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# DEVELOPING AND APPLICATION METHODS OF CERAMIC COATING

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No Drawing. Continuation-in-part of application Ser. No. 162,910, Dec. 28, 1961. This application June 2, 1965, Ser. No. 461,229

7 Claims. (Cl. 117—129)

## ABSTRACT OF THE DISCLOSURE

The quality of ceramic coatings for application to ferrous metal can be considerably improved by employing stated amounts of alkali metal borate, boric acid, a thermally alterable siliceous compound, plastic clay and an adhesive. The siliceous compound is one that either melts or dissolves or sometimes both at least by a temperature of about 1300° C. The components of the composition are mixed according to standard techniques and applied to the surface of ferrous metal by processes understood in the art. Essentially, the coating is applied to the surface of the metal, dried and baked to a temperature of about 700° C. to 1300° C., preferably at 850° C. to 1100° C. The resulting coating has enhanced hardness and durability.

This application is a continuation-in-part of application Serial No. 162,910, filed December 28, 1961 now abandoned.

The present invention concerns a single layer ceramic coating for application to ferrous metal surfaces such as mild steel, stainless steel, alloy steel, cast iron, nodular cast iron, and the like. It further deals with a method for forming a single layer ceramic coating for application to ferrous metal surfaces thereby providing a protective coating film resistant to heat, oxidation, corrosion, acids, percussion and the like. It also concerns the coated ferrous metal articles.

Various processes have heretofore been proposed for applying enamels or heat-resisting enamels. Traditional enamels are usually baked on metal surfaces using specially prepared frits for a ground coat followed by a cover coat thereon, thus involving a two-stage finishing process. If this were to be accomplished by a one-stage process involving a single layer of coating film, a saving in materials and labor would result. Unfortunately all the methods tried hitherto have shown a single-layer film to be poor in adhesion and generally impractical. It has heretofore been commonly acknowledged that enamel coatings could not be successfully applied as a single-layer film. In order to form a single-layer film, the surfaces are usually plated with metals such as nickel or zinc, or the ceramic coating is applied over a ground coat obtained by pretreatment of the metal such as with phosphates. In such a method, special techniques and equipment are required for preparing the ground coat and hence, not only is there no economic advantage but sometimes use of such a process is harmful to the quality of the ground coat film formed on the product. Moreover, the materials which are to be enameled, such as low carbon steels and cast iron with relatively low combined carbon and gas content, have to be specially prepared in order to render them suitable for enamel coating.



An object of the present invention is to provide a single-layer ceramic coating needing neither special installation nor technique, and involving no surface preparation or ground coat. The coating and time required for forming the coating may be as little as half those required for a two-layer treatment, with resulting economical advantages. The coatings may be applied to a wide range of ferrous materials, as stated heretofore to give a product that can withstand flexing, bending, forming, swaging or drawing without dislodging the ceramic coating.

The ceramic coating of the present invention comprises on a weight basis 4–42%, preferably 10–35%, of an alkali metal borate, 4–10%, preferably 5–8% of boric acid, 7 to 60%, preferably 10 to 40% of a thermally alterable siliceous compound, 0.5 to 35%, preferably 4 to 30% of plastic clay, and 0.1 to 10%, preferably 2 to 8% of adhesives.

There may also be employed, if desired for special effects, 1 to 25% of titanium oxide or chromium oxide or mixtures thereof, employed in a finely comminuted condition. Other auxiliary material known to the ceramic art may be employed, if desired.

The alkali metal borate employed may be any of the several known borates of sodium, potassium, lithium or mixtures thereof. The sodium borates are preferred and may be typified as follows:

Sodium metaborate ($NaBO_2 \cdot 2H_2O$, $NaBO_2 \cdot 4H_2O$, $Na_2B_2O_4 \cdot 4H_2O$, $Na_2B_2O_4 \cdot 8H_2O$, $NaH_2BO_3 \cdot H_2O$, $NaH_2BO_3 \cdot 3H_2O$)
Sodium orthoborate ($Na_3BO_3$)
Sodium pyroborate ($Na_4B_2O_5$)
Borax ($Na_2B_4O_7 \cdot 10H_2O$)
Sodium triborate ($NaB_3O_5$)
Disodium octaborate ($Na_2B_8O_{13}$)
Sodium pentaborate ($NaB_5O_8$)

Boric acid may be employed as such or in the form of its anhydride. The two embodiments are equivalent for the present purposes.

