NOTE ON PORCELAIN GLASS POT MIXTURES^{1,2}

By D. H. FULLER

The use of porcelain pot mixtures in this laboratory made it desirable to know the physical properties of these materials, with reference to their drying shrinkage and porosity upon firing to a series of temperatures, mechanical strength in the fired state, resistance to load conditions and their softening point. Such data are important for checking up the properties of the body produced, as a matter of record and for the determination of the proper pre-firing or arching temperature.

It was also thought desirable to study a number of such compositions varying principally with reference to the sizing of the grog, for which whiteware bisque was invariably employed and with reference to the presence or absence of feldspar.

The compositions of the body mixtures are given in table I. It will be observed that the amount of grog dust was kept down to a

TABLE I—BODY COMPOSITIONS

	Body No.						
	1	2	3	4	5	6	7
	%	%	%	%	%	%	%
Feldspar.....	6.50	0.00	0.00	6.50	6.50	6.00	6.00
Ky. Ball No. 4.....	11.00	11.00	14.25	11.00	11.00	10.00	10.00
Tenn. Ball No. 5.....	11.00	11.00	14.25	11.00	11.00	10.00	10.00
N. C. kaolin.....	11.75	18.25	11.75	11.75	11.75	12.50	12.50
Del. kaolin.....	5.87	5.87	5.87	5.87	5.87	4.50	4.50
Ga. kaolin.....	5.87	5.87	5.87	5.87	5.87	4.50	4.50
Grog 10-20 mesh.....	16.80	14.40	14.40	.00	38.40	18.40	15.80
Grog 20-40 mesh.....	19.20	19.20	19.20	43.20	.00	23.60	21.00
Grog 40-80 mesh.....	9.60	12.00	12.00	.00	4.80	10.50	8.90
Grog 80 dust.....	2.40	2.40	2.40	4.80	4.80		6.80

low figure, a condition made necessary by the quick cooling of the glass pots in use. The results of the physical tests are compiled in table II. A description of the tests is unnecessary since they have been discussed amply in the literature. It might be

¹ Received Feb. 27, 1920.

² By permission of the Director, Bureau of Standards.

stated, however, that the load test was carried to a maximum temperature of 1350° C and the pressure maintained was 50 pounds per square inch. The specimens for this test were fired to cone 15. The transverse strength of the fired bodies was upon bars previously burned to cone 15.

TABLE 2—RESULTS OF PHYSICAL TESTS

No.	Water content in plastic state Per cent	Drying shrinkage in terms of dry vol. Per cent	Modulus of rupture in dried state, lbs. per sq. in.	Modulus of rupture fired to cone 15 lbs. per sq. in.	Contraction in load test, per cent of original length	Fusion point Cones
1..	19.43	5.39	298	1976	1.4	31
2..	21.82	7.54	269	2095	0.24	31
3..	21.82	7.68	260	1838	0.12	32
4..	21.41	7.08	263	2244	0.29	31
5..	20.23	6.67	155	1572	0.02	32
6..	19.66	6.31	213	1998	0.06	31
7..	19.83	7.22	250	2299	0.12	31

Discussion of Results.—It will be noted that the water content and the drying shrinkage show no marked differences, and that the strength in the dry state is greatest when the content of coarse grog, 10–20 mesh, is relatively low and the material sized between the 20 and 80-mesh sieve higher. Undoubtedly the presence of larger amounts of finer dust would have resulted in greater strength in the dried state. Practically the same statement holds for the transverse strength of the bodies fired to cone 15. From the load tests results it is apparent that these bodies resist pressure conditions under furnace conditions very satisfactorily indeed, due principally to the high silica content of the whiteware bisque grog. The relatively large contraction of body No. 1 cannot be explained from the composition but is perhaps due to a lower degree of burning. The fusion points of the porcelain materials are practically of the same magnitude, cones 31–32.

Firing Behavior.—Briquettes of the seven bodies were made and fired to 8 temperatures, from cones 1 to 15, inclusive, maintaining as closely as possible a steady temperature increase of 20° C per hour. The usual determinations of the volume shrinkage, expressed in terms of the dry volume and of the porosity were made.

The results of this work are compiled in table 3. From the values obtained it is noted that the general behavior of these bodies in firing is practically the same. The most rapid rate of vitrification takes place between cones 11 and 13. The densest body at the latter temperature is No. 7, though No. 1 is very close

FIG. 1.

to it. The most open structure is shown by No. 2. At cone 15 the minimum porosity is again shown by No. 7, followed closely by Nos. 1 and 6. That lower porosities have not been reached is evidently due to the comparatively coarse grog employed, a condition made necessary by the treatment of the pots which were exposed to an air blast, immediately after the finish of the stirring. Pots practically completely vitrified, obtained through

the use of fine bisque were apt to crack in the cooling. It is evident, however, that the pre-firing of pots of this type must be carried at least to the temperature corresponding to cone 15. The higher porosities of bodies Nos. 2 and 3 are evidently due to the absence of feldspar and in No. 5 to the use of a coarse grog mixture.

