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ORIGINAL PAPERS

WET PROCESS ENAMELS FOR CAST IRON¹

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ABSTRACT

Wet process enameling of cast iron is becoming of importance because of its application to the enameling of stove parts, sanitary fittings and hardware. This paper is a report of an extended investigation of wet process enamels for cast iron, in connection with the use of a ground coat.

Compositions used in dry process enameling have served as a basis for the work, which includes a study of ground coats and white cover enamels. The effect of varying methods of preparing the frits, mill additions, and the relation of composition of the enamels to such properties as adherence, texture and opacity have been carefully studied.

Ground Coats.—Sintering of most ground coat frits has been found desirable in order to develop best adherence on the castings. Clay gave best results as a mill addition for the ground coats, and flint and feldspar were found to be less satisfactory. Excessive additions of clay or flint produced flaking of the ground coat while feldspar tended to develop blistering. About 15 per cent of clay or 10 per cent each of clay and flint are recommended as mill additions for the ground coats.

Excessive additions of any one flux were not desirable, and best results were obtained when sodium, lead and boric oxides were combined in more or less definite proportions. Sodium oxide in excess of about 10 per cent gave rise to blistering. Boric oxide increased the firing range of the ground coats and was preferable to lead oxide on this account, although it tended to promote crawling of ground coats high in boric oxide if they were applied somewhat heavily.

The best ground coats developed are Rg-26, 17, 1, 25 and 18.

¹ By permission of the Director, Bureau of Standards.

² Read before the Enamel Division, St. Louis Meeting, Feb. 28, 1922.

Cover Enamels.—Cover enamels were smelted in the usual manner. The mill additions consisted of 5 per cent of clay, 8 per cent of tin oxide, and 45 per cent of water, all based on the weight of the dry frit.

For best results, the cover enamel must be adapted to the ground coat in refractoriness. Boric acid increased the firing range of the enamels but tended to promote crawling, although this was less pronounced in the case of the more fusible compositions. Boric oxide improved the opacity when substituted for such fluxes as sodium and lead oxides. Cryolite increased opacity but additions above 10 per cent, based on the melted weight, tended to promote crawling. Considering all factors, cover enamels R-14 11, 28, 1 and 18 gave best results.

Introduction

Wet process enameling for cast iron has become of great importance, particularly in the stove industry, within the last few years. This is undoubtedly due to the fact that small castings required for stoves can be handled in greater volume and at less cost by this process. Less skilled labor is required for manipulation and the method lends itself readily to the enameling of irregularly shaped castings.

Very little has been published regarding this method of enameling, although it has been used for some time in the manufacture of cast iron cooking ware. The literature of the American Ceramic Society lacks any reference to wet process enameling of cast iron, and the various treatises on the subject of enameling either make no reference to or are so vague in their treatment of this particular method that they are of no help to those interested in the development of suitable compositions and technique.

The strength of enamels is inversely proportional to the thickness of the coat when the properly balanced composition is used. The heavy coats of enamel as used in the dry process are apt to chip on sharp edges when subjected to impact. The wet process tends to overcome this difficulty as it is possible to apply the enamel in much thinner coats.

Two distinct types of wet process cast iron enamels are commonly used, two or three coat process in connection with the use of a ground coat, and one or two coat process without the use of a ground coat, using one composition for both coats. This paper will treat of enamels that are used in connection with a ground coat and will deal particularly with the development of white enamels.

The method is similar to that for steel enameling, as the ground or first coat is fired and allowed to cool before the cover is applied, while the dry process necessitates sieving on the dry cover before the ground coat has cooled and the return of the casting to the furnace to gloss over the enamel, thus making it impossible to fire more than a limited number of pieces at a time.

Since it was believed that ground coats were as important as the covers, the first principal work has been in the development of suitable composi-

tions for such grounds. The basis of this work consisted of a number of typical ground coats now in use for the dry process. In order to obtain an enamel of the proper fitting qualities and expansion, the above procedure was considered advisable.

In studying cover enamels the same procedure was employed, several enamels which had given good results in commercial practice when used by the dry process being selected as the basis for the studies. This work consisted of noting the effects of variation in composition and heat treatment.

In studying the three coat wet process enamels the methods of preparing the enamels and the technic employed were based on the conclusions drawn from previous preliminary studies.

Preparation of Enamels

In the preliminary study the ground coats were prepared by weighing in five pound batches, mixing thoroughly and smelting in crucibles to the same degree as that for ground coats for sheet steel. It was soon found that the ground coats prepared by this method had very poor adherence so the sintering method was resorted to. The latter gave excellent results and was adopted, therefore, in the preparation of all ground coats used in this investigation. The materials were placed in crucibles and fired in a kiln to the temperature of approximately 975°C (1775°F) over a period of two hours. Upon cooling, the frits were broken from the crucibles and crushed in a jaw crusher to a size suitable for grinding in the ball mills.

The sintering method undoubtedly prevents the volatilization of the fluxes and also results in a ground coat having greater strength than that obtained in the melting of the materials to a glass. These results have been checked with a large number of varying compositions and even in the case of the more fusible grounds the sintering method gave far better adherence, although it is quite possible that satisfactory results may be obtained in the smelting of certain compositions.

The covers were prepared in the usual way by melting, except that the customary content of tin oxide was reserved for the mill addition. The latter consisted of 8 per cent tin oxide, 5 per cent Johnson-Porter Tennessee ball clay, with the necessary amount of water to form a slip for spraying.

The cast iron specimens for test were corner fittings and oval discs used in the manufacture of enameled stoves. They made ideal samples as they had a number of curved surfaces and sharp corners which would accentuate poor adherence of the enamel. The castings were prepared for enameling by annealing at temperatures approximating 815°C (1500°F). They were then sandblasted with a mixture of about 80 per cent sand and 20 per cent crushed steel shot.

The cleaned castings were coated with the various ground coats with a light application by means of an air spray. They were then dried thoroughly and fired in an electric furnace at temperatures varying from 760° to 815°C (1400° to 1500°F). The time of firing varied from five to ten minutes depending upon the particular ground and the type of casting used. After the firing and cooling of the ground coat, they were coated with the cover enamel by spraying. The cover enamel was dried thoroughly, and it is well to emphasize at this point the necessity of thorough drying if crawling of the enamel is to be avoided. The covers were fired at 730° to 760°C (1350° to 1400°F), the time of firing varying from five to ten minutes depending on the refractoriness of the composition.

To note the working qualities of the ground coats in respect to the cover coats, especially as to adherence and texture, enamels R-1 and R-5 (in Table III) were used with each ground coat. R-1 was a medium refractory enamel while R-5 was comparatively soft.