The thermally alterable siliceous compound includes the acid forms such as metasilicic acid and the alkali metal and alkaline earth metal salt forms such as sodium silicate, potassium, orthosilicate, calcium metasilicate, barium metasilicate, magnesium orthosilicate, and the like. The siliceous compounds contemplated are those that melt or decompose or both at least by about 1300° C., preferably between about 700° C. and 1300° C.

The plastic clay to be used is that typified by the ball clays known by those skilled in the ceramic arts.

An adhesive or binding agent of either the organic or inorganic type is employed. Typically such an adhesive includes dextrin, starch, gum arabic, gum tragacanth, gum acacia, and the like. Dextrin is the preferred adhesive.

By rigid adherence to the above defined components and proportions, one can consistently achieve the valuable aspects of the present invention.

In order to apply conveniently the ceramic coating of this invention one employs sufficient water to make a solution of the soluble components and a slurry of suitable consistency of the remaining components. The over-

all consistency will frequently be that of paint as the ceramic coating is ready for application.

The present invention may be more fully understood from the following illustrative examples in which parts by weight are used throughout.

EXAMPLE 1

| | |
|---|---|
| Sodium metaborate | 300–800 |
| Boric acid | 100–150 |
| Barium metasilicate | 50–100 |
| Calcium metasilicate | 100–300 |
| Plastic clay | 200–600 |
| Adhesive (dextrin) | 50–200 |
| Titanium oxide | 100–400 |
| Water | 1000–2000 |

This formation is applied and allowed to dry at ambient temperature. Baking is effected at 958–1050° C.

EXAMPLE 2

| | |
|---|---|
| Sodium metaborate | 300–800 |
| Boric acid | 100–200 |
| Silicic acid (anhydrous) | 1000–1100 |
| Plastic clay | 20–150 |
| Adhesive (gum arabic) | 10–50 |
| Sodium carbonate (anhydrous) | 0–80 |
| Water | 1000–1500 |

This formation is applied and dried at room temperature. Baking temperature is 980–1100° C.

EXAMPLE 3

| | |
|---|---|
| Borax | 100–300 |
| Boric acid | 200–300 |
| Crystal glass | 1500–2000 |
| Plastic clay | 100–300 |
| Adhesive (gum tragacanth) | 5–50 |
| Sodium carbonate (anhydrous) | 100–180 |
| Water | 1500–2000 |

This formulation is applied and dried at room temperature. Baking follows at 700–1100° C.

The material forming these ceramic coating materials may be mixed directly and applied to the entire surface, properly prepared such as by sand-blasting. They are then dried and baked. It is a characteristic of this invention that immediately after the drying of the coating, the baking process may be carried out. Of course, it is also possible to first form a frit as in the method more usually employed for enameling.

Frit 1 (parts by weight):

| | |
|---|---|
| Crystal glass | 1500–2000 |
| Boric acid | 150–300 |
| Sodium carbonate (anhydrous) | 200–450 |

The above components are fused at 1300° C. and after heating for 2.5–3 hours, quenched in water. After cooling, the product is crushed to make a frit.

Slip (parts by weight):

| | |
|---|---|
| Frit | 70–85 |
| Plastic clay | 5–10 |
| Chromium oxide | 10–20 |
| Water | 45–60 |

The dried and finely divided frit is mixed in a porcelain ball mill with the other components, adding adequate water. The mixture is kneaded for 4 hours to make up approximately 4 litres. A 50-cc. portion of the slip thus obtained when screened through a sieve of 200 mesh, should leave less than 0.4 gram of residue. The particle size should lie between 1$\mu$ and 80$\mu$, with an average particle size of 8 to 10$\mu$. The slip is then applied, adding appropriate water, and is baked at a temperature of 900° to 1030° C.

The conventional enamel films tend to be liable to such defects as partial cracking or peeling and it is usual to repair such parts from which the film has been removed,



by recoating on the undercoat and baking the entire portion again in an oven.

