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ภาคผนวก

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37-1484 Wavelength= 1.5405981

ZrO_2

Zirconium Oxide

Baddeleyite, syn

Rad.: CuKa1λ: 1.5405 Filter: Graph Mono d-sp: Diffractometer

Cut off: 17.7 Int.: Diffract. I/Icor.: 2.6

Ref: McMurdie, H et al., Powder Diffraction, 1, 275 (1986)

Sys.: Monoclinic S.G.: $P2_1/a$ (14)

a: 5.3129(4) b: 5.2125(4) c: 5.1471(5) A: 1.0193 C: 0.9875

α: β: 99.218(8) γ: Z: 4 mp:

Ref: Ibid.

Dx: 5.817 Dm: SS/FOM$_{30}$=111(.0073, 37)

Color: Colorless
Peak height intensity. The mean temperature of the data collection was 25.5°. Sample was obtained from Titanium Alloy Manufacturing Co. (1990) and was heated to 1300° for 48 hours. CAS #: 1314-23-4. Spectrographic analysis showed that this sample contained less than 0.01% each of Al, Hf and Mg and between 0.1 and 0.01% each of Fe, Si and Ti. Pattern reviewed by Holzer, J., McCarthy, G., North Dakota State Univ., Fargo, ND, USA, ICDD Grant-in-Aid (1990). Agrees well with experimental and calculated patterns. Additional weak reflections [indicated by brackets] were observed. $\sigma(I_{obs})$= ±1. There are a number of polymorphic forms of Zr O2 stable at different temperatures and pressures. The structure of Zr O2 (baddeleyite) was determined by McCullough and Trueblood (1) and confirmed by Smith and Newkirk (2). O2 Zr type. Also called: zirconium dioxide.Also called: zirkite.Silver, fluorophlogopite used as an internal stands. PSC: mP12. To replace 13-307 and 36-420 and validated by calculated pattern 24-1165. Mwt: 123.22. Volume[CD]: 140.70.

2θ	Int	h	k	l
17.419*	3	0	0	1
24.048'	14	1	1	0
24.441'	10	0	1	1
28.175	100	$\bar{1}$	1	1
31.468'	68	1	1	1
34.160'	21	2	0	0
34.383'	11	0	2	0
35.309'	13	0	0	2
35.900*	2	$\bar{2}$	0	1
38.396	1	[$\bar{2}$	1	0]
38.541*	4	1	2	0
39.411'	<1	0	1	2
39.990'	<1	$\bar{2}$	1	1
40.725'	12	$\bar{1}$	1	2
41.150*	5	2	0	1
41.374*	5	$\bar{1}$	2	1
44.826*	7	2	1	1
45.522*	6	$\bar{2}$	0	2
48.949*	2	$\bar{2}$	1	2
49.266'	18	2	2	0
50.116'	22	0	2	2
50.559'	13	$\bar{2}$	2	1
51.193*	5	$\bar{1}$	2	2
54.104'	11	0	0	3
54.680'	<1	2	2	1
55.270	11	[1	2	2]
55.400'	11	3	1	0
55.570*	9	$\bar{3}$	1	1
55.883*	6	0	3	1
57.168*	7	$\bar{1}$	1	3
57.861*	4	$\bar{1}$	3	1
58.268*	3	$\bar{2}$	2	2
59.775*	8	1	3	1
60.055*	7	$\bar{2}$	0	3
61.367*	5	3	1	1
61.984*	5	$\bar{3}$	1	2
62.838*	8	1	1	3
64.079*	1	3	2	0
64.250*	2	2	3	0
64.966'	<1	0	3	2
65.384*	2	$\bar{2}$	3	1
65.700*	6	0	2	3
65.884*	4	$\bar{1}$	3	2
68.912*	1	2	3	1
69.620'	<1	3	2	1
70.190'	<1	$\bar{3}$	2	2
71.071*	2	$\bar{2}$	2	3
71.300*	4	$\bar{4}$	0	1
71.950*	1	4	0	0
72.104*	1	$\bar{2}$	3	2
72.450'	<1	0	4	0
72.642'	<1	3	1	2
73.580'	<1	$\bar{3}$	1	3
74.682*	2	0	0	4
75.046*	4	1	4	0
76.410*	1	$\bar{1}$	1	4
77.392'	<1	3	3	0
78.079'	<1	4	0	1
78.866*	1	0	3	3

