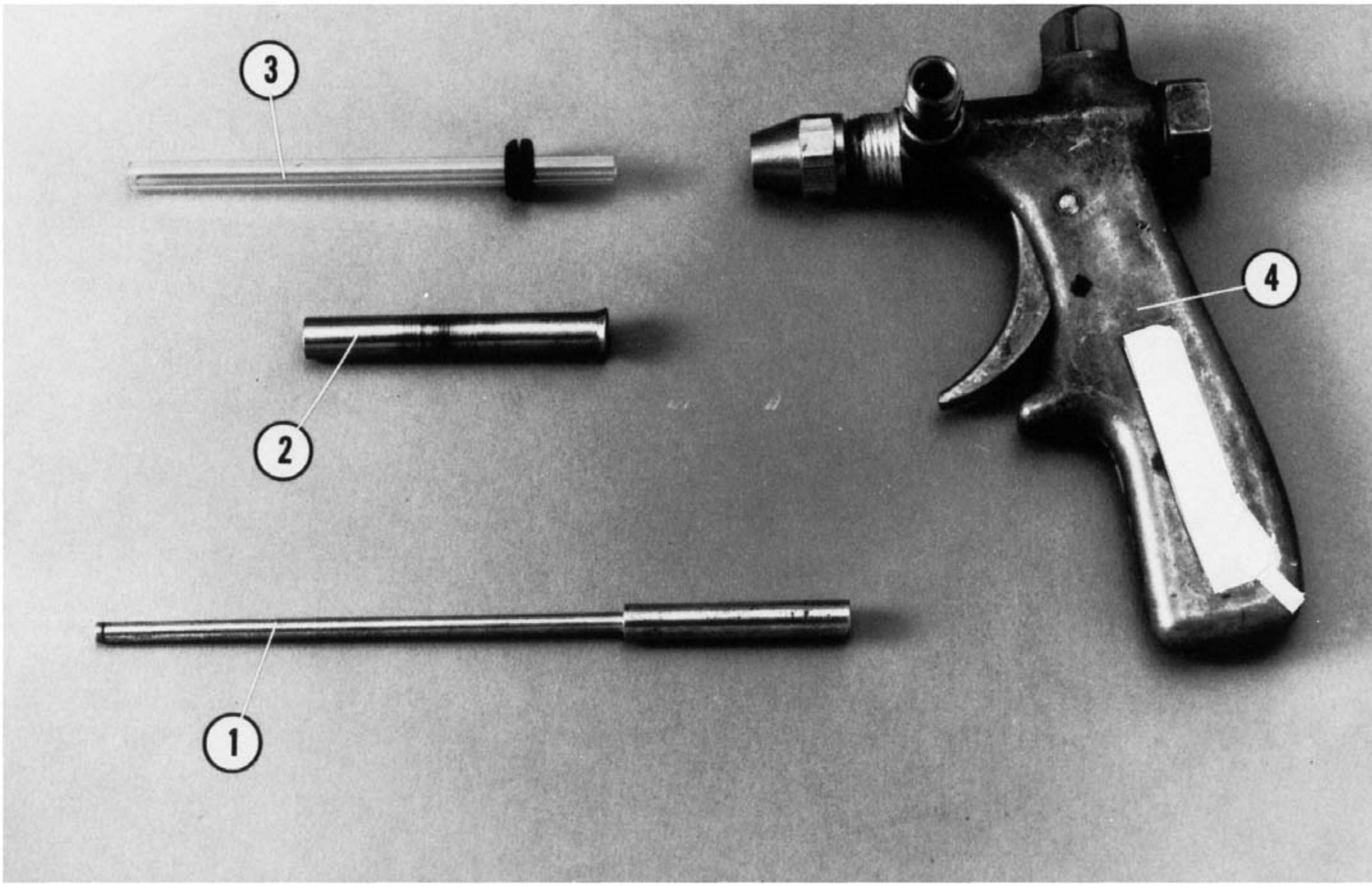
FIG. 2 Abrasion Tester

with a density of between 2.48 to 2.51 g/cc. It is recommended that calibration samples be run after any equipment maintenance or part changes are performed except for routine flint glass nozzle and air generator nozzle change outs. It is also recommended that calibration checks be performed every 20 test runs to assure the abrasion apparatus is in compliance to test requirements. Refer to Table 2 for the acceptable precision statistics for float glass plate.

8. Procedure

8.1 Dry the test specimens to a constant weight at 105 to 110°C [220 to 230°F] before testing.

8.2 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.



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

8.3 Place the nominal 114 by 114 mm [4½ by 4½ in.] 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.

8.4 Turn on the air pressure. The air pressure shall be regulated to 448 kPa [65 psi]. Check the air pressure before and after the abrading media is run through the system.

