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APPENDICES

Appendix A

X-ray Diffraction Card

of

Hydroxyapatite

$(Ca_5(PO_4)_3OH)$

9-432 MAJOR CORRECTION

d	2.81	2.78	2.72	8.17
I/I$_1$	100	60	60	12

$Ca_5(PO_4)_3(OH)$ — $1/2[Ca(OH)_2 \cdot 3Ca_3(PO_4)_2]$ ★

Calcium Hydroxide Orthophosphate (Hydroxyapatite)

Rad. CuKα λ 1.5405 Filter Dia. 114.6mm
Cut off 2.0 I/I$_1$ Diffractometer (Guinier camera)
Ref. Wilson, Trans. Farad. Discuss., Draft, Holland

Sys. Hexagonal S.G. $P6_3/m$ (176)
a 9.418 b c 6.884 A C 0.7309
α β γ Z 2 Dx 3.16
Ref. Ibid.

ε nωβ I$_f$ Sign
2V D 3.08 mp Color
Ref.

* I/I$_1$ are peak values from a pattern which shows slight broadening of prism reflections.
Sample obtained following the procedure indicated by Hauge C.S., Ind. Eng. Chem. Anal. Ed. 10 154 (1938).

d Å	I/I$_1$	hkl	d Å	I/I$_1$	hkl
8.17	12	100	2.040	2	400
5.28	6	101	2.000	6	203
4.72	4	110	1.943	20	222
4.07	10	200	1.890	16	312
3.88	10	111	1.871	4	320
3.51	2	201	1.841	40	213
3.44	40	002	1.806	20	321
3.17	12	102	1.780	12	410
3.08	18	210	1.754	16	402,303
2.814	100	211	1.722	20	004,411
2.778	60	112	1.634	4	104
2.720	60	300	1.644	10	322,223
2.631	25	202	1.611	8	313
2.528	6	301	1.587	4	501,204
2.296	8	212	1.542	6	420
2.262	20	310	1.530	6	331
2.228	2	221	1.503	10	214,421
2.148	16	311	1.474	12	502
2.134	4	302	1.465	4	510
2.085	8	113	PLUS ADDITIONAL LINES		

Designation: C 373 – 72 (Reapproved 1982)

Appendix B

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 method covers procedures for determining water absorption, bulk density, apparent porosity, and apparent specific gravity of fired unglazed whiteware products.

2. Apparatus and Materials

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

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

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

2.4 *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 2.3, is completely immersed in water with the sample and the wire loop being completely free of contact with any part of the container.

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

2.6 *Distilled Water*.

3. Test Specimens

3.1 At least 5 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.

4. Procedure

4.1 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 4.3 and 4.4. In this case, the second dry mass shall be used in all appropriate calculations.

4.2 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 14 h.

4.3 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

[1] This method is under the jurisdiction of ASTM Committee C-21 on Ceramic Whitewares and Related Products.

Current edition approved Aug. 29, 1972. Published October 1972. Originally published as C 373 – 55 T. Last previous edition C 373 – 56 (1970).

desired to determine only the percentage of water absorption, omit the suspended mass operation.

4.4 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.

5. Calculations

5.1 In the following calculations, the assumption is made that 1 cm³ of water weighs 1 g. This is true within about 3 parts in 1000 for water at room temperature.

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

$$V = M - S$$

5.1.2 Calculate the volumes of open pores and impervious portions in cubic centimetres as follows:

$$\text{Volume of open pores, cm}^3 = M - D$$

$$\text{Volume of impervious portions, cm}^3 = D - S$$

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

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

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

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

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

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

5.1.6 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:

$$B = D/V$$

6. Report

6.1 For each property, report the average of the values obtained with at least 5 specimens, and also the individual values. Where there are pronounced differences among the individual values, another lot of 5 specimens shall be tested and in addition to individual values the average of all 10 determinations shall be reported.

7. Precision and Accuracy

7.1 This method is accurate to ±0.2 percent 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 percent water absorption on measurements made by a single experienced operator.