42-1164 Wavelength= 1.5418 *

ZrO_2

Zirconium Oxide

Rad.: CuKa λ: 1.5418 Filter: d-sp: Calculated

Cut off: Int.: Diffract. I/Icor.:

Ref: Teufer, G., Acta Crystallogr., 15, 1187 (1962)

Sys.: Tetragonal S.G.: $P4_2/nmc$ (137)

a: 3.64 b: c: 5.27 A: C: 1.4478

α: β: γ: Z: 2 mp:

Ref: Ibid.

Dx: 5.861 Dm: SS/FOM_{30}=253(.0030, 40)

Pattern taken at 1250 C. D-values calculated using cell parameters reported in reference. O2 Zr type. PSC: tP6. To replace 24-1164. Mwt: 123.22. Volume[CD]: 69.83.

2θ	Int	h	k	l	2θ	Int	h	k	l
29.831	100	1	0	1	115.805	3	4	0	0
34.023'	39	0	0	2	121.236	1	2	1	5
34.855'	34	1	1	0	122.737	1	0	0	6
42.354*	2	1	0	2	123.460	1	3	2	3
49.510'	34	1	1	2	124.597	1	4	1	1
50.121'	38	2	0	0	125.587	1	3	1	4
58.326'	12	1	0	3	127.323	1	4	0	2
59.427'	13	2	1	1	127.919	1	3	3	0
61.967*	7	2	0	2	136.049	1	1	1	6
67.643'	<1	2	1	2	141.805	3	3	3	2
71.623*	6	0	0	4	142.585	3	4	2	0
73.595*	8	2	2	0	151.315	2	3	0	5
76.968'	<1	1	0	4	154.112	3	2	0	6
80.428*	3	2	1	3	155.541	3	4	1	3
81.382*	3	3	0	1	164.835	3	4	2	2
82.191*	3	1	1	4					
83.616*	2	2	2	2					
84.089*	2	3	1	0					
92.499*	2	2	0	4					
93.915*	3	3	1	2					
99.186*	2	1	0	5					
101.106	2	3	0	3					
102.066	2	3	2	1					
113.731	2	2	2	4					

26-0341 Wavelength= 1.54056 *

Ca0.15Zr0.85O1.85

Calcium Zirconium Oxide

Rad.: Cu λ: 1.5405 Filter: Ni Beta M d-sp: Diffractometer

Cut off: Int.: Diffract. I/Icor.: 8.50

Ref: McIlvried, McCarthy, Penn State University, University Park, Pennsylvania, USA, ICDD Grant-in-Aid, (1972)

Sys.: Cubic S.G.: Fm3m (225)

a: 5.135 b: c: A: C:

α: β: γ: Z: 4 mp:

Ref: Ibid.

Dx: 5.551 Dm: SS/FOM$_{11}$=42(.024, 11)

Composition of most "lime stabilized zirconia" refractories and ceramics. PSC: cF11.40. Mwt: 113.15. Volume[CD]: 135.40.

2θ	Int	h	k	l
30.157	100	1	1	1
34.952'	20	2	0	0
50.225'	45	2	2	0
59.682'	25	3	1	1
62.632*	4	2	2	2
73.726*	4	4	0	0
81.671*	6	3	3	1
84.285*	4	4	2	0
94.614*	5	4	2	2
102.454	4	5	1	1
116.060	1	4	4	0

ภาคผนวก ข.