In Table I are shown four basic ground coat compositions giving the melted weights, batch weights and mill additions for each composition. These are typical compositions of ground coats used for dry process enameling of cast iron.¹ Rg-1 is a representative of the flint type with a considerable amount of raw clay in the mill mix. Rg-2 is a combined flint and feldspar type, this ground being a fairly refractory type with small additions of clay and cobalt oxide in the mill batch. In ground Rg-3 is shown a combination of two fusible frits containing large amounts of lead oxide, both the feldspar and flint types being represented. The mill additions consist of medium quantities of clay, flint and feldspar. Ground Rg-4 differs from the other compositions in this series as it has a comparatively high content of boric acid and feldspar. The mill additions consist of a medium amount of clay and a small percentage of cobalt oxide.

Although these ground coats had given very good results when used by the dry process, it was noted that when subjected to the wet process there was considerable variation in such properties as adherence, texture, etc., both in respect to the ground coat and the cover enamel.

Apparently the best results were obtained with Rg-1. This ground coat gave fair adherence, but the most desirable feature was the comparative freedom from pinholes in the cover enamel.

Ground coat Rg-2 adhered poorly to the iron, showing that this type of ground did not have the proper physical properties to withstand the stresses, set up in cooling, without the use of a cover for protection. It also had a short firing range so that there was a tendency for the cover enamel to develop pinholes.

With ground Rg-3, fairly good results were obtained, approaching those

¹ H. F. Staley, Bureau of Standards, *Tech. Paper* 142, p. 79-82.

of Rg-1, although there was a tendency to develop fine pinholes, especially when slightly overfired.

When the frit compositions "a" and "b" of Rg-3 were combined to give a single frit, the results differed very much. The resulting ground coat had poor adherence, showing that the physical condition of the enamel is fully as important as its chemical composition.

Ground Rg-4 had very good adherence, but had a decided tendency to form pinholes which may have been due to its fusibility as compared with the cover coats.

TABLE I
GROUND COATS FOR WET PROCESS CAST IRON ENAMELS

FRITS					
Composition	Rg-1	Rg-2	Rg-3		Rg-4
			a	b	
Flint	57.4	24.5	..	42.0	..
Borax	30.2	33.3	20.5	25.3	48.3
Sodium Nitrate	5.7	..	3.6	5.1	3.5
Red Lead	6.7	3.6	22.3	27.6	1.7
Maine Feldspar	..	38.6	53.6	..	46.5
Total	100.0	100.0	100.0	100.0	100.0

MILL BATCHES				
Frit	100	100	Frit a: 66.6 Frit b: 33.3	100
Flint	69	..	10	...
Clay (Johnson-Porter)	36	6	10	15
Cobalt Oxide	..	0.33	..	0.33
Maine Feldspar	..	..	16	...

Since Rg-1 with a high content of raw mill additions had fairly good adherence and the covers applied to this ground gave the best results as to texture and opacity, it was decided to study the effect of varying mill additions. Since Rg-1 contained a considerable amount of flint and clay, it was planned to study the effect of replacing the flint by feldspar and clay, and also the replacement of clay by flint and feldspar, simply retaining enough clay to float the frit. In this procedure it was hoped that a composition might be developed which would have good adherence as well as the other desired qualities. In making these substitutions, the ratio of fusibilities, as suggested for various enamel refractories by Coe¹ in his work on ground coats for cast iron, was used. Coe gives the following ratio: 40 clay equals 66 flint equals 100 feldspar, and the substitutions were made in Rg-1 on this basis.

¹ J. H. Coe, "Compositions of Commercial Ground Coats for Cast Iron Enamels," *Trans. Amer. Ceram. Soc.*, 13, 531 (1911).

In Series 1, Table II, ground coat 1B-Rg-1 has the flint addition in the mill batch of Rg-1 replaced by clay in the ratios given by Coe. This should result in a composition with the same refractoriness as Rg-1. To the remaining members of the series, clay has been added or subtracted in units of 15.5 parts.

Table II shows very clearly that with the increase of raw additions in the mill batch the adherence is not satisfactory, except in Series 1 where several compositions with a high clay content had fair adherence. Later

TABLE II
EFFECT OF VARIATIONS IN MILL ADDITIONS
Frit Constant 100 Grams

Specimen	Clay	Flint	Feldspar	Adherence		Cover pinholes
				Ground coat	After applying cover	
1E-Rg-1	108.5	...	...	Flaked	...	..
1C-Rg-1	93.0	...	...	O. K.	O. K.	None
1B-Rg-1	77.5	...	...	O. K.	O. K.	None
1A-Rg-1	62.0	...	...	O. K.	O. K.	None
1D-Rg-1	46.5	...	...	O. K.	O. K.	Few
1F-Rg-1	31.0	...	...	O. K.	O. K.	Few
1G-Rg-1	15.5	...	...	O. K.	O. K.	Few
IIC-Rg-1	6.0	114.0	...	Flaked	...	..
IIB-Rg-1	6.0	120.0	...	Flaked	...	..
IIA-Rg-1	6.0	96.0	...	Flaked	...	..
IID-Rg-1	6.0	73.0	...	Chipped on edge	O. K.	None
IIE-Rg-1	6.0	48.0	...	Chipped on edge	O. K.	Many
IIF-Rg-1	6.0	24.0	...	O. K.	O. K.	Many
IIIC-Rg-1	6.0	...	216.0	Flaked	...	..
IIIB-Rg-1	6.0	...	180.0	Flaked	...	..
IIIA-Rg-1	6.0	...	144.0	Flaked	...	..
IIID-Rg-1	6.0	...	108.0	Flaked	...	..
IIIE-Rg-1	6.0	...	72.0	O. K.	O. K.	Few
IIIF-Rg-1	6.0	...	36.0	O. K.	O. K.	Few

these were found to be undesirable as commercial compositions because the results were not consistent over a large number of trials, there being a tendency for chipping to develop in some cases. In Series 2 and 3 with flint or feldspar substituted for clay the adherence was very poor except where the additions were small. It will, therefore, be noted that flint and feldspar are poor substitutes for clay in the mill additions for ground coats, as they evidently detract from the adherent quality of the enamel.

Since it was concluded that an excessive amount of raw material in the mill batch was detrimental to the desired results, it was decided to make

a study of the effect of variation in the composition of the frit, using 15 per cent of clay in the mill batch, approximately the maximum amount consistently giving proper adherence. Ground Rg-1 was taken as a basis for this work. The different substitutions were made within the limits of workable ground coats. The latter must necessarily have the correct physical properties to permit them to undergo three distinct firings without blistering.

The melted and batch weights of the 21 ground coats studied are given in Tables III-H and III-I.

