THE SOLUBILITY AND FUSIBILITY OF SOME FELDSPAR FRITS¹

BY H. H. SORTWELL

ABSTRACT

Twenty frits were made covering the field 10–50% fused borax, 20–90% feldspar, and 0–30% calcium oxide. (1). The *solubilities* of the entire field were found to be less than 1.5% showing that the variations in composition in this field had less effect on the resulting solubility than the degree of smelting, and that all of the frits were sufficiently insoluble for use in glazes. The inclusion of CaO in the frit had a beneficial effect in decreasing the solubility. (2). The *fusibilities* were found to vary from 660° to 1050°C. Substitution of CaO for feldspar up to 10%, maintaining the borax constant, increased the deformation point, but further substitution in this direction had little effect. Substitution of either CaO or feldspar for borax appeared to raise the deformation temperature about the same in either case. A large part of the field was sufficiently fusible for easy working in the frit kiln.

Introduction

In ceramic literature there is a lack of definite information on the solubility of frits for whiteware glazes.

That frits in commercial use are sometimes poorly chosen in regard to solubility was shown by Blumenthal,² who determined the solubility of several frits now in use, the compositions of which were unknown.

There are some qualitative data as to what compositions are insoluble and what soluble, but no studies have been made showing the ranges of the materials ordinarily fritted, in which frits of sufficiently low solubility for judicious use in glazes lie.

As a beginning toward the accumulation of such data, a field of frits composed of feldspar, whiting, and borax was made, and the solubilities and, incidentally, the fusibilities determined.

¹ Published by permission of the Director, Bureau of Standards. Received March 10, 1921.

² Blumenthal, George, *J. Am. Ceram. Soc.*, **3**, 152–154 (1920).

FIG. 1.—Deformation temperatures of used frits.

Experimental

Table 1 shows the melted and raw compositions of the 20 frits made covering the range, 10–50 per cent fused borax, 20–90 per cent feldspar, and 0–30 per cent calcium oxide.

The Maine feldspar used analyzed:

SiO ₂	72.85
Fe ₂ O ₃	0.48
Al ₂ O ₃	15.45
CaO.....	0.31
K ₂ O.....	7.89
Na ₂ O.....	2.31
Loss on ignition.....	0.25

99.54

The frits were weighed out separately, thoroughly mixed, fused in crucibles and poured into water. As nearly as could be judged, each frit was given just the heat treatment necessary to properly fuse it, in order to avoid as much as possible variations in the re-

sults which would be introduced by the difference in the degree of smelting, as shown by Poste and Rice¹ in their work on enamels.

The solubilities were determined by the method employed by Blumenthal,² which consisted of taking five grams of frit sized through 20-mesh and retained on 40-mesh, with 350 cc of distilled water, agitating 24 hours in a rotary shaker, making 17 revolutions per minute, allowing to settle one-half hour, and determining the suspended material and the amount of material dissolved.

TABLE 1
COMPOSITION OF FRITS

No.	Percentage melted		Na ₂ B ₄ O ₇	Feldspar	Raw batch	
	Feldspar	CaO			Whiting	Borax
1	90	..	10	900	...	189.2
2	80	..	20	800	...	378.4
3	70	..	30	700	...	567.6
4	60	..	40	600	...	756.8
5	50	..	50	500	...	946.0
6	80	10	10	800	178.6	189.2
7	70	10	20	700	178.6	378.4
8	60	10	30	600	178.6	567.6
9	50	10	40	500	178.6	756.8
10	40	10	50	400	178.6	946.0
11	70	20	10	700	357.2	189.2
12	60	20	20	600	357.2	378.4
13	50	20	30	500	357.2	567.6
14	40	20	40	400	357.2	756.8
15	30	20	50	300	357.2	946.0
16	60	30	10	600	535.8	189.2
17	50	30	20	500	535.8	378.4
18	40	30	30	400	535.8	567.6
19	30	30	40	300	535.8	756.8
20	20	30	50	200	535.8	946.0

To determine the fusibilities, test cones of standard size were made from the frits passed through 100 mesh, using gum tragacanth for a binder. The fusions were made in a small chromel electric resistance furnace. The temperature measurements were made with a platinum-rhodium thermocouple and a potentiometer indicator. The cold junction of the thermo-

¹ Poste and Rice, *J. Am. Ceram. Soc.*, 1, 221-233 (1918).

² *Loc. cit.*

couple was maintained at zero by means of an iced thermos bottle. The temperature was raised at the rate of 10°C per minute.

Results

Solubility Determinations.—The results of the solubility determinations are shown in table 2. The entire field was sufficiently insoluble for use as frits in glazes. The degree of smelting has greater effect on the solubility than the variations in composition covered in this work. The frits having the greatest solubilities, a little over one per cent, are those consisting of borax and feldspar alone. From this it would appear that a little whiting has a beneficent effect in reducing the solubility.

Fusibility Determinations.—Difficulty was experienced in determining the fusibilities by cones due to the tendency of the borax to segregate at the bottom of the cone, leaving a skeleton of the harder materials. This would occur in successive fusions of the same frit in varying degree. This difficulty has been experienced before in this laboratory in studying the fusibility of enamels for metals. Difference in the degree of melting would also affect the results.

Therefore, the results obtained are only approximate, being the average of several cones of each frit which appeared to fuse with the least segregation. They serve satisfactorily as a basis for comparison and are fairly consistent.

Examination of figure 1, which is a graphical representation of the field showing the isotherms as approximately indicated, shows that replacement of either feldspar or calcium oxide by fused borax lowers the deformation temperature about the same amount in each case.

Substitution of calcium oxide for feldspar maintaining the borax constant increases the deformation temperature up to 10 per cent calcium oxide. Further substitution in this direction has but slight effect in increasing the temperature of deformation.

The deformation temperatures of three representative frits now in use being made in frit-kilns fired by both coal and gas were determined as a criterion of the proper fusibility for frit-kiln frits. These were found to be 717° , 690° and 773°C , respectively.

Judging by these figures and the behavior of the frits in the crucibles, it was estimated that approximately 800° C was about the maximum deformation temperature of the melted frit for easy working of a frit in the ordinary hearth frit kiln.

Consulting figure 1, it is seen that the number of mixtures in this field suitable for frits is large.

TABLE 2
RESULTS
Solubilities and Fusibilities

No.	Deformation temperature °C	Suspended material per Cent	Soluble matter per Cent
1	865	0.21	0.25
2	773	.17	.67
3	720	.09	1.05
4	700	.04	1.08
5	660	.19	1.51
6	943	.16	.24
7	805	.18	.47
8	765	.07	.23
9	715	.07	.40
10	685	.14	.76
11	875	.15	.62
12	810	.10	.21
13	765	.07	.63
14	715	.05	.68
15	692	.09	.98
16	1056	.10	.23
17	810	.16	.38
18	765	.14	.58
19	715	.08	.42
20	702	.02	.63