Designation: B 213 - 90

Standard Test Method for Flow Rate of Metal Powders[1]

This standard is issued under the fixed designation B 213; 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. B 213

1. Scope

1.1 This test method covers the determination of the flow rate of metal powders and is suitable only for those powders which will flow unaided through the specified apparatus.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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. Significance and Use

2.1 The flow rate of a metal powder determines the rate of filling of a die cavity in the pressing of sintered metal parts or bearings. High flow rates (low flow times) are usually desired for high productivity. The test method may be part of the purchase agreement between powder manufacturer and P/M parts producers, or it may be an internal quality control test for powder blended by a parts producer. It is commonly applied to ferrous powders and copper base alloys, but may be used on other powders as well. The test is not applicable to wet or pasty mixtures of metal powders, since they will not flow through the funnel and are not commonly used in P/M processing.

3. Apparatus

3.1 *Powder Flowmeter Funnel*—A standard flowmeter funnel[2] (Fig. 1) having a calibrated orifice of 0.10 in. (2.54 mm) in diameter.

3.2 *Stand*[2]—A stand (Fig. 1) to support the powder flowmeter funnel.

3.3 *Base*—A level, vibration-free base to support the powder flowmeter.

3.4 *Stop Watch.*

3.5 *Balance*—A balance suitable for weighing accurately to 0.01 g.

4. Test Specimen

4.1 The test specimen shall be 50 g, weighed to the nearest 0.1 g.

5. Procedure

5.1 The test specimen shall be tested as sampled. It should be noted, however, that moisture, oils, stearic acid, stearates, waxes, etc., may alter the characteristics of the powder.

5.2 Carefully load the test specimen into the flowmeter funnel while keeping closed the discharge orifice at the bottom of the funnel by placing a dry finger under it. Take care that the short stem of the funnel is filled.

5.3 Start the stop watch simultaneously with removal of the finger from the discharge orifice and stop it at the instant the last of the powder leaves the funnel. Record the elapsed time in seconds.

6. Report

6.1 The elapsed time shall be multiplied by the correction factor (see Note) and the result reported in seconds to the nearest second.

NOTE —The manufacturer supplies the funnel calibrated as follows: Using the procedure described in Section 5, the flow rate of standard 150-mesh Turkish emery is determined. The average of five determinations (the extremes of which shall not differ by more than 0.4 s) is stamped on the bottom of the funnel. The correction factor of the unused funnel is 40.0 divided by this number. It is recommended that the factor be periodically verified by the user by determining, by the above method, the flow rate of the standard 150-mesh Turkish emery.[3] If the flow rate has changed from that stamped on the instrument, the new correction factor will be 40.0 divided by this new flow rate. Before adopting the new correction factor, however, it is recommended that the cause of the change be investigated. If the flow rate has increased, it is probable that repeated use has burnished the orifice and the new correction factor may be used. A decrease in flow rate may indicate a plating of soft powder upon the orifice. This should be carefully removed with the aid of a pipe cleaner and the calibration test rerun, the new correction factor being calculated if required. It is recommended that the use of a funnel be discontinued after the flow rate of the standard sample has increased such that the time of flow is less than 37 s. The manufacturer's experience indicates that, under conditions of almost continuous daily use, a decrease in time of flow of 3 s should be expected after 5 years of service.

7. Precision and Bias

7.1 The precision of this test method is presently being determined by Subcommittee B09.02.

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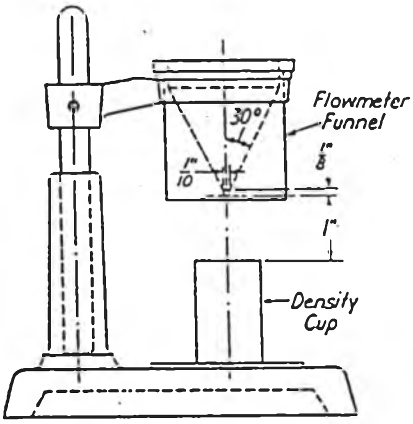
[1] This test method is under the jurisdiction of ASTM Committee B-9 on Metal Powders and Metal Powder Products and is the direct responsibility of Subcommittee B09.02 on Base Metal Powders.