TABLE III-A
FLINT-PbO SERIES

The Effect of Varying Flint and PbO in Ground Coats.
Constant Portion Melted 22.10,—13.57 B₂O₃, 8.43 Na₂O.
Variable Portion Melted 77.90,—Flint and PbO

Number	Melted weights		Remarks		
	Flint	PbO	Adherence	Texture	
				R-1	R-5
Rg-5	73.50	4.40	Crawled	..	..
Rg-1	69.90	8.00	Good	Good	Good
Rg-6	66.30	11.60	Good	Fair	Good
Rg-7	62.70	15.20	Good	Fair	Good

TABLE III-B
B₂O₃-PbO SERIES

The Effect of Varying B₂O₃ and PbO in Ground Coats.
Constant Portion Melted 78.43,—69.90 Flint, 8.53 Na₂O.
Variable Portion Melted 21.57,—B₂O₃ and PbO

Number	Melted weights		Remarks		
	B ₂ O ₃	PbO	Adherence	Texture	
				R-1	R-5
Rg-16	21.57	0.00	Good	Few Pinholes	Good
Rg-17	17.57	4.00	Good	Good	Good
Rg-1	13.57	8.00	Good	Good	Good
Rg-18	9.57	12.00	Good	Good	Good

For comparison of the various compositions and their properties, it is possible to group the ground coats according to variation in the melted weights as shown in Tables III-A to III-G inclusive.

Table III-A shows the effect of replacement of quartz by lead oxide. The adherence of the ground coat apparently is benefited by the replacements noted. Rg-1 with 70 per cent of flint evidently contains the maximum amount of flint for workable ground coats. There is apparent in the study of cover coats as applied to these ground coats a tendency for the more fusible covers to give the most satisfactory enamels. The re-

fractory covers not only produce blistering of the ground coat in the firing necessary to give the covers desirable gloss and finish, but portions of the over-fused ground coat are absorbed by the cover causing black specks in the resultant enamel.

As a whole, the lead-oxide boric-oxide series (Table III-B) gave very good results. However, in Rg-16 with the replacement of all the lead oxide by boric oxide, there was a tendency of the ground coat to crawl in

TABLE III-C
Na₂O—PbO SERIES

The Effect of Varying Na₂O and PbO in Ground Coats.
Constant Portion Melted 83.47,—69.90 Flint, 13.57 B₂O₃.
Variable Portion Melted 16.53,—Na₂O and PbO

Number	Melted weights		Remarks		
	Na ₂ O	PbO	Adherence	Texture	
				R-1	R-5
Rg-19	16.53	0.00	Good	Many Pinholes	Many Pinholes
Rg-20	12.53	4.00	Good	Few Pinholes	Few Pinholes
Rg-1	8.53	8.00	Good	Good	Good
Rg-21	4.53	12.00	Good	Few Pinholes	Good

TABLE III-D
FLINT-FELDSPAR SERIES

The Effect of Varying Flint and Feldspar in Ground Coats.
Constant Portion Melted 30.10,—13.57 B₂O₃, 8.53 Na₂O, 8.0 PbO.
Variable Portion Melted 69.90,—Flint and Feldspar

Number	Melted weights		Remarks		
	Flint	Feldspar	Adherence	Texture	
				R-1	R-5
Rg-1	69.90	...	Good	Good	Good
Rg-9	...	104.8	Poor		
Rg-10	34.90	52.40	Poor		
Rg-11	...	87.40	Poor		
Rg-12	34.90	43.65	Fair	Pinhole	Pinhole
Rg-13	...	69.90	Good	Pinhole	Pinhole
Rg-14	34.90	34.90	Good	Pinhole	Pinhole

firing and for the boric acid to crystallize from the enamel if the latter was not used very soon after milling. The crawling is undoubtedly due to the higher viscosity imparted by excessive boric oxide. This, with the crystallization noted, would indicate an excess of boric oxide in the enamel. Replacing lead oxide with sodium oxide (Table III-C) gave compositions which had a decided tendency to develop pinholes.

Table III-D shows the effect of replacing flint by feldspar. In Rg-9 and 10 the ratio of three parts of feldspar to two parts of flint was adopted.

This was the relation of feldspar to flint suggested by Staley¹ for cast iron enamels. In Rg-9 all the flint was replaced by feldspar, and in Rg-10 half of the flint was replaced by feldspar. However, it was noted that replacements in this ratio increased the refractoriness and resulted in a ground coat of poor adherence. The ratio of five to four was employed in replacing the flint by feldspar in Rg-11 and 12, and one to one in Rg-13 and 14. Although these compositions possessed the desired fusibility, there was a decided tendency for the cover enamels applied to the ground to form pinholes. The feldspar, because of its alumina content, would undoubtedly

TABLE III-E

Na₂O-FLINT SERIES

The Effect of Varying Na₂O and Flint in Ground Coats.

Constant Portion Melted 21.57,—13.57 B₂O₃, 8.00 PbO.

Variable Portion Melted 78.43,—Na₂O and Flint

Number	Melted weights		Remarks		
	SiO ₂	Na ₂ O	Adherence	Texture	
				R-1	R-5
Rg-1	69.90	8.53	Good	Good	Good
Rg-22	65.90	12.53	Good	Many pinholes	Many pinholes
Rg-23	61.90	16.53	Good	Many pinholes	Many pinholes

TABLE III-F

B₂O₃-Na₂O SERIES

The Effect of Varying B₂O₃ and Na₂O in Ground Coats.

Constant Portion Melted 77.90,—69.90 Flint, 8.00 PbO.

Variable Portion Melted 22.10,—B₂O₃ and Na₂O

Number	Melted weights		Remarks		
	B ₂ O ₃	Na ₂ O	Adherence	Texture	
				R-1	R-5
Rg-1	13.57	8.53	Good	Good	Good
Rg-24	17.57	4.53	Good	Few pinholes	Good
Rg-25	9.57	12.53	Good	Good	Few pinholes

increase the viscosity of the ground coats and might account for the tendency of these compositions high in feldspar to form pinholes.

Increasing sodium oxide at the expense of flint gave poor results, as the ground coat showed many pinholes (Table III-E). This also resulted in unsatisfactory covers. For this type of ground coat, it was evident that the limit for sodium oxide is between 8.5 and 12.5 per cent.

When boric oxide was replaced by sodium oxide (Table III-F) there was some slight formation of pinholes but fairly good results were obtained with the more refractory covers.

¹ Bur. of Standards, *Tech. Paper* 142, p. 22.

In replacing flint by boric oxide, as in Table III-G, little change was noted, the results corresponding very closely to Rg-1. Excessive boric acid, however, tended to slightly increase the number of pinholes.

Excessive addition of raw materials to the mill batch is to be discouraged. Clay and flint as mill additions give the best results although the limits for these are fairly low. Such additions as 15 per cent of clay or 10 per cent each of clay and flint should give most satisfactory results.

Sintering of the ground coats is recommended, since melting of the materials to a glass weakens the resultant ground coat.

TABLE III-G

B₂O₃-FLINT SERIES

The Effect of Varying B₂O₃ and Flint in Ground Coats.

Constant Portion Melted 16.53,—8.53 Na₂O, 8.00 PbO.