8.5 Measure the cabinet pressure using the 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.

8.6 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.

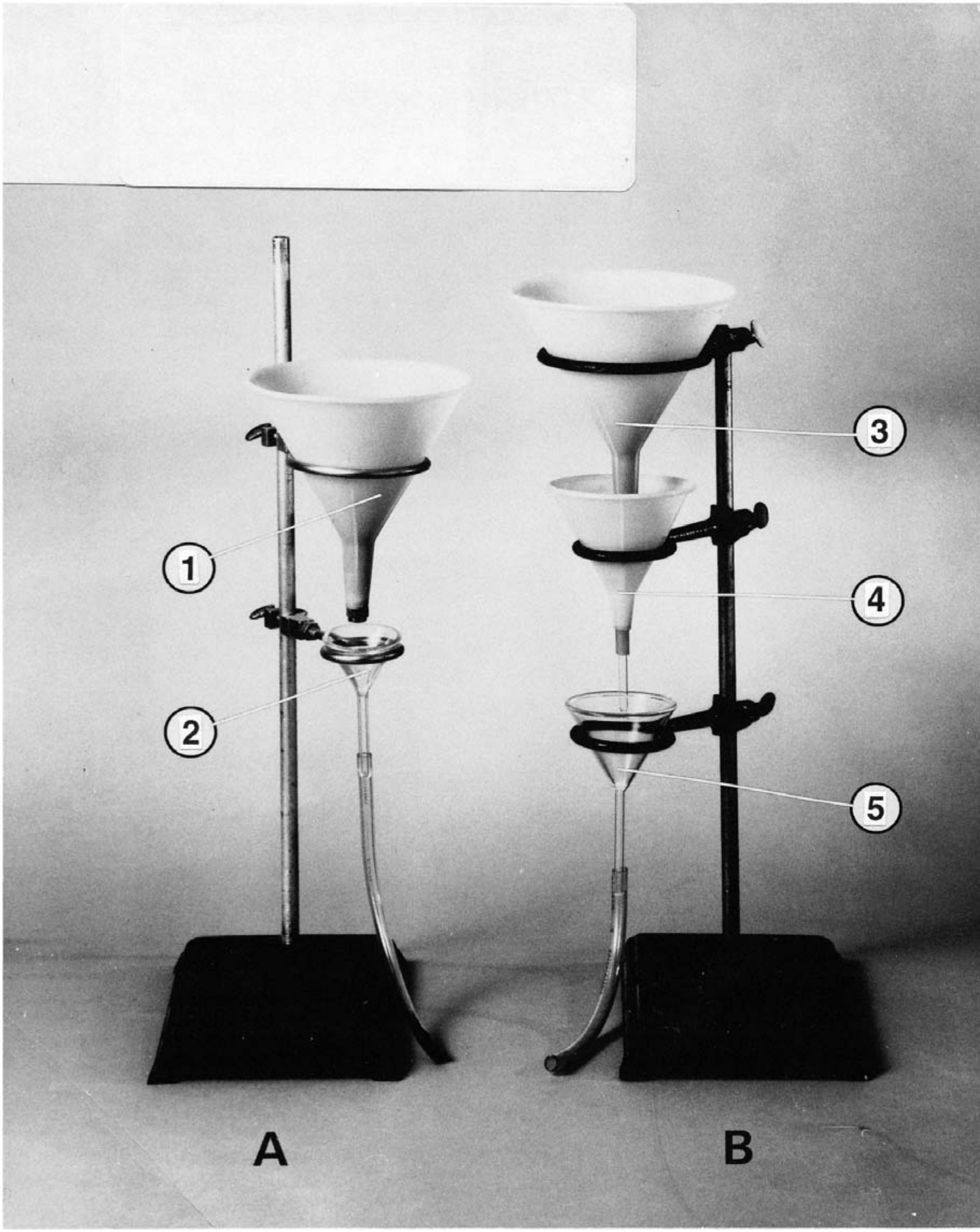
8.7 The silicon carbide abrading media shall be used only once and then discarded.

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

9. Calculation and Report

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

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



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

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
Plate Glass Standard	9.28	0.34	1.51	0.95	4.23	3.66	16.27	10.24	45.58

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

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.

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

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

9.5 Report which surface was abraded.

10. Precision and Bias [6]

10.1 *Interlaboratory Test Data*—An interlaboratory study was completed among eight laboratories in 1999. Five different types of refractories, along with a float glass plate standard, 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 specimens 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 specimens to ensure uniformity. Specimens were then randomly selected for distribution to the participating laboratories.

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

10.2.1 *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.

10.2.2 *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.

10.3 *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.

11. Keywords

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

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C08-1019.