FIG. 2.

The volume shrinkage of the different bodies at 1342° C vary from 15.57 to 22.32%, the lowest value being again that of the coarsest grog combination. The typical firing behavior of these porcelain pot compositions is shown graphically in the diagrams of Figs. 1 and 2.

It would seem from the results obtained that an important factor in regulating the structure of such bodies is to be looked for in the sizing of the bisque grog. Coarser calcine will retard vitrification and result in a more open texture white fine material

TABLE 3—RESULTS OF FIRING TESTS

No.	Cone 1, 1090° C		Cone 3, 1100° C		Cone 5, 1164° C		Cone 7, 1180° C	
	Vol. shrink. Per cent	Porosity Per cent	Vol. shrink. Per cent	Porosity Per cent	Vol. shrink. Per cent	Porosity Per cent	Vol. shrink. Per cent	Porosity Per cent
1.....	7.24	31.18	7.40	30.47	8.69	30.13	10.01	27.78
2.....	7.48	34.58	7.42	33.22	8.02	33.15	8.60	32.33
3.....	7.78	34.23	8.90	33.90	10.17	33.48	10.80	31.97
4.....	7.88	33.17	8.40	32.78	9.35	31.58	11.22	30.52
5.....	7.03	31.03	8.07	30.90	8.68	30.76	10.37	29.55
6.....	5.65	31.77	7.28	31.47	8.92	30.60	10.72	28.67
7.....	6.93	30.17	7.05	30.10	7.65	29.30	10.30	27.52
No.	Cone 9, 1203° C		Cone 11, 1244° C		Cone 13, 1312° C		Cone 15, 1343° C	
	Vol. shrink. Per cent	Porosity Per cent	Vol. shrink. Per cent	Porosity Per cent	Vol. shrink. Per cent	Porosity Per cent	Vol. shrink. Per cent	Porosity Per cent
1.....	12.18	25.92	14.13	23.62	19.53	13.78	20.17	11.83
2.....	10.13	31.33	11.95	29.47	18.45	20.50	20.75	16.07
3.....	12.05	31.25	13.05	29.68	19.62	19.57	20.73	15.73
4.....	13.82	27.73	15.57	26.47	21.07	16.72	22.32	12.83
5.....	10.70	26.68	11.83	24.58	15.22	16.85	15.57	15.18
6.....	12.25	26.65	14.70	24.00	20.43	15.27	20.62	11.47
7.....	12.18	24.07	12.95	23.08	19.32	12.42	19.55	11.33

will promote the vitrifying process and yield a denser body. This factor appears to be as effective as the addition or elimination of feldspar. It is evident that in this case we are dealing with a grog tending itself to vitrify at higher temperatures and which develops this action in proportion to its fineness.

The second important factor in governing the state of vitrification is the addition of feldspar which is more effective the finer the bisque grog, and *vice versa*. For obvious reasons there is a definite limit of feldspar content which can not be exceeded without impairing the rigidity of the pots at the higher melting temperatures, around 1450° C, and this seems to be at about 8 per cent. For the purpose for which these pot bodies have been employed the compositions corresponding to Nos. 1, 6 and 7 would appear to be most satisfactory, the last one having perhaps the most desirable structure.

Discussion

MR. A. F. GORTON.—Although the paper deals with pot compositions of the porcelain type and of coarser texture than ordinary commercial pot bodies, I believe that the results obtained should be of great value to all pot manufacturers. Mr. Fuller has selected those physical properties for his tests which are of greatest importance in estimating the value of pot materials, and the results, on the whole, conform very closely to what might be expected from consideration of the composition of the seven bodies.

I would call attention particularly to the load test and to the effect of the sizing of the grog. Those who have used the warp-age test as a means of judging the tendency of pot walls to bulge at high temperatures will, I think, agree that the test is of dubious value, except in a purely comparative way, because it is difficult to standardize testing conditions, and the distortion itself does not correspond exactly to actual conditions. If one considers the hydrostatic pressure of the glass inside the pot, and the pressure due to the weight of the walls and crown above the level in question (which is, say, six inches above the bottom, inside) then it appears that the former quantity is numerically about 1.5 to 2 pounds per square inch, and the latter is from 3 to 5 pounds per square inch, depending on the thickness of wall at that level. Consequently the greater distorting force is that due to the supported weight of clay. Hence the load test may logically be employed, and it seems that it would be better to perform the load test at a temperature higher than 1350° C, also under a smaller load than 40 pounds per square inch.

Mr. Fuller has well brought out the effect of the size of grog upon the modulus of rupture, porosity, and so forth, and I wish that this matter were more deeply appreciated by pot manufacturers, as I believe there is more to be gained by regulating the proportions of fine and coarse grog and the elimination of dust, than by an anxious search for some clay or blend of clays which shall approximate to the old German clay.

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.