Variable Portion Melted 83.47,—B₂O₃ and Flint

Number	Melted weights		Remarks		
	SiO ₂	B ₂ O ₃	Adherence	Texture	
				R-1	R-5
Rg-1	69.90	13.57	Good	Good	Good
Rg-26	66.90	17.17	Good	Few Pinholes	Good
Rg-27	62.70	20.77	Good	Few Pinholes	Few Pinholes

TABLE III-H

GROUND COATS OF SERIES III

Melted Compositions

Enamel	Flint	Feldspar	B ₂ O ₃	Na ₂ O	PbO
Rg-1	69.90	...	13.57	8.53	8.00
Rg-5	73.50	...	13.57	8.53	4.40
Rg-6	66.30	...	13.57	8.53	11.60
Rg-7	62.70	...	13.57	8.53	15.20
Rg-9	...	104.8	13.57	8.53	8.00
Rg-10	34.90	52.4	13.57	8.53	8.00
Rg-11	...	87.40	13.57	8.53	8.00
Rg-12	34.90	44.00	13.57	8.53	8.00
Rg-13	...	69.90	13.57	8.53	8.00
Rg-14	34.90	34.95	13.57	8.53	8.00
Rg-16	69.90	...	21.57	8.53	0.00
Rg-17	69.90	...	17.57	8.53	4.00
Rg-18	69.90	...	9.57	8.53	12.00
Rg-19	69.90	...	13.57	16.53	0.00
Rg-20	69.90	...	13.57	12.53	4.00
Rg-21	69.90	...	13.57	4.53	12.00
Rg-22	65.90	...	13.57	12.53	8.00
Rg-23	61.90	...	13.57	16.53	8.00
Rg-24	69.90	...	17.57	4.53	8.00
Rg-25	69.90	...	9.57	12.53	8.00
Rg-26	66.30	...	17.17	8.53	8.00
Rg-27	62.70	...	20.77	8.53	8.00

TABLE III-I
GROUND COATS OF SERIES III
Batch Compositions

Enamel	Flint	Feldspar	Borax	Sodium nitrate	Soda ash	Red lead	Boric acid
Rg-1	69.90	...	36.96	6.95	..	8.17	...
Rg-5	70.32	...	46.75	..	..	5.01	...
Rg-6	66.30	...	36.96	6.95	..	11.84	...
Rg-7	62.70	...	36.96	6.95	..	15.51	...
Rg-9	...	104.80	36.96	6.95	..	8.17	...
Rg-10	34.90	52.4	36.96	6.95	..	8.17	...
Rg-11	...	87.40	36.96	6.95	..	8.17	...
Rg-12	34.90	44.00	36.96	6.95	..	8.17	...
Rg-13	...	69.90	36.96	6.95	..	8.17	...
Rg-14	34.90	34.90	36.96	6.95	..	8.17	...
Rg-16	69.90	...	36.96	6.95	..	..	14.16
Rg-17	69.90	...	36.96	6.95	..	4.08	7.08
Rg-18	69.90	...	26.07	6.95	3.04	12.24	...
Rg-19	69.90	...	36.96	6.95	13.67	..	...
Rg-20	69.90	...	36.96	6.95	6.84	4.08	...
Rg-21	69.90	...	12.34	6.95	..	12.24	16.00
Rg-22	65.90	...	36.96	6.95	6.84	8.17	...
Rg-23	61.95	...	36.96	6.95	13.67	8.17	...
Rg-24	69.90	...	12.34	6.95	..	8.17	23.06
Rg-25	69.90	...	26.07	6.95	9.88	8.17	...
Rg-26	66.30	...	36.96	6.95	..	8.17	6.37
Rg-27	62.70	...	36.96	6.95	..	8.17	12.75

Excessive additions of any one flux were not desirable, and the best results were obtained when sodium, lead and boric oxides were combined in their proper proportions. Sodium oxide in excess of about 10 per cent, on the basis of melted weights, gave rise to blistering. Boric oxide increased the firing range of the ground coats and was preferable to lead oxide in this respect, although it tended to promote crawling of those ground coats high in boric oxide if they were applied somewhat heavily.

The best ground coats, considering both adherence of the enamel and texture of the cover coats, named in order, were Rg-26, 17, 1, 25, and 18.

Cover Enamels

In view of the results obtained with the cover enamels applied to the various ground coats, it was decided to make a study of the effect of varying composition in cover enamels. In order to bring out the relation of the ground coats and cover coats, the latter were applied to each of three different types of ground coats, namely: a high lead, a medium lead, and a leadless type, or Rg-7, Rg-1, and Rg-16, in the latter all of the lead oxide being replaced by boric oxide. As in the ground coats the replacement of one oxide by another was adopted.

In varying the compositions it was intended to bring out definitely the effect of the various constituents on adherence of the ground coat as well as the relation of the latter to the texture and opacity of the cover enamels. In the study of the ground coats certain defects developed upon the application of cover coats which apparently were not adapted to the particular ground coats; these consisted mainly of black specks, lack of gloss and small incipient pinholes. The black specks had the appearance of dirt or impurities which might have been present in the raw material or which might have been collected in the preparation of the enamel, but this evidently was not the case as the trouble was avoided when the same compositions were used by the dry process. Therefore, it was believed that the specking was due to the longer time required in melting down the covers by the wet process whereby the ground coat became overfired and small particles of it would be dissolved by the cover, resulting in dark specks.

Open pinholes on the surface of the enamels could in most cases be healed over by increasing the length of firing, but it was observed that there still remained small incipient pinholes in the covers and it was impossible to entirely eliminate this defect. The lack of opacity in these cover enamels was caused by solution of the opacifying agents and volatilization of the fluorides. This naturally would be expected to occur when an unreasonable length of time of firing was required to obtain the desired texture as compared with the time for fusing these cover coats when used in the dry process.

It was therefore evident that in order to obtain desirable results it would be necessary to accept several basic compositions and make such substitutions in these as might be expected to develop commercial enamels.

As a basis for this work two types of enamel were chosen, R-1, a medium refractory composition, and R-7, which was comparatively fusible. All cover enamels were smelted in the usual way and the frit was milled with 5 per cent of Johnson-Porter clay, 8 per cent tin oxide, and 45 per cent of water.

Cover R-1 was a rather refractory enamel containing feldspar and quartz, but comparatively low in boric oxide, while R-7 was a more fusible composition, containing feldspar and a high content of boric oxide but no quartz. These compositions were also selected to bring out any relation between ground coats and cover enamels, that is, whether a high boric oxide type could be expected to give better results with a ground coat high in boric oxide.

In Tables IV-E and IV-F and Tables V-F and V-G are shown the melted and batch weights of the compositions studied. These compositions can be grouped in series showing definite variations in composition as shown in Tables IV-A to IV-D for enamels R-8 to 19, based on R-1; and Tables V-A to V-E for enamels R-20 to 35, which are based on R-7.

