Standard Practices for Production and Preparation of Gray Iron Castings for Porcelain Enameling[1]

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INTRODUCTION

Porcelain-enameled gray iron is a composite of a vitreous or glassy inorganic coating, bonded to a casting by fusion at temperatures above 800°F (425°C). Porcelain enamels are a family of coatings available in a wide variety of compositions and properties, but all are characterized by their glass-like nature. Selection of an appropriate porcelain enamel must be made on the basis of the end-use requirements. Certain casting design features and processing considerations can facilitate the application and efficient use of the selected enamel.

Two general types of enamels are available for use on cast iron. These are commonly referred to as wet-process and dry-process enamels (see Definitions C 286). In wet-process enameling, a slurry of wet-ground materials is dipped or sprayed on the casting, the water removed by drying, and the coating matured by heating in a furnace for sufficient time to bring about fusion of the glassy particles. In dry-process enameling, dry-powdered glassy material is applied by dusting onto a redhot casting that has been ground-coated by the wet process prior to firing. The partially matured dusted coating is returned to the furnace to complete the fusion process. In general, wet-process enamels are thinner over-all than dry-process enamels.

1. Scope

1.1 These practices are intended to indicate certain casting characteristics and pre-enameling practices which will facilitate finishing by the wet- or dry-process methods of procelain enameling. All of the listed recommendations are based on experiences with gray iron casting and enameling.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 48 Specification for Gray Iron Castings[2]

A 74 Specification for Cast Iron Soil Pipe and Fittings[2]

A 126 Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings[2]

A 278 Specification for Gray Iron Castings for Pressure-Containing Parts for Temperature up to 650°F[2]

C 286 Terminology Relating to Porcelain Enamel and Ceramic-Metal Systems[3]

3. Recommended Casting Characteristics

3.1 Design of the casting should be such as to minimize variations in temperature during firing and cooling. Section thickness should be uniform to eliminate possible warping and fire cracking of castings; to facilitate an even rate of heating and cooling and to prevent possible spalling, hairlining, and blistering of the porcelain enamel.

3.2 When a variation in section thickness is unavoidable, the transition of the two sections should be gradual and smooth. Abrupt changes in sections give rise to significant differences in heating and cooling rates, resulting in nonuniform coating conditions.

3.3 Special styling techniques should be used for designing appendages, internal passages, and lug-fastening faces so as not to emplace a mass of metal near an otherwise uniform enameling surface. These design considerations should include a thorough review of the available mold-making techniques in conjunction with the pattern designer.

3.4 Where functional or mating surfaces of an enameled casting are a design consideration, allowances must be included for the thickness of the coating and the method of application. The optimum thickness of wet-process enamels is

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[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 02.05.

about 10 mils (0.25 mm) in dry process enamels it is about 40 mils (1.0 mm).

3.5 Sharp edges on castings should be avoided, because neither the wetnor dry-process coatings will adequately cover sharp edges. Inside and outside corners should be rounded to uniform thickness and generous radii provided for fillets and outside corners.

3.6 Material identifications for the castings should be selected from appropriate ASTM specifications which are found under the various headings for gray iron.[2]

3.6.1 An example of the more desirable types of iron for enameling purposes are the normally ferritic Class 20 irons (see Specification A 48 for Gray Iron Castings). They cast more readily into complex shapes, and are better suited to the coating process.

3.6.2 Some applications, such as valve bodies, may require other types of gray iron for which Class B, Specification A 126, would be selected. Other appropriate Specifications would be A 74 and A 278, in which the lowest strength class is preferable for coating purposes.

3.7 Parting lines coincident with an enameling surface should be accessible for grind finishing.

4. Recommended Foundry Practices

4.1 The governing factors in pattern layout and shop control are elimination of discontinuities, chill, and inclusions at or near the surfaces to be coated.

4.2 Metal compositions and unnecessary increases of carbon equivalents in hypereutectic irons that give rise to coarse graphite or kish in heavy sections should be avoided. Heavy combined carbon will result in the formation of kish during the enameling fire and may cause poor adherence, spalling, or blistering, or combination thereof.

4.2.1 For lighter section castings ¼ in. (6.35 mm) thick and under, the desirable range for carbon equivalent is 4.3 to 4.5 %. Carbon equivalent is generally calculated as: C.E. = percent total carbon + ⅓ (percent silicon + percent phosphorus).

4.2.2 Sulfur in excess of 0.14 % and out-of-balance sulfur will cause enamel defects.

4.2.3 Manganese content of the iron must be sufficient to balance the sulfur content. A slight excess of manganese is preferred in order to assure sulfur tie-up; that is, Mn, percent = $(1.7 \times S, \text{percent}) + 0.3$.

4.2.4 High phosphorus content of 0.70 % may be desirable for improved strength at enameling temperatures. Phosphorus in the iron has no reported association with boiling defects in the coating.