Current edition approved Feb. 23, 1990. Published April 1990. Originally published as B 213 - 46 T. Last previous edition B 213 - 83.

[2] The powder flowmeter funnel, density cup, and stand are available from Alcan Powders and Pigments, 901 Lehigh Ave., Union, NJ 07083-7632.

[3] Standardized No. 150 emery grit is no longer being sold. In those instances where the user desires to verify the correction factor and does not possess the No. 150 emery grit, the funnel may be returned to Alcan Powders and Pigments, 901 Lehigh Ave., Union, NJ 07083-7632, for re-calibration and re-certification. It is recommended that verification be done at least annually depending on frequency of use.



Metric Equivalents

in.	mm
1/10	2.54
1/8	3
1	25

FIG. 1 Flowmeter Apparatus

Designation: B 527 – 93

Standard Test Method for Determination of Tap Density of Metallic Powders and Compounds[1]

This standard is issued under the fixed designation B 527; 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 specifies a method for the determination of tap density (packed density) of metallic powders and compounds, that is, the density of a powder that has been tapped, to settle contents, in a container under specified conditions.

1.2 *This standard does not purport to address all of the safety problems, 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:*

B 212 Test Method for Apparent Density of Free-Flowing Metal Powders[2]

B 215 Practice for Sampling Finished Lots of Metal Powders[2]

B 243 Terminology of Powder Metallurgy[2]

B 329 Test Method for Apparent Density of Powders of Refractory Metals and Compounds by Scott Volumeter[2]

B 417 Test Method for Apparent Density of Non-Free-Flowing Metal Powders[2]

B 703 Test Method for Apparent Density of Metal Powders Using the Arnold Meter[2]

3. Significance and Use

3.1 This test method covers the evaluation of the tapped density physical characteristic of metallic powders and compounds. The degree of correlation between the results of this test method and the quality of powders in use will vary with each particular application and has not been fully determined.

4. Apparatus

4.1 *Balance*, of appropriate capacity an accuracy to satisfy the requirements shown in Table 1.

4.2 *Graduated Glass Cylinder*[3], calibrated to contain 100 cm^3 at 20°C, the height of the graduated portion being approximately 175 mm. The graduations shall be at 1 cm^3 intervals, thus allowing a measuring accuracy of ± 0.5 cm^3. For apparent densities over 4.0 g/cm^3, do not use the 100 cm^3 cylinder.

TABLE 1 Accuracy and Capacity of Balance

Cylinder Capacity, cm^3	Apparent Density, g/cm^3	Mass of Test Portion, g
100	>1	100 ± 0.5
100	<1	50 ± 0.2
25	>7	100 ± 0.5
25	2 to 7	50 ± 0.2
25	<2	20 ± 0.1

4.2.1 Alternatively, the following may be used:

4.2.1.1 *Graduated Glass Cylinder*, calibrated to contain 25 cm^3 at 20°C, the height of the graduated portion being approximately 135 mm. The graduations shall be at 0.2 cm^3 intervals.

4.2.1.2 A 25-cm^3 cylinder shall be used for powders of apparent density higher than 4 g/cm^3, in particular for refractory metal powders, but may also be used for powder of lower apparent density.

4.3 *Tapping Apparatus*,[4] which permits the tapping of the graduated cylinder against a firm base. The tapping shall be such that a densification of the powder can take place without any loosening of its surface layers. The stroke shall be 3 mm (0.118 in.) and the tapping frequency shall be between 100 and 300 taps/min. An example of a tapping apparatus is shown in Fig. 1.