Appendix C

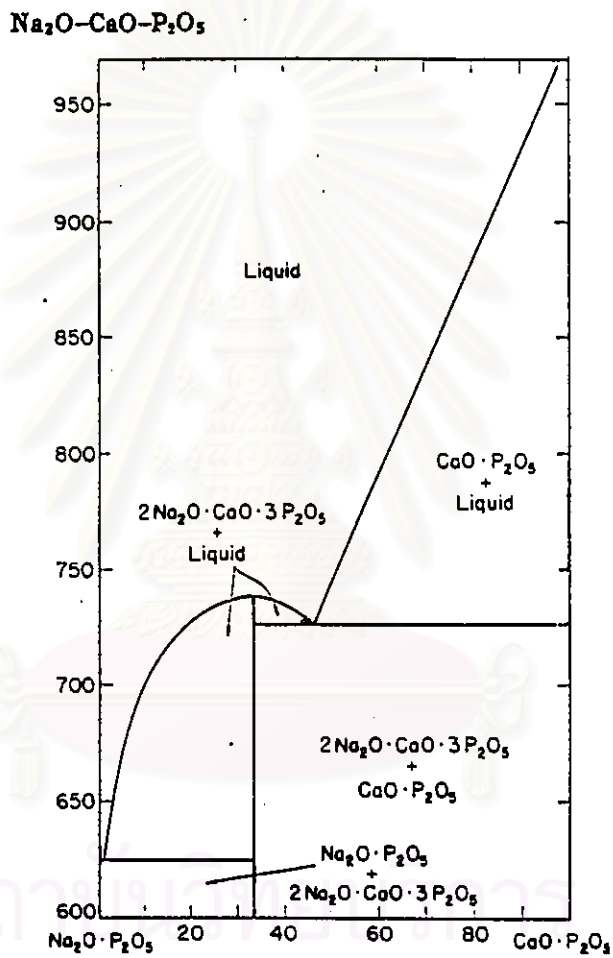

FIG. 486.—System $Na_2O \cdot P_2O_5$–$CaO \cdot P_2O_5$.
G. W. Morey, *J. Am. Chem. Soc.*, 74, 5783 (1952).

Appendix D

Calculation of Glass Formulation

From chemical analysis of hydroxyapatite

CaO 54.0 wt.%

P_2O_5 41.3 wt.%

Na_2O 1.22 wt.%

MgO 1.24 wt.%

Convert to mol by dividing wt.% with molecular weight

CaO = 0.9629 mol = 1.0000 mol

P_2O_5 = 0.2909 mol = 0.3021 mol

Na_2O = 0.0196 mol = 0.0203 mol

MgO = 0.0307 mol = 0.0318 mol

C1 0.02 mol Na_2O

	CaO	P_2O_5	Na_2O	MgO	wt.(g)	wt.(g)
expect	0.98	1.00	0.02+0.0203	0.0318	-	-
0.98 bone	0.98	0.2960	0.0118	0.0311	99.4534	49.47
require	-	0.7040	0.0205	0.0007	-	-
add $NaPO_3HPO_3$	-	2x0.0205	-	-	7.4595	3.71
add P_2O_5	-	0.6630	-	-	94.1062	46.82
					201.0191	100.00

C2 0.03 mol Na_2O

	CaO	P_2O_5	Na_2O	MgO	wt.(g)	wt.(g)
expect	0.97	1.00	0.03+0.0203	0.0318	-	-
0.97 bone	0.97	0.2930	0.0197	0.0308	98.4483	48.92
require	-	0.7070	0.0306	0.0010	-	-
add $NaPO_3HPO_3$	-	2x0.0306	-	-	11.1347	5.53
add P_2O_5	-	0.6458	-	-	91.6648	45.55
					201.2478	100.00

C3 0.04 mol Na_2O

	CaO	P_2O_5	Na_2O	MgO	wt.(g)	wt.(g)
expect	0.96	1.00	0.04+0.0203	0.0318	-	-
0.96 bone	0.96	0.2900	0.0194	0.0305	97.4836	48.37
require	-	0.7100	0.0409	0.0013	-	-
add $NaPO_3HPO_3$	-	2x0.0409	-	-	14.8826	7.39
add P_2O_5	-	0.6282	-	-	89.1667	44.24
					201.5329	100.00

C4 0.10 mol Na_2O

	CaO	P_2O_5	Na_2O	MgO	wt.(g)	wt.(g)
expect	0.90	1.00	0.10+0.0203	0.0318	-	-
0.90 bone	0.90	0.2718	0.0182	0.0286	91.3320	45.02
require	-	0.7282	0.1021	0.0032	-	-
add $NaPO_3HPO_3$	-	2x0.1021	-	-	37.1521	18.32
add P_2O_5	-	0.5240	-	-	74.3765	36.66
					202.8606	100.00

C5 0.15 mol Na_2O

	CaO	P_2O_5	Na_2O	MgO	wt.(g)	wt.(g)
expect	0.85	1.00	0.15+0.0203	0.0318	-	-
0.85 bone	0.85	0.2567	0.0172	0.0270	86.2582	42.28
require	-	0.7433	0.1531	0.0048	-	-
add $NaPO_3HPO_3$	-	2x0.1531	-	-	55.7100	27.31
add P_2O_5	-	0.4371	-	-	62.0419	30.41
					204.0101	100.00

C6 0.18 mol Na_2O

	CaO	P_2O_5	Na_2O	MgO	wt.(g)	wt.(g)
expect	0.82	1.00	0.18+0.0203	0.0318	-	-
0.82 bone	0.82	0.2477	0.0166	0.0260	83.2210	40.66
require	-	0.7523	0.1837	0.0058	-	-
add $NaPO_3HPO_3$	-	2x0.1837	-	-	66.8447	32.65
add P_2O_5	-	0.3849	-	-	54.6327	26.69
					204.6984	100.00

C7 0.20 mol Na_2O

	CaO	P_2O_5	Na_2O	MgO	wt.(g)	wt.(g)
expect	0.80	1.00	0.20+0.0203	0.0318	-	-
0.80 bone	0.80	0.2416	0.0162	0.0254	81.1845	39.57
require	-	0.7584	0.2041	0.0064	-	-
add $NaPO_3HPO_3$	-	2x0.2041	-	-	74.2679	36.20
add P_2O_5	-	0.3502	-	-	49.7073	24.23
					205.1597	100.00

Vita

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