4.3 When pouring thin-walled or complex shapes to be enameled, one must consider the effect of metal composition on microstructure. White or mottled structures will not roughen adequately during cleaning, and also may introduce other problems in the coating process. Silicon content over 2.4 % and the use of heater strips may be effective, but a suitable anneal is the desirable corrective measure.

4.4 Metal having a microstructure containing massive carbides and high pearlite content will introduce enameling problems. Heat treatments employed to obtain desired mechanical properties in the casting should minimize these problems.

4.5 Where annealing is a regular part of the foundry operations, an oxidizing furnace atmosphere is highly desirable in order to produce easily removed scale and obtain decarburized enameling surfaces. Decarburized surfaces are advantageous to enameling.

4.6 Heating and cooling cycles employed in the enameling process cause transformations that affect microstructure. Appropriate metallurgical constituents used to stabilize or retard these conditions should not be incorporated until a thorough study is made of their effect on the coating results. Examples of pearlite stabilizers are tin or manganese.

4.7 Shakeout techniques must be geared to both casting warpage and potential effect on enameling results. Castings should be fully separated from the sand once shakeout is started to prevent high internal stress that would later cause casting warpage or cracking or enameling defects.

4.8 Contaminants, harmful to the coating process, should be avoided in the molding sands and cores for castings to be enameled. Carbonaceous coatings for cores and molds are reported to be particularly harmful.

5. Recommended Pre-Enameling Practices

5.1 Visual inspection methods for enameling surfaces should place emphasis on the detection and remedy of porosity, sand inclusions, and gas holes. Porosity consisting of essentially subsurface pinholes, shallow covered blows, body scars, or shrinkage near the surface may or may not be acceptable for correction, depending upon severity.

5.1.1 Non-continuous metal consisting mainly of misrun (in which metal fails to fill out the mold cavity) or cold shut (imperfect fusion of metal against metal) should not be coated where appearance requirements of the finish are involved. Mold shifts, core shifts, or improperly aligned patterns resulting in an improperly positioned casting surface are not detrimental to the coating processes unless they give rise to unequal heating rates.

5.1.2 Machined or ground surfaces and metallic-cosmetic repairs should be cleaned by appropriate methods prior to inspection.

5.1.2.1 Cosmetic repair of various-surface blemishes, using metallic or ceramic fillers, should be made subject to agreement by coater and founder, and influenced by economic and feasibility aspects.

5.1.2.2 Metal-filler repairs of blemishes after elimination by mechanical methods such as grinding should be based on the extent and condition of the repair area. Under certain circumstances repair methods such as welding, brazing, or mechanical peening may not be wholly desirable.

5.1.2.3 Ceramic-filler repair on small-subsurface holes that do not contain inclusions can usually be made with a water-based, quartz-clay-soda ash putty.

5.1.3 White fractures due to chilled iron at edges and sharp corners, and structures containing massive carbides are not readily decomposed during enameling. Such castings should be heat treated to a softened condition prior to mechanical cleaning.

5.1.3.1 Oils and greases, whether used for temporary surface preparation or resulting from machining operations, should be removed by methods that will produce an enamel-compatible surface.

5.1.3.2 Thermal cleaning or heating the casting sufficiently to burn out organic soil is the most desirable pretreatment method prior to mechanical cleaning.

5.1.3.3 Oxide films, scale, and similar surface matter should be removed by mechanical cleaning.

5.1.3.4 Cleaning prior to the enameling process should remove foreign material and produce a sharply roughened surface without peening or contaminating it.

5.1.3.5 Two mechanical cleaning methods usually employed are sand blasting and airless grit blasting. Shot is not recommended, as it tends to peen rather than cut the surface. A third category of tumbling is rarely used. In all mechanical cleaning methods, the longer the cleaning time, the less tendency there is for boil-type defects. Grit or sand used to clean castings should be free of extraneous matter such as nonferrous metal, cutting oils, paint, dust, or other soils that tend to contaminate enameling surfaces.

5.1.4 Chemical cleaning processes used to remove organic soils should be followed by a roughening action such as blasting. Pickling is not resorted to since it gives rise to defects in enameling.

5.1.5 Heat treating employed prior to enameling if performed in an oxidizing atmosphere will minimize boiling defects and partially relieve stresses. Two general types are considered for different heat treating results:

5.1.5.1 Normalizing the casting for partial graphitization of massive combined carbon and decomposition of pearlite is one type of heat treating. Normalizing should be done in the 1625 to 1650°F (885 to 900°C) temperature range and for 1 h/in. of section with a minimum of 20 min at temperature per casting.

5.1.5.2 The other type of heat treating is subcritical anneal to partially graphitize pearlite. Subcritical annealing should be done in the 1360 to 1420°F (735 to 770°C) temperature range and for 1 h/in. of section with a mininum of 20 min per casting.

5.1.6 Enameling operations should begin on castings as soon as possible, within a week after foundry finishing.

5.1.7 Castings should be stored in a dry place. They should not be "aged." If aged castings are to be enameled, an annealing treatment prior to enameling operations is beneficial.