5. Test Specimen

5.1 For the quantities of powder required for each test, see Table 1. Obtain test powder samples according to Practices B 215.

5.2 In general, the powder should be tested in the as-received condition. In certain instances the powder may be dried. However, if the powder is susceptible to oxidation, the drying shall take place in a vacuum or in inert gas. If the powder contains volatile substances, it shall not be dried.

5.3 The test shall be carried out on three test samples.

6. Procedure

6.1 Clean the inside the wall of the graduated cylinder (5.2) with a suitable clean brush or, if necessary, by rinsing with a solvent, such as acetone. If a solvent is used, thoroughly dry the cylinder before reuse.

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[1] This specification is under the jurisdiction of ASTM Committee B-9 on Metal Powders and Metal Powder Products and is the direct responsibility of Subcommittee B09.03 on Refractory Metal Powders.

Current edition approved Dec. 15, 1993. Published April 1994. Originally published as B 527 – 70. Last previous edition B 527 – 85 (1991).$^{\epsilon 1}$

[2] *Annual Book of ASTM Standards*, Vol 02.05.

[3] Corning No. 3046. Pyrex brand has been found suitable.

[4] The following have been found suitable: Shandon Southern Instruments, Inc. Tap-Pak Volumeter Model JEL-ST2 (Manufactured by J. Engelsmann A.G. of Ludwigshafen 9, Rh. West Germany), 515 Broad Street, Sewickly, PA 15143; Vankel Industries, Vanderkamp Tap Density Tester, 36 Meridian Road, Edison NJ 08820; Quantachrome Corp., Dual Autotap, 6 Aerial Way, Syosset, NY 11791

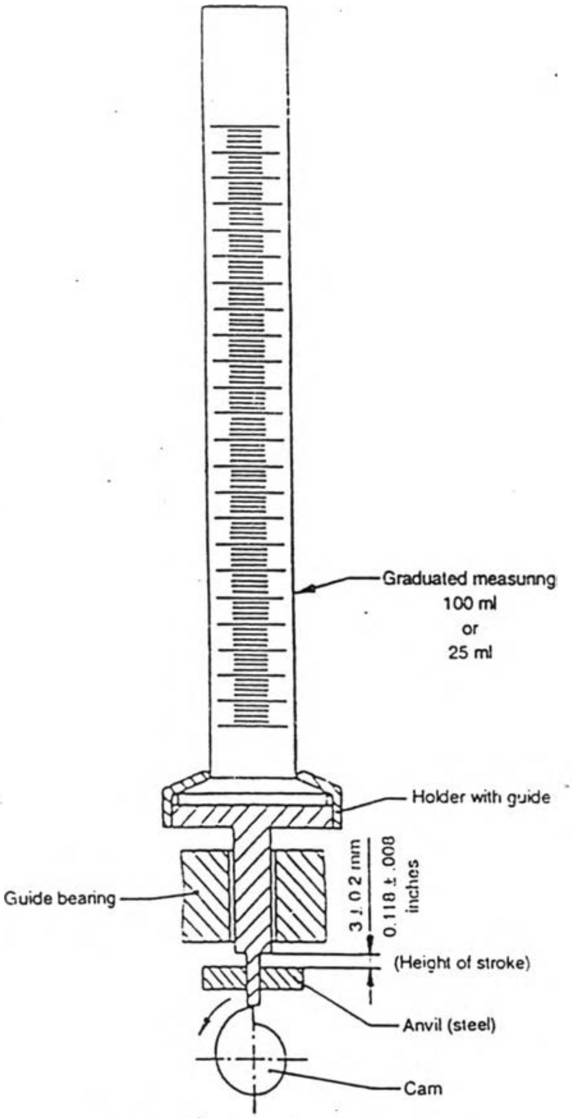

FIG. 1 Example of Tapping Apparatus

6.2 Weigh, to the nearest 0.1 g, the mass of the test portion as indicated in Table 1, using a balance (4.1).

6.3 Pour the test portion into the graduated cylinder. Take care that a level surface of the powder is formed. Place the cylinder in the tapping apparatus (4.3). Tap the cylinder until no further decrease in the volume of the powder takes place (see Note 1).