The compositions based on R-1 have flint, sodium oxide, zinc oxide, and fluorspar constant, since these were present in amounts usually required for satisfactory cover enamels. The flint was not replaced as the refractoriness was varied in the different compositions by replacing the feldspar. Six per cent of zinc oxide in a composition is about the usual amount contained in cast iron cover enamels. An increase of this amount would induce crawling, while decreasing it would lessen the opacity of the enamel. An excessive amount of sodium oxide in covers produced pinholes. Sufficient sodium oxide was reserved in each composition to give about 5 per cent of sodium nitrate in the batch, which is necessary to prevent reduction of the lead compounds. The maximum amount of fluorspar usually added in cast iron covers is about 6 per cent.

TABLE IV-A
(FELDSPAR- B_2O_3) SERIES

The Effect of Varying Feldspar and B_2O_3 in White Cover Enamels.
Constant Portion Melted 53,—12 SiO_2 , 8.5 Na_2O , 6 ZnO , 5.5 CaF_2 , 5 Cryolite.
Variable Portion Melted 47,—Feldspar and B_2O_3

Enamel	Melted weights		Remarks					
	Feldspar	B_2O_3	Rg-1		Rg-7		Rg-16	
			Texture	Opacity	Texture	Opacity	Texture	Opacity
R-1	38.0	9.0	Good	Good	Good	Good	Good	Good
R-8	33.0	14.0	Good	Good	Good	Good	Good	Good
R-9	28.0	19.0	Slight crawling	Good	Slight crawling	Fair	Slight crawling	Good
R-10	23.0	24.0	Badly	...	Badly	...	Badly	...
			crawled	...	crawled	...	crawled	...

For the reasons stated above, the compounds of sodium oxide, zinc oxide and fluorspar in the compositions based on R-7 were not varied, and since lead oxide and boric oxide were the principal fluxes, it was not thought necessary to vary the amount of barium oxide.

As shown in Table IV-A with boric oxide increased at the expense of feldspar, the results were not very favorable because of the decided tendency of the enamel to crawl or bead. An increase of 5 per cent of boric oxide, over that for R-1, as in R-8, gave results similar to R-1. Although the enamel did not show any tendency to crawl, the incipient pinholes were not entirely avoided. Further increases in boric oxide improved the texture of the enamel but increased the tendency to crawling when applied in a sufficiently heavy coat to give the desired opacity. In cover R-10 the crawling was so increased that the enamel failed to cover the casting properly.

It will be noted that in lowering the refractoriness of the enamels by increasing the boric oxide, the pinholes became fewer when these covers

were applied to the more fusible ground coats. The opacity was also improved but some crawling occurred. From these results it was decided that 14 per cent of boric oxide was practically the limit in this particular type of composition in order to produce an enamel of the proper working qualities.

The effect of increasing lead oxide at the expense of feldspar, as noted in Table IV-B, gave some very interesting and instructive results which show more definitely the relation between cover enamels and the different types of ground coats. The data indicated the most suitable cover compositions for each individual ground and appeared to support the assumption made in the preliminary study of this investigation. These compositions on the whole gave very good results. However, it was noted that certain samples were not satisfactory owing to the appearance of black specks and the lack of opacity.

TABLE IV-B
(FELDSPAR-PbO) SERIES

The Effect of Varying Feldspar and PbO in White Cover Enamels.
C stant Portion Melted 46,—12 SiO₂, 9 B₂O₃, 8.5 Na₂O, 6 ZnO, 5.5 CaF₂, 5 Cryolite.
Variable Portion Melted 54,—Feldspar and PbO

Enamel	Melted weights		Remarks					
	Feldspar	PbO	Rg-1		Rg-7		Rg-16	
			Texture	Opacity	Texture	Opacity	Texture	Opacity
R-1	38.0	16.0	Good	Good	Good	Good	Good	Good
R-11	33.0	21.0	Good	Good	Few pin-holes	Good	Black specks	Good
R-12	28.0	26.0	Good	Good	Few pin-holes	Fair	Black specks	Good
R-13	23.0	31.0	Few pin-holes	Fair	Few pin-holes	Fair	Many pinholes	Fair

It was indicated that varying results could be expected with a particular cover coat, depending on the properties of the ground coat to which it might be applied. It will, therefore, be necessary, in discussing the results obtained with the cover coats, to consider the ground coats which had been used.

The best results obtained with R-11 containing 21 per cent of lead oxide were in connection with Rg-1 ground coat. This combination appeared to give consistent results on a number of trials requiring apparently the same length of time to melt it down. The same cover with Rg-7 and 16 showed a tendency to form pinholes and to develop black specks which was probably due to the ground over-firing before the cover had matured. Cover enamel R-12 containing 26 per cent of lead oxide gave very good results with both Rg-1 and 16, but no improvement over the combination of cover R-1 and ground Rg-1 could be observed.

Covers R-11 or 12 in connection with the use of ground Rg-1 gave practically the same results with the exception of a slight decrease of opacity in R-12. With 31 per cent of lead oxide, as in R-13, pinholes were encountered, this cover giving best results with ground Rg-7. With ground Rg-1 a few pinholes were observed.

The data given above show that the covers should be fusible enough to flow down sufficiently regardless of the composition of the ground coat. An excessive amount of lead oxide in the cover coats used on medium-hard ground coats results in pinholes. It was believed that the fusion point of ground coats and cover enamels should bear a close relation to each other, the best results being obtained when the ground was slightly the more refractory of the two.

TABLE IV-C
B₂O₃-PbO SERIES

The Effect of Varying B₂O₃ and PbO in White Cover Enamels.
Constant Portion Melted 75,—38 Feldspar, 12 SiO₂, 8.5 Na₂O, 6 ZnO, 5.5 CaF₂,
5 Cryolite.

Variable Portion Melted, 25,—B₂O₃ and PbO

Enamel	Melted weights		Remarks					
	B ₂ O ₃	PbO	Rg-1		Rg-7		Rg-16	
			Texture	Opacity	Texture	Opacity	Texture	Opacity
R-14	4.0	21.0	Good	Good	Good	Good	Good	Good
R-1	9.0	16.0	Good	Good	Good	Good	Good	Good
R-15	14.0	11.0	Good	Good	Good	Good	Black specks	Good
R-16	19.0	6.0	Slight crawling	Good	Slight crawling	Good	Slight crawling	Good
R-17	24.0	1.0	Crawled	Good	Crawled	Good	Crawled	Good

The results obtained in replacing lead oxide by boric oxide (Table IV-C) were not as satisfactory as in the previous series. This variation maintained the refractoriness of the composition practically constant. The results showed clearly that neither of the two fluxes could be eliminated in the composition as each gave certain necessary fusible properties in the enamel. In R-14, with 5 per cent of boric oxide replaced by lead oxide, little difference in opacity was noted between it and R-1. This enamel had a good texture and consistent results were obtained with a number of samples. It was apparent that the effect of replacing boric oxide with lead oxide was more satisfactory than that of replacing feldspar by lead oxide as the elasticity of the enamel was increased, permitting the application of a heavier coat. With the increase of boric oxide, crawling increased. In R-15, where 5 per cent of lead oxide was replaced by boric oxide, good results were obtained with Rg-1, the enamel having good

texture and opacity. This change slightly increased the refractoriness of the cover and offers further evidence that the melting points of both compositions should be about the same, because R-15 with both Rg-7 and Rg-16 had a decided tendency to produce black specks. Very poor results were obtained with both R-16 and R-17 in connection with the use of the three different ground coats. Crawling was increased in proportion to the increase of boric oxide. In order to prevent crawling with these enamels it would be necessary to apply it so thin that the opacity would be lacking.