The ceramic coating according to this invention requires no special base treatment such as metal-plating and it can be applied as a repair coating when ordinary enamels have been used, putting the part in an oven for reproducing perfect form again. Moreover such repairs can be completed without the use of ovens, but by a partial application of torches for heating. In such cases any of the above-described single-layer ceramic coatings may be employed.

The ceramic coatings of this invention are simple and economical in application. With any of them, a single treatment of the materials involved will result in an excellent single layer of the coating film. The method of application is as follows:

(1) Preparation of the metal surfaces

The metal surface to be coated should be cleaned and freed from scale, oil, grease, and foreign matter, should be uncontaminated, and should preferably be appropriately roughened. Experience shows that the use of sand-blasting is advantageous, for which the following are recommended;

| | |
|---|---|
| Abrasives to be used (sand), mesh | 40–50 |
| Air pressure to be used, p.s.i.g. | 60–80 |

Materials such as steel grits should not be used. Other treatment, for example metal plating and phosphate treatment, is not necessary.

(2) Application

Either the direct application method or the methods using the frit can be carried out by spraying or by immersion. The materials composing the coating or frit are mixed in water and applied in appropriate specific gravity and particle size. For spraying, a 50 lb. air pressure is preferably used. Application by immersion is conveniently used for such places as interiors of piping materials which are difficult to spray. In any case, the coating film thickness is preferably in the range of 0.025 to 0.06 mm.

(3) Drying

Drying is accomplished by natural drying action at room or ambient temperature. In order to avoid any cracks developing on the surface, any rapid change in temperature should be avoided.

(4) Baking

The coated metal, after being completely dried, is baked in an oven at a temperature of at least 700° C. up to about 1300° C. and above, preferably 850° C. to 1100° C., for an appropriate time so that the film is fused evenly. It is then left to cool. The oven may be of any conventional type such as electric, gas or the like, and should provide a constantly maintained even distribution of the temperature for uniform heating.

In the case of repairs, satisfactory results may be obtained if the defective part and its surroundings are heated by gas burner or torch. If considered necessary, however, a whole item can be put in an oven for uniform heating.

The result, in any case, is a single-layer ceramic coating on ferrous material that has superior properties of hardness, durability and resistance to wear and attack of all kinds.

I claim:

1. A ceramic coating for application to ferrous metal consisting essentially of on a weight basis:

| | Percent |
|---|---|
| Alkali metal borate | 4–42 |
| Boric acid | 4–10 |
| Thermally alterable siliceous compound | 7–60 |
| Plastic clay | 0.5–35 |
| Adhesive | 0.1–10 |

said compound being thermally alterable at least by about 1300° C., wherein said compound is metasilicic acid or an alkali or alkaline earth metal silicate, orthosilicate or metasilicate.

2. A single layer ceramic coating for application to ferrous metal consisting essentially of on a weight basis:

| | Percent |
|---|---|
| Alkali metal borate | 10–35 |
| Boric acid | 5–8 |
| Thermally alterable siliceous compound | 10–40 |
| Plastic clay | 4–30 |
| Adhesive | 2–8 |

said compound being thermally alterable between about 700° C. and 1300° C., wherein said compound is metasilicic acid or an alkali or alkaline earth metal of silicate, orthosilicate or metasilicate.

3. A ceramic coating according to claim 1, additionally including 1 to 25% of titanium oxide or chromium oxide.

4. A method of forming a ceramic coating on ferrous metal comprising applying the ceramic coating of claim 1 to the surface of the metal, drying said coating, and baking said coating at about 700° C. to 1300° C.



5. A method of forming a ceramic coating on ferrous metal comprising applying the ceramic coating of claim 2 to the surface of the metal, drying said coating, and baking said coating at about 850° C. to 1100° C.

6. A ferrous metal article having on the surface thereof a hard protective ceramic coating resulting from the application thereto and the drying and baking thereon the ceramic coating of claim 1.

7. A ferrous metal article having on the surface thereof a hard protective ceramic coating resulting from the application thereto and the drying and baking thereon the ceramic coating of claim 2.

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