NOTE 1—In practice, the minimum number of taps, N, such that no further change in volume takes place would be determined. For all further tests on the same type of powder, the cylinder would be subjected to $2N$ taps, except where general experience and acceptance have established a specific number of taps (no less than N taps) as being satisfactory. For fine refractory metal powders, 3000 taps has been found to be satisfactory for all sizes.

6.4 If the tapped surface is level, read the volume directly. If the tapped surface is not level, determine the tape volume by calculating the mean value between the highest and the lowest reading of the tapped surface. Read the final volume to the nearest 0.5 cm³ when using a 100 cm³ cylinder and to the nearest 0.2 cm³ when using a 25 cm³ cylinder.

7. Calculation

7.1 The tap density is given in the following equation

$$Pt = \frac{M}{V}$$

where:

Pt = tap density, g/cm³,
M = mass of powder, g, and
V = volume of tapped powder, cm³.

8. Report

8.1 Report the following information:

8.1.1 Reference to this test method,

8.1.2 All details necessary for identification of the test sample,

8.1.3 The drying procedure, if the powder has been dried,

8.1.4 Cylinder capacity, mass of test portion and method used,

8.1.5 The result obtained,

8.1.6 All operations not specified in this test method or regarded as optional,

8.1.7 Details of any occurrence that may have affected the result.

9. Precision and Bias

9.1 Precision and bias cannot be stated at this time because this test method covers a broad range of powders and associated densities.

10. Keywords

10.1 apparent density; bulk density; density; density ratio; metal powders; packed density; powder metallurgy; tap density

Designation: C 373 – 88 (Reapproved 1994)

Standard Test Method for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products[1]

This standard is issued under the fixed designation C 373; 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 procedures for determining water absorption, bulk density, apparent porosity, and apparent specific gravity of fired unglazed whiteware products.

1.2 *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. Significance and Use

2.1 Measurement of density, porosity, and specific gravity is a tool for determining the degree of maturation of a ceramic body, or for determining structural properties that may be required for a given application.

3. Apparatus and Materials

3.1 *Balance*, of adequate capacity, suitable to weigh accurately to 0.01 g.

3.2 *Oven*, capable of maintaining a temperature of 150 ± 5°C (302 ± 9°F).

3.3 *Wire Loop, Halter, or Basket*, capable of supporting specimens under water for making suspended mass measurements.

3.4 *Container*—A glass beaker or similar container of such size and shape that the sample, when suspended from the balance by the wire loop, specified in 3.3, is completely immersed in water with the sample and the wire loop being completely free of contact with any part of the container.

3.5 *Pan*, in which the specimens may be boiled.

3.6 *Distilled Water*.

4. Test Specimens

4.1 At least five representative test specimens shall be selected. The specimens shall be unglazed and shall have as much of the surface freshly fractured as is practical. Sharp edges or corners shall be removed. The specimens shall contain no cracks. The individual test specimens shall weigh at least 50 g.

5. Procedure

5.1 Dry the test specimens to constant mass (Note) by heating in an oven at 150°C (302°F), followed by cooling in a desiccator. Determine the dry mass, *D*, to the nearest 0.01 g.

NOTE—The drying of the specimens to constant mass and the determination of their masses may be done either before or after the specimens have been impregnated with water. Usually the dry mass is determined before impregnation. However, if the specimens are friable or evidence indicates that particles have broken loose during the impregnation, the specimens shall be dried and weighed after the suspended mass and the saturated mass have been determined, in accordance with 5.3 and 5.4 In this case, the second dry mass shall be used in all appropriate calculations.