As shown in Table IV-D, where feldspar was replaced by cryolite, the results obtained were very satisfactory considering both texture and opacity. The advantage of replacing feldspar by cryolite over the re-

TABLE IV-D
FELDSPAR-CRYOLITE SERIES

The Effect of Varying Feldspar and Cryolite in White Cover Enamels.
Constant Portion Melted 57,—12 SiO₂, 9 B₂O₃, 8.5 Na₂O, 16 PbO, 6 ZnO, 5.5 CaF₂.
Variable Portion Melted 43,—Feldspar and Cryolite

Enamel	Melted weights		Remarks					
	Feldspar	Cryolite	Rg-1		Rg-7		Rg-16	
			Texture	Opacity	Texture	Opacity	Texture	Opacity
R-1	38.0	5.0	Good	Good	Good	Good	Good	Good
R-18a	35.5	7.5	Good	Good	Good	Good	Good	Good
R-18	33.0	10.0	Good	Very good	Good	Very good	Good	Good
R-19a	30.5	12.5	Good	Very good	Good	Very good	Black specks	Good
R-19	28.0	15.0	Good	Very good	Good	Very good	Black specks	Good

placement of feldspar by lead oxide was the increase of opacity as well as the fusibility of the composition. Replacing 5 per cent of the feldspar by cryolite gave very good results with the three different types of ground coats, but when 10 per cent of feldspar was replaced by cryolite the results were not so favorable, pinholes being apparent in the covers used with both Rg-1 and Rg-16. Aside from this feature, it was noted that this enamel had a slight tendency to crawl when applied rather heavily. R-18a, with 7.5 per cent of feldspar replaced by cryolite, gave results similar to those of R-18, while in R-19a, with 12.5 per cent of feldspar replaced by cryolite, the same trouble was incurred as in R-19 with a further increase of cryolite to 15 per cent.

The above results indicate that cryolite should not exceed 10 per cent to give the most satisfactory results in cover enamels of this type.

When using R-7 as a basic composition the results obtained by the

various substitutions were not as satisfactory in their entirety as those in the previous series because of the lack of opacity. However, several good compositions were developed, and the work shows definitely the different effects on cover enamels of this type when the same substitutions are made as in the previous series. As the basic composition R-7 was

TABLE IV-E
WHITE COVER ENAMELS OF SERIES IV
Melted Compositions

Enamel	Feldspar	Flint	B ₂ O ₃	Na ₂ O	PbO	ZnO	CaF ₂	Cryolite
R-1	38.0	12.0	9.0	8.5	16.0	6.0	5.5	5.0
R-8	33.0	12.0	14.0	8.5	16.0	6.0	5.5	5.0
R-9	28.0	12.0	19.0	8.5	16.0	6.0	5.5	5.0
R-10	23.0	12.0	24.0	8.5	16.0	6.0	5.5	5.0
R-11	33.0	12.0	9.0	8.5	21.0	6.0	5.5	5.0
R-12	28.0	12.0	9.0	8.5	26.0	6.0	5.5	5.0
R-13	23.0	12.0	9.0	8.5	31.0	6.0	5.5	5.0
R-14	38.0	12.0	4.0	8.5	21.0	6.0	5.5	5.0
R-15	38.0	12.0	14.0	8.5	11.0	6.0	5.5	5.0
R-16	38.0	12.0	19.0	8.5	6.0	6.0	5.5	5.0
R-17	38.0	12.0	24.0	8.5	1.0	6.0	5.5	5.0
R-18	33.0	12.0	9.0	8.5	16.0	6.0	5.5	10.0
R-19	28.0	12.0	9.0	8.5	16.0	6.0	5.5	15.0
R-18a	35.0	12.0	9.0	8.5	16.0	6.0	5.5	7.5
R-19a	30.5	12.0	9.0	8.5	16.0	6.0	5.5	12.5

TABLE IV-F
WHITE COVER ENAMELS OF SERIES IV
Batch Compositions

Enamel	Feldspar	Flint	Borax	Sodium nitrate	Soda ash	Red lead	Zinc oxide	Fluorspar	Cryolite	Boric acid
R-1	38.0	12.0	24.52	6.20	3.86	16.42	6.0	5.5	5.0	...
R-8	33.0	12.0	38.14	6.35	..	16.42	6.0	5.5	5.0	...
R-9	28.0	12.0	38.14	6.35	..	16.42	6.0	5.5	5.0	8.85
R-10	23.0	12.0	38.14	6.35	...	16.42	6.0	5.5	5.0	17.70
R-11	33.0	12.0	24.52	6.20	3.86	21.60	6.0	5.5	5.0	...
R-12	28.0	12.0	24.52	6.20	3.86	26.70	6.0	5.5	5.0	...
R-13	23.0	12.0	24.52	6.20	3.86	31.80	6.0	5.5	5.0	...
R-14	38.0	12.0	10.90	6.20	7.70	21.60	6.0	5.5	5.0	...
R-15	38.0	12.0	38.14	6.35	..	11.30	6.0	5.5	5.0	...
R-16	38.0	12.0	38.14	6.35	..	6.20	6.0	5.5	5.0	8.85
R-17	38.0	12.0	38.14	6.35	..	1.03	6.0	5.5	5.0	17.75
R-18	33.0	12.0	38.14	6.20	3.86	16.42	6.0	5.5	5.0	...
R-19	28.0	12.0	24.52	6.20	3.86	16.42	6.0	5.5	5.0	...
R-18a	35.5	12.0	24.52	6.20	3.86	16.42	6.0	5.5	5.0	...
R-19a	30.5	12.0	24.52	6.20	3.86	16.42	6.0	5.5	5.0	...

considerably more fusible than R-1, the results with enamels in which the feldspar content remained constant or was increased, proved more favorable than where feldspar was decreased below that percentage in the base enamel.