5.2 Place the specimens in a pan of distilled water and boil for 5 h, taking care that the specimens are covered with water at all times. Use setter pins or some similar device to separate the specimens from the bottom and sides of the pan and from each other. After the 5-h boil, allow the specimens to soak for an additional 24 h.

5.3 After impregnation of the test specimens, determine to the nearest 0.01 g the mass, *S*, of each specimen while suspended in water. Perform the weighing by placing the specimen in a wire loop, halter, or basket that is suspended from one arm of the balance. Before actually weighing, counterbalance the scale with the loop, halter, or basket in place and immerse in water to the same depth as is used when the specimens are in place. If it is desired to determine only the percentage of water absorption, omit the suspended mass operation.

5.4 After the determination of the suspended mass or after impregnation, if the suspended mass is not determined, blot each specimen lightly with a moistened, lint-free linen or cotton cloth to remove all excess water from the surface, and determine the saturated mass, *M*, to the nearest 0.01 g. Perform the blotting operation by rolling the specimen lightly on the wet cloth, which shall previously have been saturated with water and then pressed only enough to remove such water as will drip from the cloth. Excessive blotting will introduce error by withdrawing water from the pores of the specimen. Make the weighing immediately after blotting, the whole operation being completed as quickly as possible to minimize errors due to evaporation of water from the specimen.

6. Calculation

6.1 In the following calculations, the assumption is made that 1 cm^3 of water weighs 1 g. This is true within about 3 parts in 1000 for water at room temperature.

6.1.1 Calculate the exterior volume, *V*, in cubic centimetres, as follows:

$$V = M - S$$

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[1] This test method is under the jurisdiction of ASTM Committee C-21 on Ceramic Whitewares and Related Products and is the direct responsibility of Subcommittee C21.03 on Fundamental Properties.

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6.1.2 Calculate the volumes of open pores V_{OP} and impervious portions V_{IP} in cubic centimetres as follows:

$$V_{OP} = M - D$$

$$V_{IP} = D - S$$

6.1.3 The apparent porosity, P, expresses, as a percent, the relationship of the volume of the open pores of the specimen to its exterior volume. Calculate the apparent porosity as follows:

$$P = [(M - D)/V] \times 100$$

6.1.4 The water absorption, A, expresses as a percent, the relationship of the mass of water absorbed to the mass of the dry specimen. Calculate the water absorption as follows:

$$A = [(M - D)/D] \times 100$$

6.1.5 Calculate the apparent specific gravity, T, of that portion of the test specimen that is impervious to water, as follows:

$$T = D/(D - S)$$

6.1.6 The bulk density, B, in grams per cubic centimetre, of a specimen is the quotient of its dry mass divided by the exterior volume, including pores. Calculate the bulk density as follows:

$$B = D/V$$

7. Report

7.1 For each property, report the average of the values obtained with at least five specimens, and also the individual values. Where there are pronounced differences among the individual values, test another lot of five specimens and, in addition to individual values, report the average of all ten determinations.

8. Precision and Bias

8.1 This test method is accurate to ±0.2 % water absorption in interlaboratory testing when the average value recorded by all laboratories is assumed to be the true water absorption. The precision is approximately ± 0.1 % water absorption on measurements made by a single experienced operator.

ประวัติผู้เขียน

นายพิชญ์รัตน์ อินทร์เอื้อ เกิดวันพฤหัสบดีที่ 25 ธันวาคม พ.ศ. 2518 ที่จังหวัดกรุงเทพ ฯ สำเร็จการศึกษาปริญญาตรีวิทยาศาสตร์บัณฑิต สาขาเซรามิก ภาควิชาวัสดุศาสตร์ คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย ในปีการศึกษา 2539 และเข้าศึกษาต่อในหลักสูตรวิทยาศาสตร์มหาบัณฑิต สาขาเทคโนโลยีเซรามิก ที่ภาควิชาวัสดุศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย เมื่อ พ.ศ. 2540