In R-20, increasing the feldspar 5 per cent at the expense of boric oxide, as in Table V-A, good results were obtained with grounds Rg-1 and 7 although the opacity was not exceptionally good in either case. There

TABLE V-A
FELDSPAR-B₂O₃ SERIES

The Effect of Varying Feldspar and B₂O₃ in White Cover Enamels.
Constant Portion Melted 40,—11 Na₂O, 15 PbO, 5 ZnO, 3.5 BaO, 5.5 CaF₂.
Variable Portion Melted 60,—Feldspar and B₂O₃

Enamel	Melted weights		Remarks					
	Feldspar	B ₂ O ₃	Rg-1		Rg-7		Rg-16	
			Texture	Opacity	Texture	Opacity	Texture	Opacity
R-21	50.0	10.0	Good	Fair	Good	Fair	Good	Fair
R-20	45.0	15.0	Good	Fair	Good	Fair	Good	Fair
R-7	40.0	20.0	Good	Fair	Good	Fair	Good	Good
R-22	35.0	25.0	Black specks	Poor	Good	Fair	Black specks	Poor

TABLE V-B
FELDSPAR-PbO SERIES

The Effect of Varying Feldspar and PbO in White Cover Enamels.
Constant Portion Melted 45,—20 B₂O₃, 11 Na₂O, 5 ZnO, 3.5 BaO, 5.5 CaF₂.
Variable Portion Melted 55,—Feldspar and PbO

Enamel	Melted weights		Remarks					
	Feldspar	PbO	Rg-1		Rg-7		Rg-16	
			Texture	Opacity	Texture	Opacity	Texture	Opacity
R-24	50.0	5.0	Good	Fair	Good	Fair	Good	Fair
R-23	45.0	10.0	Good	Fair	Good	Fair	Good	Fair
R-7	40.0	15.0	Good	Fair	Good	Fair	Good	Fair
R-25	35.0	20.0	Good	Poor	Good	Poor	Good	Poor
R-26	30.0	25.0	Good	Poor	Good	Poor	Good	Poor
R-27	25.0	30.0	Good	Poor	Good	Poor	Good	Poor

was a slight improvement over R-7. Increasing the feldspar 10 per cent at the expense of the boric oxide gave good results with the three different types of ground coats. The opacity was not improved over R-20 and in certain samples there was a tendency to form black specks, the latter fact indicating that the cover was too refractory for the different ground coats. Increasing the boric oxide 5 per cent at the expense of feldspar, as in cover R-22, affected the properties of the composition as might be expected from the results obtained from R-20 and R-21. This cover used with Rg-1 and 16 had poor texture and opacity. In both cases

many black specks were apparent. When used with Rg-7 the texture was free from black specks but the opacity was not improved. Apparently the best combination obtained from this study was R-20 used in connection with ground Rg-1.

In Table V-B is shown a series with lead oxide replaced by feldspar and feldspar replaced by lead oxide. The results obtained were fairly satisfactory as to texture, but opacity was lacking throughout the whole series. With these various substitutions Rg-1 appeared to be the most suitable ground coat. Increasing the lead oxide bettered the texture with covers applied on ground Rg-1; however, a decrease of opacity was noticed as the lead oxide was increased.

TABLE V-C
PbO-B₂O₃ SERIES

The Effect of Varying PbO and B₂O₃ in White Cover Enamels.
Constant Portion Melted 65,—40 Feldspar, 11 Na₂O, 5 ZnO, 3.5 BaO, 5.5 CaF₂.
Variable Portion Melted 35,—PbO and B₂O₃

Enamel	Melted weights		Remarks					
	B ₂ O ₃	PbO	Rg-1		Rg-7		Rg-16	
			Texture	Opacity	Texture	Opacity	Texture	Opacity
R-28	25.0	10.0	Good	Good	Good	Good	Good	Good
R-7	20.0	15.0	Good	Fair	Good	Fair	Good	Good
R-29	15.0	20.0	Good	Fair	Good	Fair	Black specks	Good
R-30	10.0	25.0	Good	Fair	Few pin-holes	Fair	Few pin-holes	Fair
R-31	5.0	30.0	Many pin-holes	Fair	Many pin-holes	Fair	Many pin-holes	Fair

Replacing 5 per cent of lead oxide with feldspar gave an enamel having good texture with either of the three types of grounds, but in each case opacity was lacking. Increasing feldspar 10 per cent at the expense of lead oxide further increased the opacity and there was considerable formation of pinholes when these cover enamels were used over the softer grounds.

Replacing the feldspar by lead oxide gave rather poor results with Rg-7 and 16, pinholes being formed with each step and the opacity decreasing proportionally with the increase of lead oxide. However, it was noted that the same composition used with Rg-1 gave enamels with fairly good texture.

From the data given above it was decided that a high content of lead oxide decreased the opacity of the enamel. Cover R-23 when used with ground Rg-1 apparently gave the best results of any enamel in this series.

Replacing lead oxide by boric oxide (Table V-C) produced enamels having more desirable properties than those obtained in the previous series

based on Cover R-7. It was noted that the opacity could be controlled more successfully by varying the proportion of the fluxes.

The most satisfactory composition developed in this series was R-28. The properties of this enamel were such that good results were obtained with the three different types of grounds.

Cover R-28 contains 25 per cent of boric oxide. This amount is unusually high, but for this particular type of enamel a high boric oxide con-

TABLE V-D
FELDSPAR-CRYOLITE SERIES

The Effect of Varying Feldspar and Cryolite in White Cover Enamels.
Constant Portion Melted 60,—20 B₂O₃, 11 Na₂O, 15 PbO, 5 ZnO, 3.5 BaO, 5.5 CaF₂.
Variable Portion Melted 40,—Feldspar and Cryolite

Enamel	Melted weights		Remarks					
	Feldspar	Cryolite	Rg-1		Rg-7		Rg-16	
			Texture	Opacity	Texture	Opacity	Texture	Opacity
R-7	40.0	...	Good	Fair	Good	Fair	Good	Good
R-32	35.0	5.0	Fine pin-holes	Fair	Black specks	Poor	Good	Poor
R-33	30.0	10.0	Crawled Few pin-holes	Poor	Crawled Many pin-holes	Poor	Crawled Black specks	Poor

TABLE V-E
B₂O₃-CRYOLITE SERIES

The Effect of Varying B₂O₃ and Cryolite in White Cover Enamels.
Constant Portion Melted 80,—40 Feldspar, 11 Na₂O, 15 PbO, 5 ZnO, 3.5 BaO, 5.5 CaF₂.
Variable Portion Melted 20,—B₂O₃ and Cryolite

Enamel	Melted weights		Remarks					
	B ₂ O ₃	Cryolite	Rg-1		Rg-7		Rg-16	
			Texture	Opacity	Texture	Opacity	Texture	Opacity
R-7	20.0	...	Good	Fair	Good	Fair	Good	Good
R-34	15.0	5.0	Good	Fair	Crawled	Fair	Few pin-holes	Fair
R-35	10.0	10.0	Many pinholes	Poor	Few pin-holes	Poor	Few pin-holes	Poor

tent produced the most beneficial results. However, it was noted that more care was required in the manipulation, as a composition of this kind is more liable to crawl than the lead type. Increasing the lead oxide at the expense of boric oxide, as in covers R-29, 30 and 31, produced enamels with lower viscosity, but with many of the samples pinholes and black specks were formed, these features being noticeable when either of the three types of ground coats was used. The opacity was decidedly decreased with the increase of lead oxide and with increase of 15 per cent the enamel approached a clear glass.

The replacement of feldspar by cryolite (Table V-D) in this type of enamel did not prove very successful. The most serious objection was crawling, while the texture and opacity were not improved to any noticeable extent.

The fact that cryolite had vastly different effects in the two different types of basic enamels shows rather definitely that a broad statement cannot be made as to its effect in different types of compositions.

The lack of opacity in these enamels containing cryolite may be due to the fusibility of the enamel, probably allowing easy volatilization of the fluorine and solution of the opacifying agents.

It was also noted that in increasing cryolite at the expense of feldspar and boric oxide, crawling of the enamel occurred.

The replacement of boric oxide by cryolite (Table V-E) as in R-34 and 35, gave results which were very similar to those obtained with R-32 and 33. These enamels had a decided tendency to crawl and the texture was not satisfactory when either composition was used with the three different types of ground coats.

It will be noted that vastly different results were obtained varying by the same constituents in the composition of R-1 and R-7. The most appreciable difference was noted when the effect of cryolite in these compositions was studied. The same amount of boric oxide in the two compositions gave decidedly different results. It is evident that the limit for boric oxide is higher in the case of the more fusible enamels. This may

TABLE V-F
WHITE COVER ENAMELS OF SERIES V
Melted Compositions

Enamel	Feldspar	B ₂ O ₃	Na ₂ O	PbO	ZnO	BaO	CaF ₂	Cryolite
R-7	40.0	20.0	11.0	15.0	5.0	3.5	5.5	..
R-20	45.0	15.0	11.0	15.0	5.0	3.5	5.5	..
R-21	50.0	10.0	11.0	15.0	5.0	3.5	5.5	..
R-22	35.0	25.0	11.0	15.0	5.0	3.5	5.5	..
R-23	45.0	20.0	11.0	10.0	5.0	3.5	5.5	..
R-24	50.0	20.0	11.0	5.0	5.0	3.5	5.5	..
R-25	35.0	20.0	11.0	20.0	5.0	3.5	5.5	..
R-26	30.0	20.0	11.0	25.0	5.0	3.5	5.5	..
R-27	25.0	20.0	11.0	30.0	5.0	3.5	5.5	..
R-28	40.0	25.0	11.0	10.0	5.0	3.5	5.5	..
R-29	40.0	15.0	11.0	20.0	5.0	3.5	5.5	..
R-30	40.0	10.0	11.0	25.0	5.0	3.5	5.5	..
R-31	40.0	5.0	11.0	30.0	5.0	3.5	5.5	..
R-32	35.0	20.0	11.0	15.0	5.0	3.5	5.5	5.0
R-33	30.0	20.0	11.0	15.0	5.0	3.5	5.5	10.0
R-34	40.0	15.0	11.0	15.0	5.0	3.5	5.5	5.0
R-35	40.0	10.0	11.0	15.0	5.0	3.5	5.5	10.0

TABLE V-G
WHITE COVER ENAMELS OF SERIES V
Batch Compositions

Enamel	Feldspar	Borax	Sodium nitrate	Soda ash	Red lead	Zinc oxide	Barium carb.	Fluorspar	Cryolite	Boric acid
R-7	40.0	24.52	5.95	..	15.40	5.0	4.5	5.5	..	..
R-20	45.0	41.0	5.95	3.73	15.4	5.0	4.5	5.5	..	..
R-21	50.0	27.3	5.95	7.55	15.4	5.0	4.5	5.5	..	8.85
R-22	35.0	54.5	5.95	..	15.4	5.0	4.5	5.5	..	..
R-23	45.0	54.5	5.95	..	10.3	5.0	4.5	5.5	..	..
R-24	50.0	54.5	5.95	..	5.15	5.0	4.5	5.5	..	..
R-25	35.0	54.5	5.95	..	20.6	5.0	4.5	5.5	..	..
R-26	30.0	54.5	5.95	..	25.7	5.0	4.5	5.5	..	..
R-27	25.0	54.5	5.95	..	30.9	5.0	4.5	5.5	..	..
R-28	50.0	54.5	5.95	..	10.3	5.0	4.5	5.5	..	8.85
R-29	40.0	41.0	5.95	3.73	20.6	5.0	4.5	5.5	..	..
R-30	40.0	27.3	5.95	7.55	25.7	5.0	4.5	5.5	..	..
R-31	40.0	13.6	5.95	11.30	30.9	5.0	4.5	5.5	..	..
R-32	35.0	54.5	5.95	..	15.4	5.0	4.5	5.5	5.0	..
R-33	30.0	54.5	5.95	..	15.4	5.0	4.5	5.5	10.0	..
R-34	40.0	41.0	5.95	3.73	15.4	5.0	4.5	5.5	5.0	..
R-35	40.0	27.3	5.95	7.55	15.4	5.0	4.5	5.5	10.0	..

be due to the fact that the refractory enamels are comparatively viscous and this property is emphasized by the additions of such a substance as boric oxide.

The different effects in the two compositions show rather definitely that the effects of boric oxide and cryolite can be stated only in relation to a definite composition.

Summary

The primary purpose of this investigation has been to learn the effect of varying composition and treatment on wet process enamels. A number of satisfactory enamels have been developed and information has been gained regarding the technic of this type of enameling. While consideration must be given to the comparative refractoriness of the ground and cover coats, the following compositions may be mentioned as having given very satisfactory results: Ground coats Rg-26, 17, 1, 25, and 18, and cover coats R-14, 11, 28, 1, and 18. The laboratory results for the more promising enamels have been checked on a factory basis, and, taking into consideration the variations in furnace and factory conditions, the conclusions drawn from the laboratory work have been confirmed.

Discussion

MR. SWEELY:—I would like to ask, if you mean crawling of the enamel before fusion or afterwards; when you first put it into the furnace?

MR. DANIELSON:—When it first goes in the furnace there is a sort of cracking of the enamel, it then peels back leaving the metal exposed. An enamel that would so crack and crawl would not be a practical ground coat to use, or in the case of cover coat it would not be satisfactory for commercial purposes.

MR. WEISTER:—How fast did you dry that enamel?

MR. DANIELSON:—That is a very important thing in connection with the use of wet process enameling. It is very important that the cover coats dry very thoroughly before they are used and dried slowly. Samples were placed in a drier at about ninety degrees and probably dried in about an hour's time, thoroughly; and for safety we then left those in an hour longer. Unless the cover compositions are dried thoroughly there would be cracking and crawling of the enamel.

The results we have obtained in that connection have also been verified in commercial practice, where wet process enamels are used. It is absolutely necessary to dry slowly and dry carefully in all cases in order to avoid cracking.

MR. MALINOVSKY:—Is not the same true also of steel enamels?

MR. DANIELSON:—It is true with sheet steel enamel, but wet process enamels on cast iron must be dried somewhat slower and much more thoroughly. One explanation of that may be that the cast iron is somewhat more porous, and, also, the moisture is retained longer in these than in sheet steel coated with a rather glassy ground coat.